DOCUMENT

3bis

Document relating to the environmental impact of operating the reactors for the following ten years

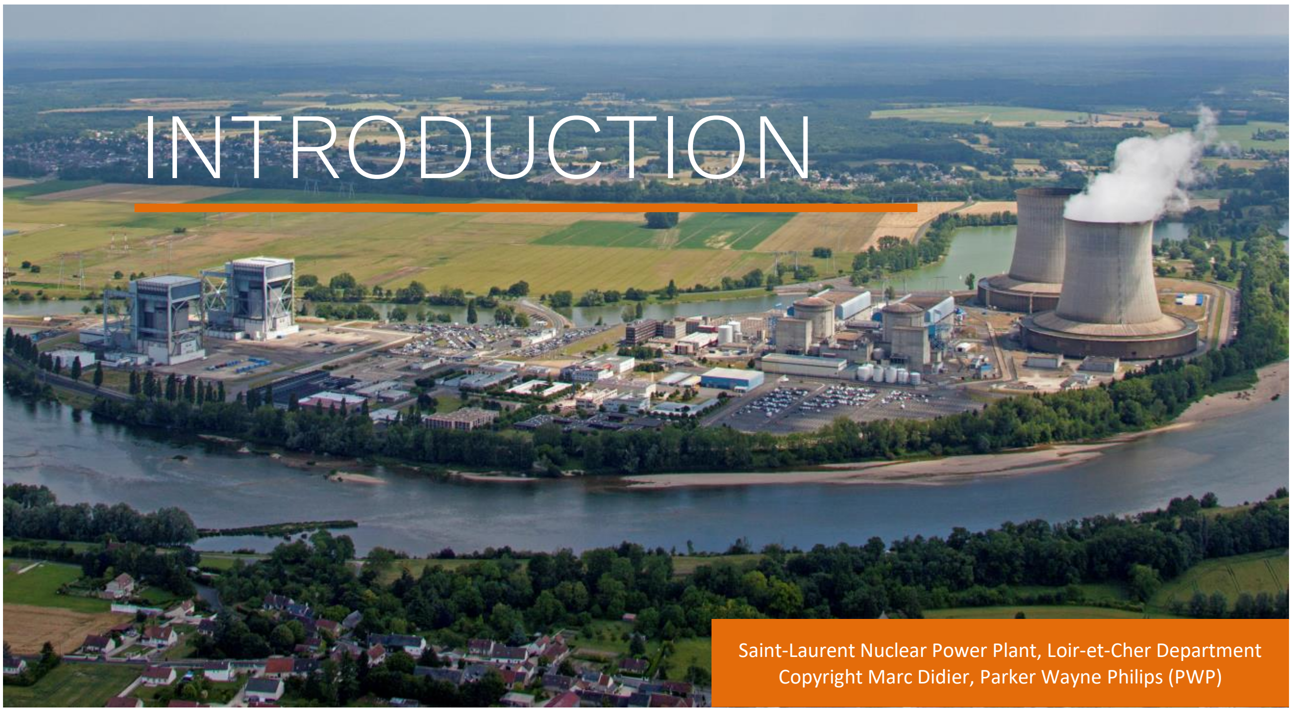
Public inquiry into the 4th periodic review

Saint-Laurent Nuclear Power Plant
Reactor No. 2

OVERVIEW

Pages

INTRODUCTION



Saint-Laurent Nuclear Power Plant, Loir-et-Cher Department
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In France, the construction of a nuclear reactor is authorised by way of a decree issued by the Minister responsible for nuclear safety. This authorisation places no time limit on service life. Nevertheless, the operator is required to carry out a periodic review every ten years to evaluate the status of the plant in relation to applicable regulations, and to update its assessment of the risks and impacts that the facility may present in terms of public health and safety, and the protection of nature and the environment, collectively referred to as the 'protected interests'.

Saint-Laurent Nuclear Power Plant's two 900 MWe pressurised water reactors, operated by Electricité de France (EDF, www.edf.fr), are undergoing their 4th periodic review.

After each review, EDF draws up a Review Findings Report [RCR] setting out its conclusions and proposed measures to strengthen the safeguarding of protected interests. The reports for reactors Nos. 1 and 2 at Saint-Laurent Nuclear Power Plant were submitted to the Government and to the Authority for Nuclear Safety and Radiation Protection (ASNR, www.asnr.fr) on 12 December 2025 and 22 January 2024, respectively.

After 35 years of plant operation, the Review Findings Report is subject to a public inquiry.

This document represents one of the supporting documents in the Public Inquiry File for the 4th periodic review of the Saint-Laurent reactors. It is a joint document for both reactors at the Saint-Laurent site.

It addresses the environmental impacts of operating these reactors for the ten years following their 4th periodic review, including the consequences, whether radiological or not, of potential incidents or accidents. It also outlines any potential transboundary impacts, given that it is submitted, where applicable, as part of a consultation with a neighbouring foreign state or another state that is a Member of the European Union or a Party to the Convention on Environmental Impact Assessment in a Transboundary Context, signed in Espoo on 25 February 1991.

The Authority for Nuclear Safety and Radiation Protection takes into account the results of the public inquiry, including those relating to the environmental impacts set out in this document, in its analysis of the Review Findings Report, and in any requirements that it may specify regarding the reactors at the Saint-Laurent site.

Saint-Laurent NPP, Loir-et-Cher Department

1. THE OPERATOR OF SAINT-LAURENT NPP AND THE BACKGROUND TO THE PERIODIC REVIEW

1.1. The operator of Saint-Laurent Power Plant

EDF is the operator of Saint-Laurent Nuclear Power Plant and, as such, is responsible for the 4th periodic reviews of its reactors.

EDF is a public limited company wholly owned by the French State. It employs nearly 180,000 people worldwide, including more than 100,000 in France. A key player in the energy transition, EDF is an integrated energy company, operating in a range of electricity-related businesses: generation, distribution, supply, trading, and energy services. EDF has developed a diversified production mix based mainly on nuclear and renewable energies, including hydropower.

EDF is Europe's largest electricity producer, with a total installed capacity of 117 GW in 2024. With over 94% carbon-free electricity generation, EDF has one of the lowest carbon intensities in the world - 33 gCO_2/kWh - compared to a European average of 230 gCO_2/kWh. In 2024, the EDF Group produced a total of around 520 TWh of electricity, 78% of which was generated by nuclear assets.

EDF is the world's leading nuclear operator, with an installed capacity of 63 GWe. It operates 57 nuclear reactors across 18 sites in France.

In 2024, Saint-Laurent Nuclear Power Plant (NPP) generated nearly 11.1 billion kilowatt-hours of low-carbon electricity, representing the electricity consumption of around 2.5 million French households, in other words, around 3% of France's nuclear-generated electricity. Saint-Laurent NPP supports the climate goals set by France and the European Union, as well as the objective of security of supply.

Saint-Laurent NPP is a major economic player in the Loir-et-Cher Department. It is a leading industrial employer in the region, with around 1,150 people on site, including 350 contractor partner employees. It is strongly committed to training young people, taking on 60 apprentices and 60 interns in 2024. It is fully invested in local life, and champions numerous initiatives and associations supporting the environment and biodiversity, sport, and young people's access to the labour market.

1.2. Background to the periodic review and regulatory framework

1.2.1. The procedure for periodic reviews

Saint-Laurent NPP is made up of two pressurised water reactors (PWR), each with an electrical output of 900 MWe, cooled by a so-called 'closed' circuit cooling system. These reactors were commissioned in 1981. They have been reliably contributing to carbon-free electricity generation for over forty years. EDF is carrying out the 4th periodic review of the two reactors currently in operation at the Saint-Laurent site.

In order to identify the improvements to be implemented as part of these reviews, at the end of 2013 EDF produced Review Guidelines [DOR] setting out the topics to be addressed and the associated improvement objectives. The Nuclear Safety Authority [ASN] examined these guidelines, drawing on its technical expertise and consulting its standing panels of subject-matter specialists [GPE][1], and then consulted the public before issuing an opinion. The ASN's examination of this 'guidelines' component of the review concluded in April 2016 with a position statement, and requests made to the operator EDF[2].

For the 4th periodic review of 900 MWe nuclear power plants, EDF has adopted the general policy of bringing their safety features into line with those of the latest-generation reactors, which for EDF is its reference design, the Flamanville 3 EPR.

During the periodic review, the improvements related to the environmental impacts of the facilities are examined in two parts:

- a **"risks" component** focused on preventing incident or accident events and limiting their potential radiological (radioactive releases) or non-radiological (thermal or toxic releases, overpressure**)** consequences. There are two categories of risk:
  1. **radiological risk**, associated with the presence of radioactive substances,
  2. **conventional risk**[3] related, for example, to the storage and use of flammable products, chemicals, or low-level radioactive products within conventional facilities.
- an **"impacts component"** covering the management of the health and environmental effects of the installation during normal operation, owing to its water abstraction and discharges, and of the impacts it is likely to generate (dispersion of pathogenic microorganisms, noise and vibration, odours and dust). Waste management falls under the 'impacts' section.

Each of these two sections is divided into two parts:

- **A verification of the installation's compliance** with applicable rules.
- **A reassessment of the risks and impacts of the installation** with the aim of improving, as far as reasonably achievable, the protection of the interests referred to in Article L.593-1 of the Environment Code, that it to say, public health and safety, and the protection of nature and the environment.

The fourth periodic review includes a third component addressing "continued plant operation beyond forty years", encompassing the **management of equipment ageing** and **equipment qualification** under accident conditions.

[1] ASNR bases its most important decisions regarding nuclear safety and radiation protection on the opinions and recommendations of standing panels of subject-matter specialists.
[2] ASN – Generic guidelines for the fourth periodic reviews of 900 MWe reactors – CODEP - DCN-2016-007286 dated 20 April 2016.
[3] See glossary.

The 4th periodic review of the Saint-Laurent reactors was conducted in two phases:

- a first so-called generic phase addressed issues common to all reactors of similar design in the French nuclear fleet, as provided for in French regulations. The Saint-Laurent reactors belong to the fleet's 900 MWe reactor series. This generic phase concluded with the publication on 23 February 2021 of ASN Decision No. 2021-DC-0706[4] governing the generic phase of the 4th periodic review of 900 MWe reactors, accompanied by generic requirements that had first been put to public consultation.
- a second phase specific to each Saint-Laurent reactor.

Following the review[5], EDF submitted the Review Findings Report [RCR] for the two Saint-Laurent reactors to the Minister responsible for nuclear safety and to ASNR. This report sets out the conclusions of the review in relation to its objectives, a summary of the methods used, and the main results. It details EDF's intended measures to enhance nuclear safety and to improve health and environmental protection.

This report has a completion deadline specified in the regulations and is generally drawn up after the ten-year outage of the reactor in question, during which inspection and maintenance operations are carried out, along with plant modifications aimed at meeting the objectives of the review. All the measures within the scope of the review are delivered through an industrial programme of implementation in the ten-year outage and subsequent outages, or through a specific programme, when the reactor is in operation (see Section § 3.3).

In regard to this 4th periodic review of the Saint-Laurent reactors, the Review Findings Report is subject to a public inquiry.

The Authority for Nuclear Safety and Radiation Protection will take into account the conclusions of the public inquiry and the outcomes of consultations with foreign states in its analysis of the report and, where appropriate, in any new requirements governing the continued operation of the Saint-Laurent reactors.

After the review, the continued operation of the Saint-Laurent reactors will ensure security of electricity supply for the next ten years, in compliance with France's and the European Union's climate targets.

1.2.2. Tie-in with the reactor decommissioning procedure

If the conditions for continued operation of a reactor, which are reassessed during periodic reviews, cannot be met, EDF will consider its decommissioning and will be required to proceed to dismantling. In this case, at least two years before the planned date, the operator shall notify the Minister responsible for nuclear safety and ASNR of its intention to decommission its installation. It shall submit its Decommissioning File to the Government, detailing in particular planned decommissioning operations, along with the measures that will be taken to minimise the impacts on people and the environment. The decommissioning of the installation is subsequently authorised by decree, once ASNR has issued its position statement: this is referred to as the Decommissioning Decree. The decommissioning stages are as follows:

[4] This Decision was amended on 19 December 2023 by Decision 2023-DC-0774.

[5] Article R.593-62 of the Environment Code stipulates that "the obligation to conduct a periodic review shall be deemed to have been fulfilled once the operator has submitted its report on this review to the Minister responsible for nuclear safety and to the Authority for Nuclear Safety and Radiation Protection".

Preliminary stage: decommissioning preparation operations

This stage, which is put into motion as soon as the plant is in final shutdown, is designed to:

- minimise the risks that are present in the installation: this involves the removal of spent and new fuel, and of waste and effluents, the draindown of circuits, and the decontamination of certain circuits. At this point, most of the radioactive material has been removed;
- prepare the installation for dismantling operations: this involves optimising access routes and circulation, adapting support functions, ventilation and handling systems in particular, and removing certain equipment;
- gain a better understanding of the status of the plant: this involves drawing up an inventory of hazardous materials and substances, identifying asbestos, and collecting samples for radiological analysis.

Stage 1: dismantling of electromechanical equipment

This stage, which requires the Decommissioning Decree to have come into effect, involves dismantling and cutting up all existing equipment and conditioning it as waste. Only the equipment needed for stage-2 clean-out operations is left in situ. The electromechanical equipment dismantling works in each building are major operations. They are as follows:

- in the reactor building (RB) [BR], the cutting and removal of large components, and the dismantling of the primary circuit loops, vessel internals, reactor vessel and other circuits and support functions;
- in the fuel building (FB) [BK], the dismantling of the pool compartments, various equipment and support functions;
- in the nuclear auxiliary building (NAB) [BAN] and the building connecting the RB and turbine hall [BW], the cutting up and removal of large components, and the dismantling of equipment in two phases, beginning with the functions that are not required for decommissioning, and moving on to the last equipment in situ.

Stage 2: site clean-up

This applies solely to nuclear premises. Any radioactivity (activation, deposition or migration of contamination) that may be present in the walls of the premises is removed. Clean-up operations can begin as soon as the electromechanical equipment inside the premises has been dismantled, and once ASNR has approved the clean-up methodology.

Once the clean-up and verification measurements have been completed, a Declaration of Declassification of the premises in question is submitted to ASNR. When a perimeter-sector of premises has been processed, the remaining structures and items are then considered as conventional waste.

Stage 3: demolition of buildings

In regard to the conventional buildings that are to be disassembled, demolition works may begin once the buildings are no longer needed for the dismantling operations. This routine demolition work will not necessarily be preceded by a phase involving the removal of equipment inside.

In respect of the nuclear buildings, demolition works will be carried out after the Declaration of Declassification of these premises has been sent to ASNR. Within a nuclear building, certain perimeter-sectors of premises that may not have been cleaned out may require prior nuclear demolition.

Stage 4: site remediation and restoration

This stage involves verifying the compatibility of soils with future uses. Any areas presenting evidence of chemical or radiological contamination are managed as required. Once the site has been cleaned out, an Application for Delicensing is submitted to ASNR for approval.

2. THE CONTINUED OPERATION OF THE SAINT-LAURENT REACTORS

Saint-Laurent NPP, Loir-et-Cher Department
Copyright Huguet Gilles, EDF

2.1. Saint-Laurent Nuclear Power Plant

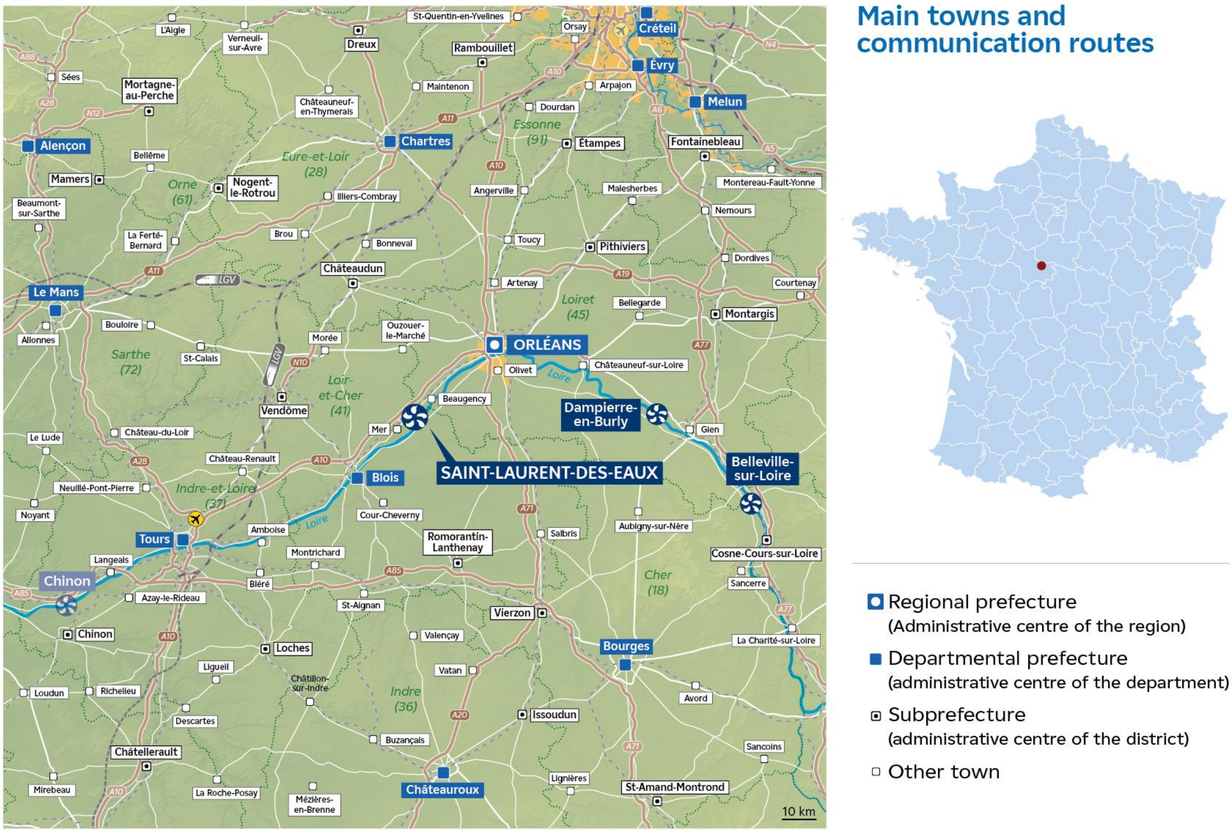
The EDF nuclear power plant is located in the Commune of Saint-Laurent-Nouan, in the Loir-et-Cher Department. It is sited on the bank of the Loire River, midway between Orléans and Blois.

The largest towns near the power plant are Orléans (32 km north-east) and Blois (24 km south-west).

The plant is close to a Regional Nature Park, two nature reserves, Natura 2000 protected sites, and areas owned by the Natural Areas Conservation Trust (Conservatoire des Espaces Naturels).

The Saint-Laurent site comprises four pressurised water reactors (PWR), namely, two pressurised water reactors (PWR) in operation, which were commissioned in 1981 and are undergoing their 4th periodic reviews, and two natural-uranium graphite gas reactors (UNGG), which are being decommissioned. Saint-Laurent-A UNGG unit A1 entered operation in 1969.

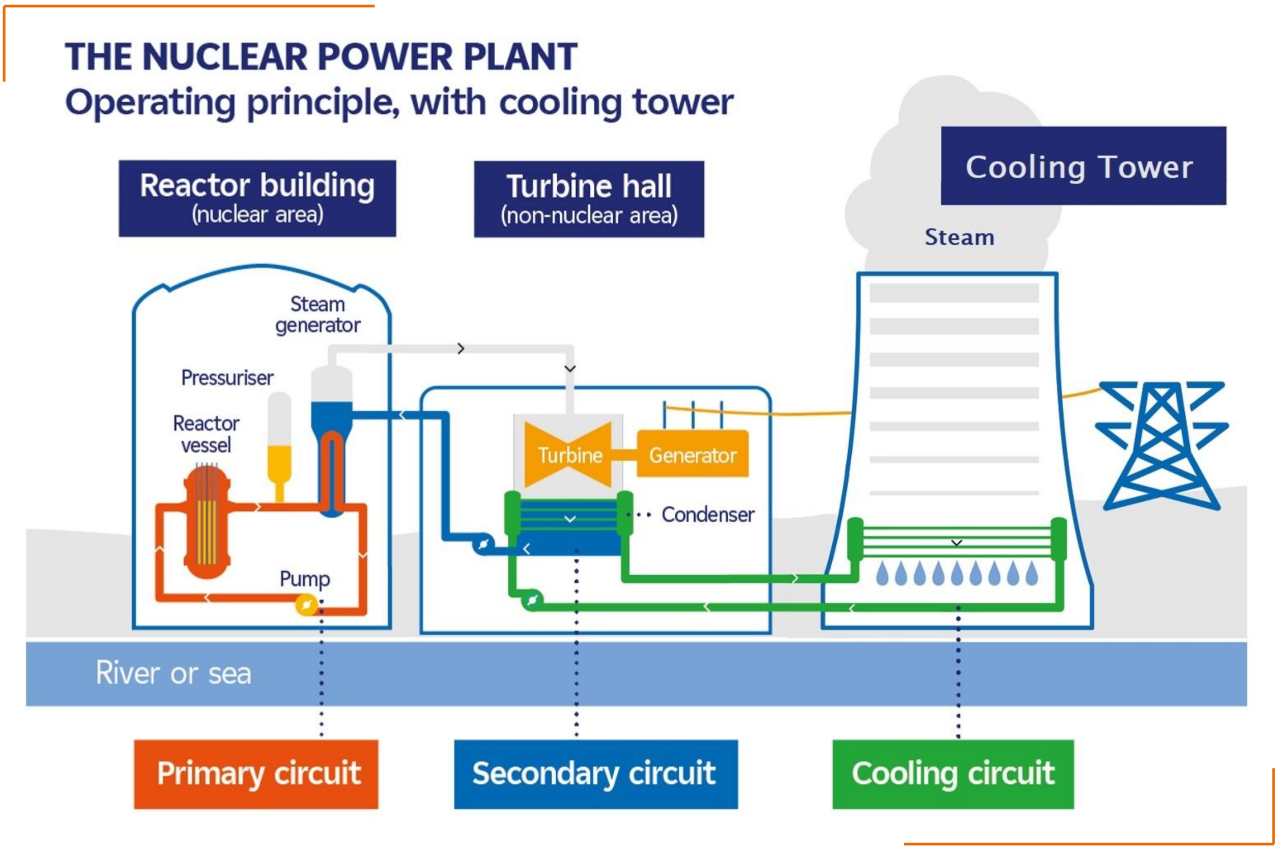
SAINT-LAURENT-DES-EAUX NUCLEAR POWER PLANT (LOIR-ET-CHER)



2.2. Overview of the power plant

The process for producing electricity is the same in a conventional thermal power plant as it is in a nuclear power plant: a fuel generates heat, which turns water into steam, thus driving a turbine and a generator that produces electricity. In a conventional thermal power plant, this heat comes from the combustion of fossil fuels (coal, fuel oil, etc.). In a nuclear reactor, heat is produced through the fission of uranium atoms.

Saint-Laurent NPP has two pressurised water reactors, each with a rated electrical output of 900 MWe, cooled by a closed cooling system. The working principle of a pressurised water reactor is based on three separate and sealed circuits (see illustration below).



1. The **primary circuit:** the fission of uranium atoms in the reactor generates a large amount of heat, which in turn heats up the water circulating around the fuel assemblies at 320°C. This water is kept at high pressure to prevent boiling. It transfers its heat to the water in a second, closed circuit.
2. The **secondary circuit:** heat is exchanged between the primary system water and the secondary system water by way of steam generators, in which the secondary-circuit water is vapourised. The pressure of this steam turns a turbine, which drives a generator. The generator produces alternating current. A transformer steps up the electrical current so that it can be more easily transmitted over long distances through very-high-voltage power line.
3. The **cooling circuit**: at the turbine outlet, the secondary-circuit steam is converted back to water by passing through a condenser circulating cold water from the sea or a river. This third circuit is the cooling system. At Saint-Laurent NPP, the water in this third circuit is drawn from the Loire River.

In 2024, Saint-Laurent NPP generated nearly 11.1 billion kilowatt-hours of low-carbon electricity, representing the electricity consumption of around 2.5 million households, in other words, 3% of France's nuclear-generated electricity.

2.3. Continued operation

EDF's raison d'être is to "*build a net-zero energy future with electricity and innovative solutions and services, to help save the planet and drive wellbeing and economic development*": it contributes to the goal of carbon neutrality set by the European Union and adopted by France in its energy and climate strategy. On this basis, EDF's nuclear power plants play a major role in supplying carbon-free, dispatchable and competitive electricity.

EDF therefore intends to continue operating its reactors, while taking the necessary measures to comply with relevant safety requirements.

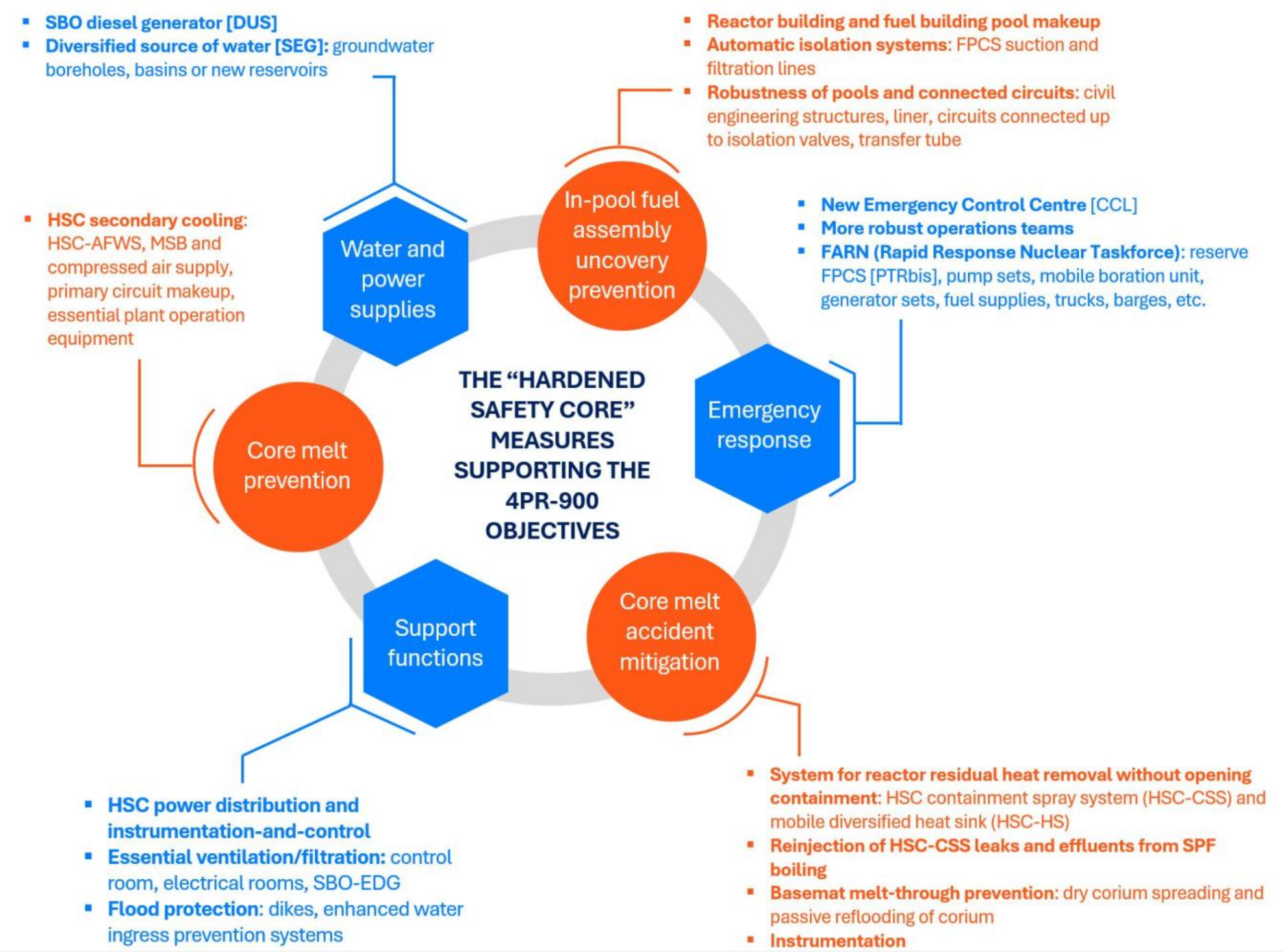
2.3.1. The measures put forward

Given the improvement objectives defined for the 4th periodic review of the 900 MWe reactors, their continued operation for a further ten years will be tied in with the implementation of measures put forward by EDF in the Review Findings Report, supplemented by the requirements laid down by ASNR, which set forth the conditions for continued operation.

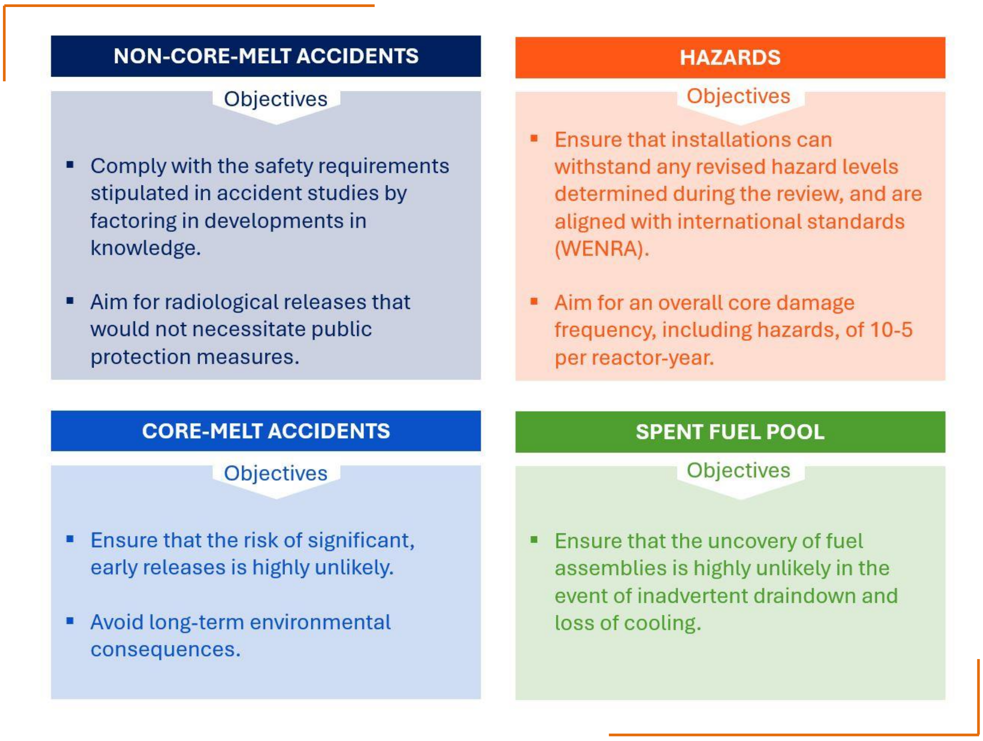
Firstly, the improvement measures consist in ensuring that the safety case for the reactors takes into account the equipment and organisational provisions made in response to the operating experience from the accident in Fukushima Daiichi Nuclear Power Plant in March 2011. These provisions were strengthened after the review and brought together under the umbrella term of 'Hardened Safety Core' measures.

The Hardened Safety Core is a set of robust fixed equipment supplemented by mobile equipment, designed for preventing large radioactive releases and long-term environmental impacts in the conditions following an extreme external natural hazard event. Such events mainly include earthquakes, external flooding and associated phenomena (lightning, hail, high winds, heavy rains), as well as tornadoes.

The main Hardened Safety Core (HSC) provisions categorised by broad safety topics



Secondly, the other improvement measures under the 4th periodic review of Saint-Laurent NPP support the overall objective of this review, which is to bring the safety features of the reactors into line with those of the latest-generation reactors, which for EDF is its reference design, the Flamanville 3 EPR. This objective hinges on four focus areas:

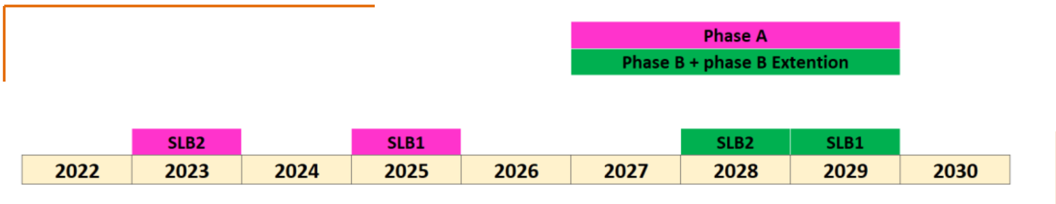


2.3.2. Industrial programme under the 4th periodic review

The industrial programme for the 4th Periodic Review of the 900 MWe reactor series plants is divided into three phases that factor in the scale and scope of activities, as well as the resulting impacts on the people and organisations of these nuclear sites[6]:

- **Phase A** corresponds to the activities that are carried out during unit operation or during shutdowns such as the ten-year outages. These activities include updating operational documentation;
- **Phase B** corresponds to the activities that are carried out during unit operation or during shutdowns that take place no later than six years after submission of the Review Findings Report;
- **Phase B Extension** covers the implementation of certain actions derived from ASN's examination of the 4th periodic review, which, due to their nature (such as the requirements to qualify a new item of equipment for resistance to very severe ambient conditions), call for a period of evaluation of around five years. These activities are carried out during unit operation or during shutdowns that take place no later than eight years after submission of the Review Findings Report.

The following illustration sets out the annual schedule for modifications related to the 4th review of the Saint-Laurent reactors:



[6] When drawing up the schedule, EDF also takes into account the very heavy industrial workload in France owing to the ten-year outages due to be carried out for the other plant series. To this end, EDF is now organised to run this review in project mode, under the umbrella of its "Grand Carénage" fleet upgrade programme.

Saint-Laurent NPP, Loir-et-Cher Department
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3.1. The regulatory procedure in France

In accordance with Article L.593-18 of the Environment Code, EDF conducts a periodic review of its reactors every ten years in order to "*evaluate the status of the plant in relation to applicable regulations, and to update its assessment of the risks and impacts that the facility may present for the interests referred to in Article L.593-1, taking into account in particular the condition of the installation, operating experience, developments in knowledge, including new information on climate change and its effects, and the rules applicable to similar facilities. This risk assessment factors in the influences of climate change on the external hazards that are addressed in the assessment.*"

Article R.593-62 of the Environment Code stipulates that "*the obligation to conduct a periodic review shall be deemed to have been fulfilled once the operator has submitted its report on this review to the Minister responsible for nuclear safety and to the Authority for Nuclear Safety and Radiation Protection*."

The report shall include "*the conclusions of the review provided for in Article L.593-18 and, where applicable, the measures proposed by the operator to address reported deficiencies or to improve the protection of the interests referred to in Article L.593-1.*" (Article L.593-19 of the Environment Code).

Pursuant to Article L.593-19, "*in regard to reviews for continued nuclear power reactor operation beyond thirty-five years, the report referred to in the first subparagraph of this Article must be put to public inquiry*."

In this context, Articles R.593-62-2 to R.593-62-9 of the Environment Code set out the procedure to be followed for the public inquiry.

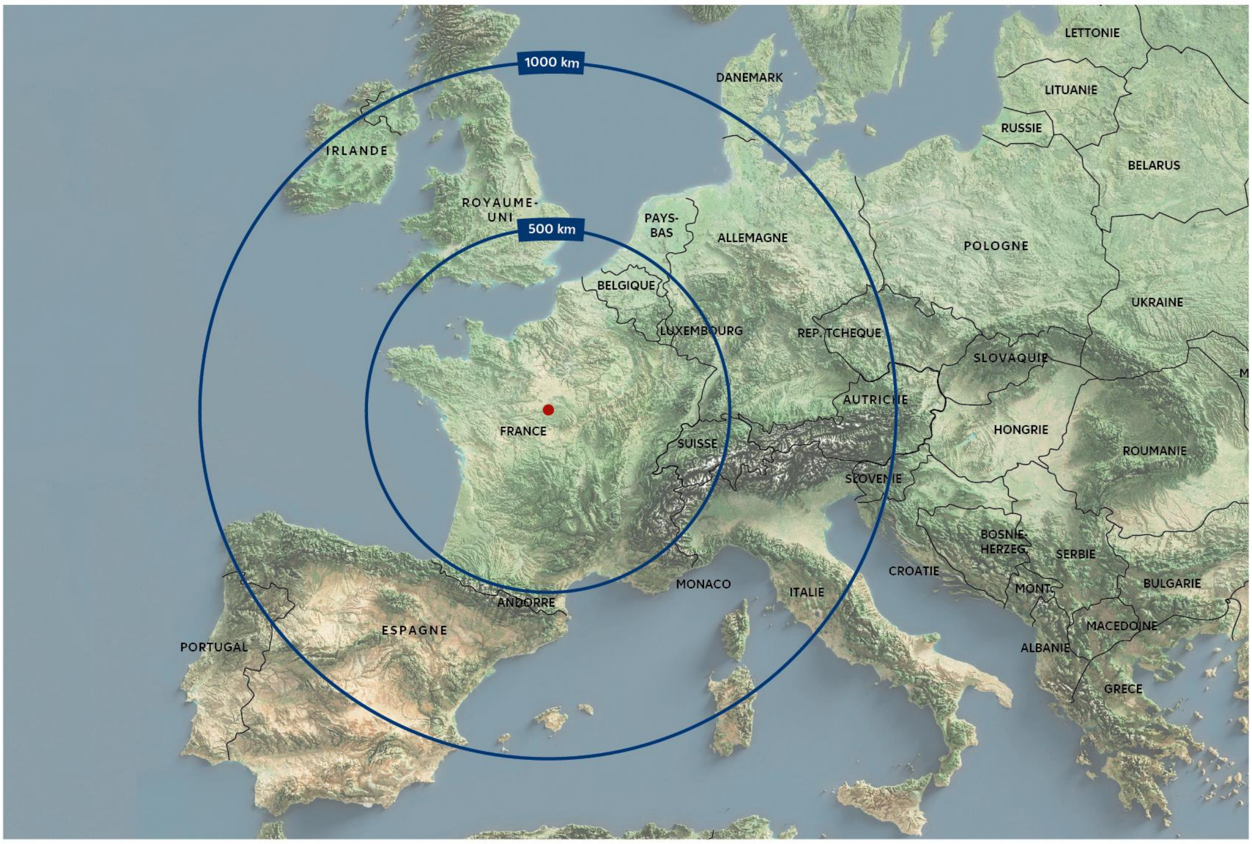
3.2. Cross-border consultation

For the purposes of this public inquiry into the Review Findings Report, Article R.593-62-6 of the Environment Code provides for consultation with foreign states. If part of a foreign state adjoins the area in scope of the public inquiry, or if a neighbouring foreign state is not immediately adjacent but the Prefect, on his own initiative, or at the request of the authorities of another European Union Member State or of a Party to the Convention on Environmental Impact Assessment in a Transboundary Context, signed in Espoo on 25 February 1991, considers that the operation of the reactor is likely to have significant transboundary effects on the environment in that state:

- The Prefect shall notify the foreign state of the order initiating the public inquiry and shall provide, in particular, a copy of the Public Inquiry File.
- The Notification of the Order Initiating the Inquiry shall specify the deadline by which the authorities of that foreign state must declare their intention to take part in the public inquiry. The public inquiry may not begin until this deadline has expired.
- The Prefect shall present the file to the Minister of Foreign Affairs.

The map below shows the location of Saint-Laurent NPP in relation to neighbouring states, up to a distance of 1,000 kilometres.

SAINT-LAURENT-DES-EAUX NUCLEAR POWER PLANT (LOIR-ET-CHER)

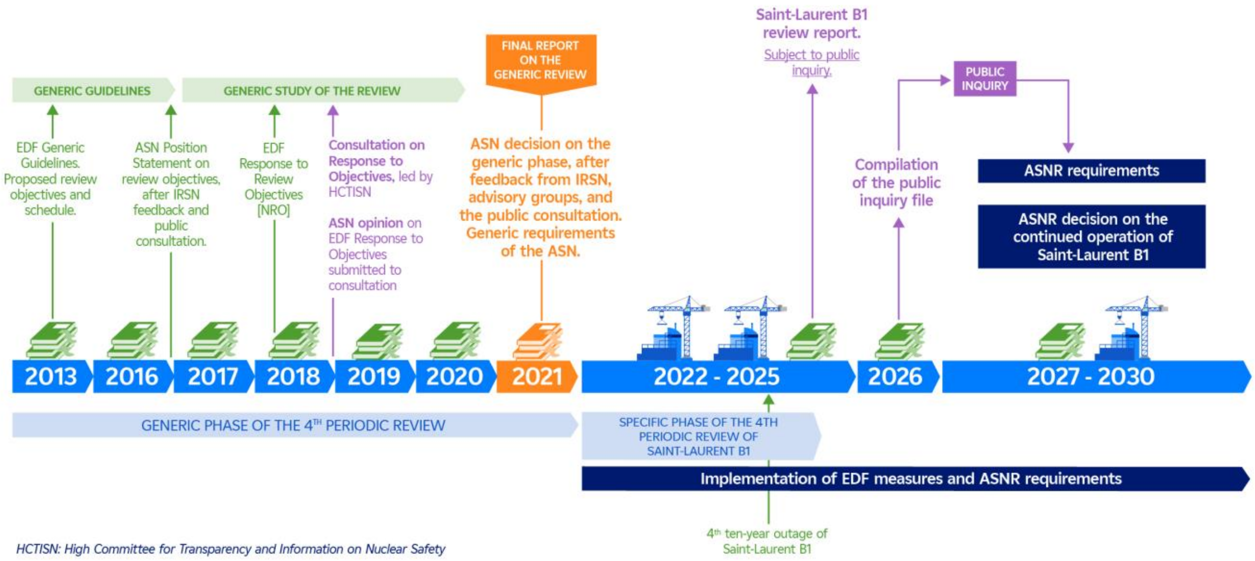


The Saint-Laurent site relative to neighbouring foreign states

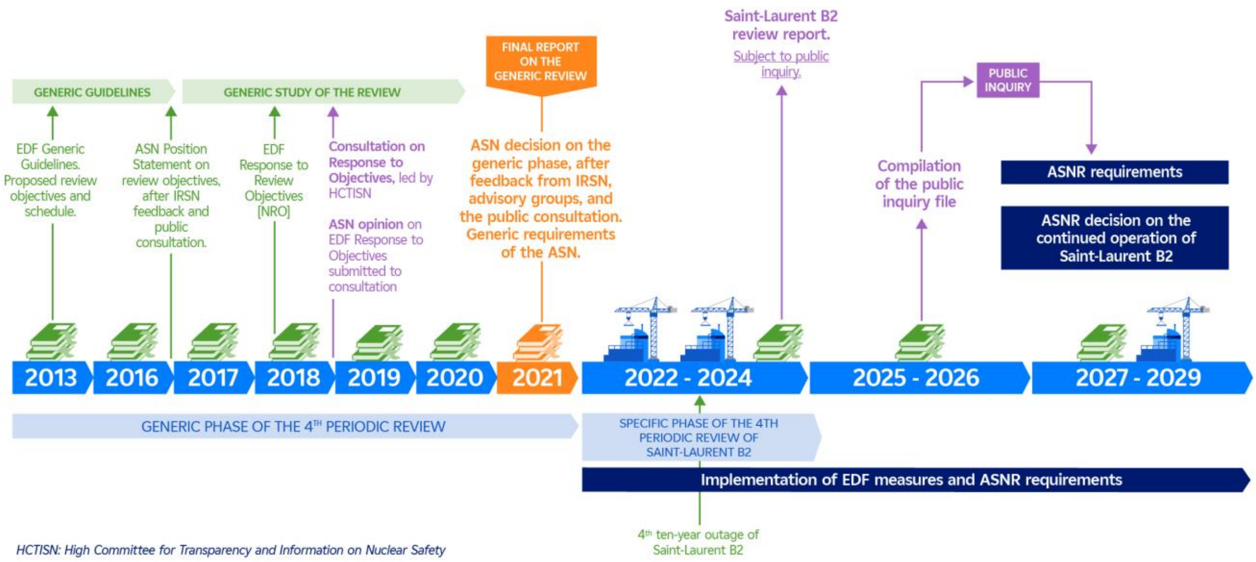
3.3. Timeline of the regulatory procedure

The Prefect of the Loire-et-Cher Department specifies, in particular, the opening date of the public inquiry and its duration (as per Article R.123-9 of the Environment Code).

The timeline for the periodic review of Saint-Laurent reactor No. 1 is summarised below.



The timeline for the periodic review of Saint-Laurent reactor No. 2 is as follows.



At the time of writing, the public inquiries for reactors Nos. 1 and 2 could be held at the end of 2026.

4. NUCLEAR POWER PLANT SAFETY

Saint-Laurent NPP, Loir-et-Cher Department
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4.1. Radiation protection

Radiation protection encompasses the rules, procedures, and prevention and monitoring measures, aimed at avoiding or reducing the harmful effects of ionising radiation on persons directly or indirectly exposed, including through environmental contamination. It is based on three fundamental principles: justification, optimisation, and dose limitation.

- **Justification**: any human activity that is likely to lead to individual exposure to ionising radiation can only be undertaken if the benefits are justified. The advantages must outweigh the drawbacks.
- **Optimisation**: for any given source, individual and collective doses must be kept as low as reasonably achievable given current technology, and economic and social factors. This is the ALARA[7] principle.
- **Dose limitation**: individual exposure to ionising radiation as a result of 'nuclear activity' must not cause the total dose received to exceed regulatory limits, except when the person is exposed for medical or biomedical research purposes.

In the remainder of this document, information on radioactive emissions, their impacts and their monitoring, relates to normal reactor operation and accident conditions.

[7] As Low as Reasonably Achievable.

4.2. Operational nuclear safety

As an industrial facility, a nuclear power plant inherently carries risks that may harm human health and the environment. A nuclear reactor contains radioactive material; and the facility contains hazardous substances (such as gas cylinders, flammable materials and chemicals) needed for plant operation.

The design and operation of nuclear power plants aim to control all risks by both reducing the likelihood of equipment failures through prevention measures, and limiting the consequences of any failures by way of protection measures. The greater the severity of the consequences, the lower the likelihood of the initiating event must be, in order to keep the risk as low as reasonably achievable, under economically acceptable conditions.

Risk management is an integral part of the fundamental principle of nuclear safety that is applied throughout the life of a nuclear facility: it involves implementing several successive lines of defence to achieve the highest level of control.

Identification of risks takes into account failures in the nuclear part of the installations, but also the failures of other equipment required for proper plant operation. For each risk, the following are defined:

- initiating events: equipment malfunction, or an internal (e.g. a pipe break) or external (e.g. an earthquake) hazard,
- the potential consequences off-site and for the operation of the plant itself.

All these risks are addressed through design and operation provisions in respect of nuclear safety and environmental protection, giving rise to multiple layers of countermeasures:

- to minimise the onset of incidents and accidents in the installation,
- to monitor the installation and maintain it in a safe state,
- to limit the effects of incidents and accidents on the installation and on the environment.

Given their respective characteristics, there are 2 categories of risk:

1. **radiological risks** linked to the presence of radioactive material,
2. **conventional risks** associated, for example, with the storage and use of flammable products, chemicals or low-level radioactive products.

There are two types of radiological risk:

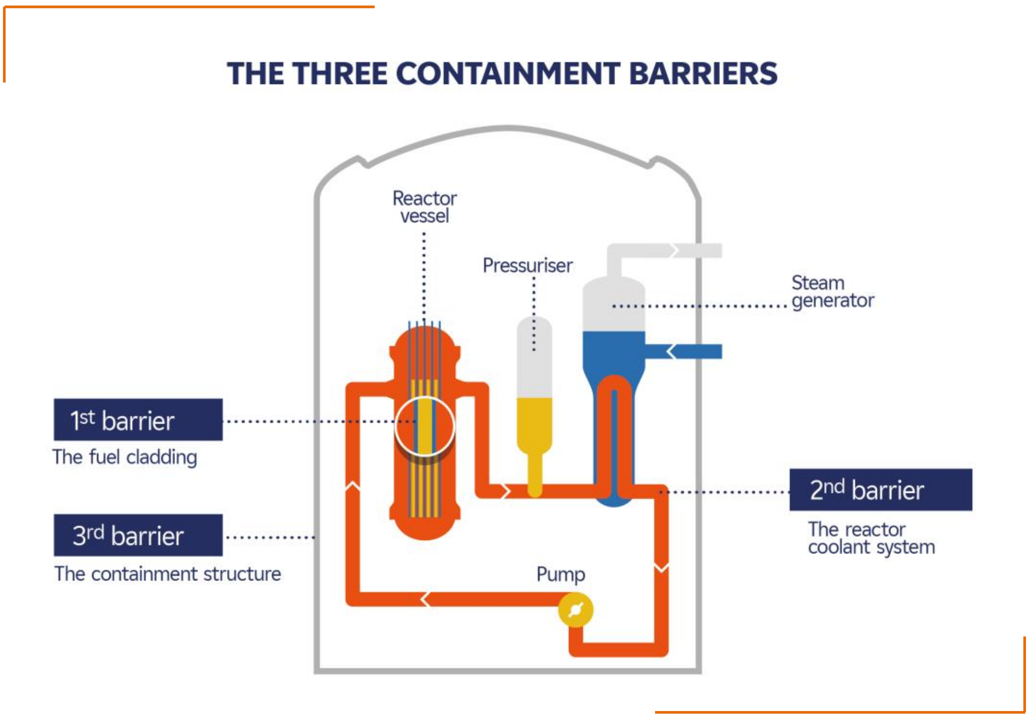
- direct exposure to radiation, known as external exposure,
- radiation exposure by ingestion and/or inhalation of radioactive material, known as internal exposure.

4.2.1. Radiological risk management

Radioactive materials are held in sealed containment structures, fitted with protective barriers (‘biological shielding’), adapted to each type of radiation, ensuring protection against the radiological risks of exposure and dissemination. The boundaries of these enclosures are called containment barriers. These barriers can be likened to a set of Russian dolls nesting inside one another. These separate, sealed and robust enclosures form a series of barriers isolating the fuel from the environment.

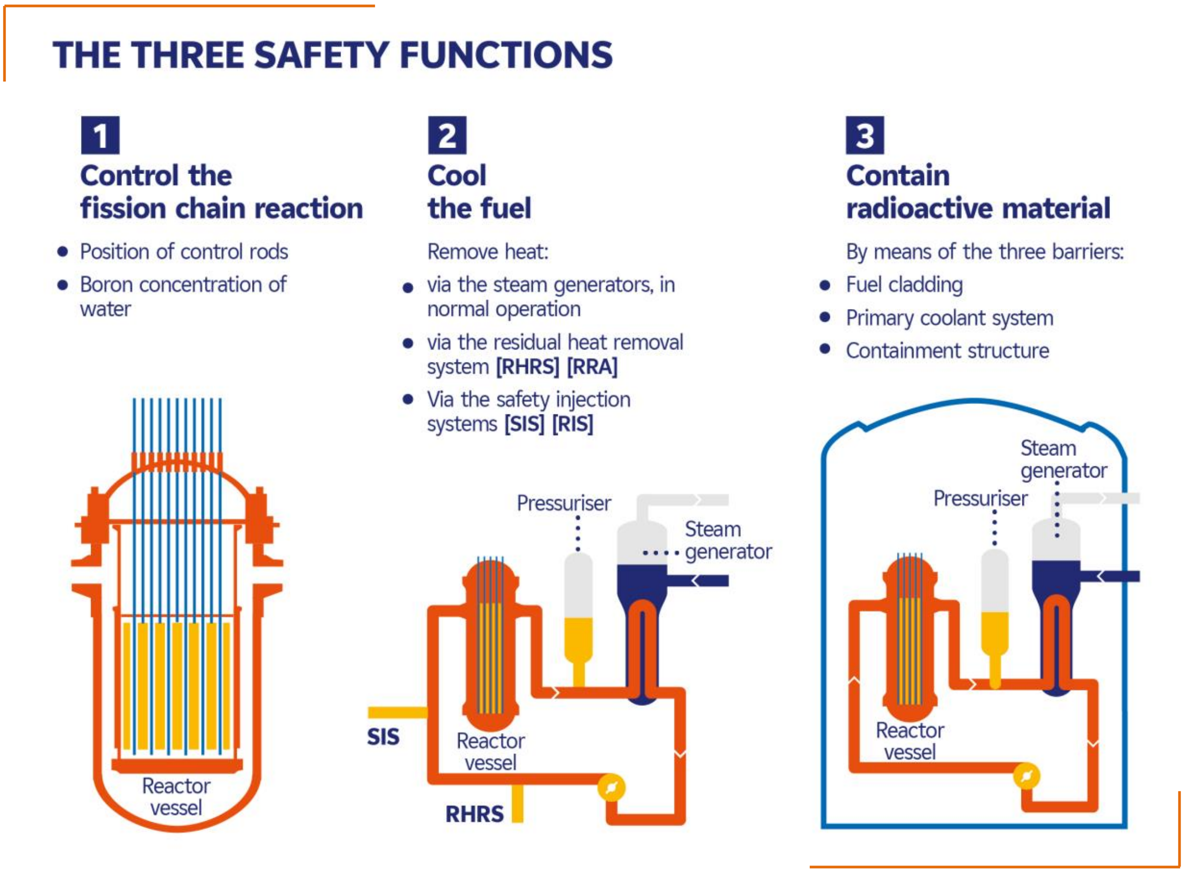
Three distinct, robust, sealed physical barriers thus work together to contain radioactivity:

- The fuel cladding,
- The reactor coolant system,
- The containment structure.



The risk analysis methodology involves identifying the possible causes of radioactive material dispersion beyond the containment barriers, and defining measures to reduce the occurrence and severity of the consequences of such events to the lowest possible levels.

In order to maintain the effectiveness of the containment barriers over time, and in all situations, equipment and systems are designed to continuously fulfil three ‘safety functions’.



The provisions put in place to fulfil these three fundamental safety functions **ensure the protection of people and the environment from ionising radiation**, and thus satisfy a fourth safety function introduced by the amended Ministerial Order of 7 February 2012 laying down the general rules for basic nuclear installations, and known as “arrêté INB”.

A “safe” reactor state relies on three safety functions:

- control of the nuclear chain reaction inside the reactor,
- cooling of the fuel,
- containment of radioactive substances,

and correct operation of the systems required to maintain these conditions.

In order to guarantee the highest level of plant safety, the design and operation of the reactors is centred on applying the concept of defence-in-depth, which calls for additional measures to protect these barriers and limit the consequences of an accident to an acceptable level for people and for the environment. Successive lines of defence, which are as reliable and independent as possible, are therefore provided for through additional technical, human and organisational measures to prevent such accidents or limit their effects.

At the design stage and during operation, defence-in-depth is applied at five levels:

1. **prevention (level 1):** prevent the occurrence of failures;
2. **monitoring or detection (level 2):** plan for the onset of the failure through inspections and tests, or detect failure as soon as it occurs in order to restore normal operation;
3. **means of action (level 3):** control the consequences of a failure or, failing that, limit any worsening of these consequences by regaining control of the facility (incident and accident management procedures);
4. **mitigation (level 4):** manage conditions so as to minimise the radiological consequences for people and the environment (ultimate emergency procedures);
5. **population protection (level 5)**: this 5th level of defence-in-depth is the responsibility of the authorities and involves the activation of the Offsite Emergency Plan [PPI] (shelter, iodine tablets, evacuation, etc.).

The safety case for radiological risk management in relation to the Saint-Laurent reactors, as described in their respective safety reports, consists of checking that the general safety objectives are met in all incident and accident sequences. To this end, numerous incident and accident scenarios have been selected and classified into categories according to their frequency of occurrence. The design of the facilities must also ensure adequate protection against scenarios induced by a combination of failures, or by any internal or external hazards that could impair the fundamental safety functions. For the 4th periodic review, the standards for the Saint-Laurent reactors will incorporate robust design features for withstanding core-melt accidents. The scenarios studied have led to the implementation of provisions[8] to limit the consequences of such accidents by preserving the integrity of the 3rd containment barrier.

Safety studies are carried out using a conservative approach, that is to say, by adopting the worst-case assumptions or influence-parameters in relation to the condition of systems and their operability, and to the physical phenomena associated with the scenarios. Where necessary, decoupling assumptions are applied so as to factor in uncertainty. This guarantees design margins with regard to the worst-case outcomes. As a result, no identified knowledge gaps are likely to call into question the conclusions of these studies.

The study of the radiological consequences of all these scenarios aims to verify the validity of the design and operational provisions that have been taken to protect the integrity of the radioactive-material containment barriers (fuel cladding, reactor coolant system, and containment structure). This also allows for verification that any off-site releases of radioactive substances following these incidents/accidents will have limited consequences for people and for the environment.

A distinction is made between:

- the radiological consequences of design-basis incidents and accidents (taken into account in the design),
- the radiological consequences of so-called beyond-design-basis accidents, not initially considered at the design stage, and corresponding to scenarios involving multiple combined failures. These accidents are studied so as to minimise the risks associated with the facility, by adding extended provisions to the standards. This is the case, in particular, for a main steam line break (MSLB) [RTV] accident combined with multiple steam generator tube ruptures (SGTR) [RTGV],
- the radiological consequences of hypothetical core-melt accidents.

[8] A number of improvements are applicable for the 900 MWe reactor series, and they will occasionally be referred to in the remainder of this document.

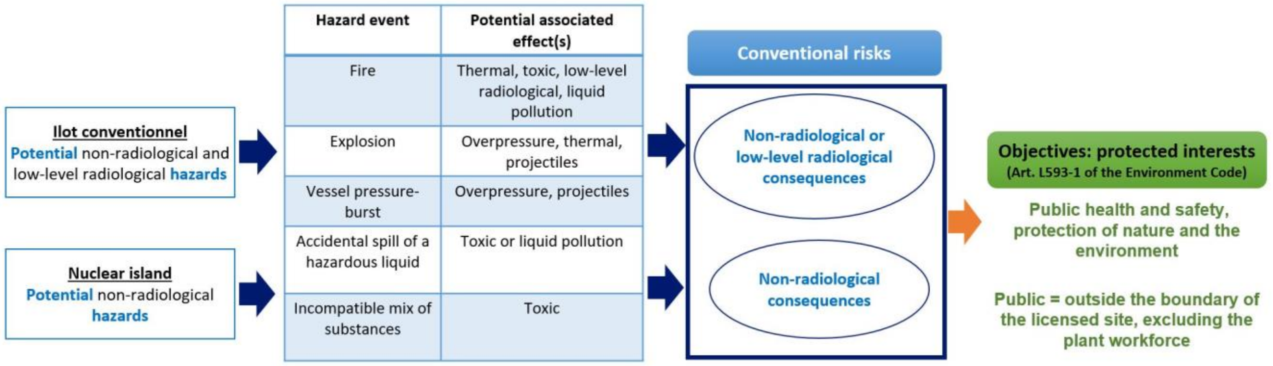
4.2.2. Management of conventional risks

4.2.2.1. Risk assessment methodology

Conventional risks are related, for example, to the storage and use of flammable products, chemical products, or low-level radioactive products in the conventional facilities of the plant.

The non-radiological safety case aims to demonstrate that these conventional risks are acceptable in relation to the interests to be protected:

- the population: the scope of the assessment covers all the areas that are accessible to the public, beyond the site boundary;
- the natural environment.



The potential off-site induced effects of these non-radiological or low-radiological conventional risks are as follows:

- Airborne effects:
  - thermal effects related to fire, a jet fire, or an explosion,
  - toxic effects from the atmospheric dispersion of fire smoke, the evaporation from a slick of toxic product, a leak of toxic gas, or a mixing of incompatible substances,
  - overpressure effects caused by an explosion or burst vessel,
  - low-level radiological effects resulting from the dispersion of radionuclides in the event of a fire in a low-level radiological facility,
  - effects related to the ejection of projectiles from rotating machinery due to an explosion or burst vessel.
- Liquid-borne effects: effects linked to the spillage of hazardous or low-level radioactive liquid substances into the environment.

Potential hazards are identified and characterised based on the effects they may have on the interests to be protected. The potential hazards that are identified cover those linked to products used or stored, as well as those associated with site activities.

Conventional accidents are managed by applying the principle of defence-in-depth and by controlling the following safety functions:

- containment of hazardous and low-level radioactive substances,
- protection of people and the environment against toxic effects, overpressure effects, thermal effects and effects related to projectile impact.

The analysis is carried out in an iterative process, until the acceptability of the risk is demonstrated through the following mechanisms:

- risk reduction at source, by seeking opportunities to reduce quantities of products or to use substitute products if operational constraints allow;
- identification and enhancement of measures for the management of organisational and technical risks (prevention, monitoring, mitigation) with a view to reducing the occurrence and/or consequences of the accident scenario.

All the facilities in which risk-significant activities are carried out, or in which hazardous products are stored, are subject to periodic inspections. Preventive maintenance operations are carried out in compliance with manufacturer instructions or on the basis of the operating experience of the equipment. Any deficiencies that are detected are addressed with corrective actions to repair to specifications.

Fire risk is given special consideration (Fire Safety Action Plan and Fire Risk Management Project), and is analysed on an ongoing basis, drawing on operating experience, as part of the continuous improvement process. Fire risk management hinges on preventing fire outbreaks, rapidly detecting and extinguishing fire outbreaks, and limiting the spread and the severity of a fire.

In regard to the liquid-borne effects linked to the accidental spillage of hazardous or low-level radioactive liquids, risk management is ensured by the installation of systems designed to contain spilled substances. Some of these systems, which form the final barrier in terms of environmental protection, are defined as Elements classified for the Protection of Interests [EIP], with associated requirements for their proper operation. **The operator's compliance with these requirements is subject to specific provisions (monitoring, inspections, maintenance), thus ensuring that these risks are controlled.**

In respect of the airborne effects, a preliminary analysis identifies the bounding accident scenarios that may have an impact off-site, as well as the measures taken to control these risks. For each of these accident scenarios, an in-depth risk analysis is carried out to determine the probability of such an accident occurring and the severity of the consequences. The measures identified to demonstrate control of conventional risks are then defined as Activities or Elements classified as Important for the Protection of Interests ([AIP], [EIP]), with associated requirements that must be implemented for effective operation. The operator’s compliance with these requirements is subject to specific provisions (monitoring, inspection and maintenance).

These measures are monitored during plant operation.

4.2.2.2. Overview for Saint-Laurent

- ***Airborne risks***

With the exception of the scenarios mentioned below, the airborne risks for the accident scenarios considered have no effects outside the site boundary. The risk analysis carried out for Saint-Laurent NPP identified two conventional accident scenarios that may impact the interests to be protected:

- In the off-loading area[9] of the demineralisation station, where several products may be unloaded from tanker-trucks, a scenario may occur during off-loading, involving the dispersion of a toxic cloud of chlorine generated by the mixing of incompatible hazardous substances inside the installation;
- A mix-up between different off-loading areas, where a tanker-truck delivering its contents may mix up the demineralisation station, the monochloramine treatment facility and the purification plant, could lead to the mixing of incompatible hazardous substances across several installations, and to the dispersal of a toxic cloud of chlorine.

[9] Off-loading is the action of unloading a truck by transferring the liquids or gases to a storage tank.

The numerous preventive measures that have been implemented defend against such accidents occurring: training of personnel, the implementation of detailed procedures, the use of visual signage and fool-proofing mechanisms to minimise the risk of hose-connection errors, the use of human error-reduction techniques, etc.
In regard to the two scenarios involving the mixing of incompatible substances, targeted preventive measures have been implemented to reduce their likelihood of onset. These risk management measures are defined as Activities classified as Important for the Protection of Interests [AIP] and are specific to each scenario. The following preventive measures are to be carried out prior to off-loading:

- A mandatory escort for trucks from the site entrance to their designated off-loading area, so as to minimise the likelihood of a mix-up between unloading areas;
- An inspection of the discharge-hose connection to the designated hose connector for the product being off-loaded;
- A sample test of the product being delivered, to physically check that the delivered product meets specifications.

Given the provisions in place, the scenarios involving the mixing of incompatible products have a frequency of occurrence categorising them as very unlikely events (less than 1 in 10,000 years).

In light of the strategy of defence-in-depth and the identification of several levers for action to control the risks, all the accident scenarios are effectively managed in regard to the interests to be protected.

Liquid-borne risks

With regard to liquid-borne risks, appropriate measures are in place to contain spilled liquids and thus protect against the accidental spillage of hazardous or low-level radioactive liquids into the environment. The liquid spill scenarios therefore have no impacts on the environment.

The conventional risks posed by Saint-Laurent Nuclear Power Plant with respect to the interests to be protected are therefore controlled.

4.3. Management of ageing and obsolescence

EDF's approach to managing the ageing and obsolescence of its operating reactors hinges on:

- the management of the ageing of systems, structures and components,
- maintenance operations,
- the management of obsolescence of equipment and spare parts.

The main measures taken or proposed by the operator in this regard address two objectives:

- to demonstrate the ability of non-replaceable equipment to perform its function after 40 years of operation:
  - Regarding the reactor vessels at Saint-Laurent,
    - hydrostatic testing is performed during the ten-year outage for full qualification of the main primary system (MPS) [CPP];
    - summary reports are drawn up to demonstrate in-service behaviour and performance, in keeping with a conservative, deterministic approach (neutronics, materials, mechanics, etc.). These reports include both the theoretical study of the most significant undetectable hypothetical generic defect (for all 900 MWe reactor vessels) and specific studies for each vessel, based on the results of the inspections conducted during the 4th ten-year outage [VD4];
    - the introduction of hafnium, a neutron-absorbing material, in the fuel assemblies of the Saint-Laurent reactors, opposite the most highly neutron-irradiated sections of the vessels, reduces vessel exposure to neutron fluence (the neutron flux integrated during the operating life of the reactor).
  - Regarding the containment structures, their mechanical performance is continuously monitored by instrumentation systems (measuring deformation, for example) and by a containment pressure test carried out during the ten-year outage.
- to demonstrate the ability of replaceable equipment to fulfil its function after 40 years operation, or to proceed with either replacement or refurbishment.

Components whose performance is likely to deteriorate owing to ageing, and whose failure could have an impact on safety, are subject to documented and periodically updated monitoring, by way of an Ageing Analysis Sheet for each piece of equipment, and a summary report of Clearance for Continued Operation for each reactor. On this basis, inspections, checks and maintenance operations are carried out during the fourth ten-year outages of the Saint-Laurent reactors on various systems, structures and components, including: civil engineering structures, instrumentation-and-control systems, nuclear-qualified electrical cables, electrical penetrations, mechanical and electromechanical equipment, electrical equipment and instrumentation.

4.4. Nuclear safety and reactor decommissioning

Each stage of dismantling is associated with a set of nuclear safety standards governing the operations that are carried out during that period.

So long as there is nuclear fuel present on site, certain nuclear safety objectives described in the facility's Operational Safety Standards are maintained, in particular those relating to the spent fuel pool:

- The reactivity of the spent fuel assemblies is managed by using storage racks that contain neutron-absorbing materials and thus keep the fuel subcritical, and by using borated water.
- If pool cooling is interrupted, residual heat removal from the fuel is not compromised in the short term due to the very low residual heat output of the fuel, and to the large volumes of water in the pools. Although restoring cooling is the primary objective, residual heat could also be removed by allowing the water to boil and by supplying makeup water to the pools. Makeup water can be added to the pools through various plant systems, including new means of makeup installed following the Fukushima Daiichi accident and subsequently incorporated into the safety standards for the 4th review.

Once the spent fuel has been removed, nuclear safety calls for control of the risks of a dispersion of hazardous materials and substances (in solid, liquid or gaseous form) and of exposure to hazardous phenomena (toxic effects due to liquid and/or airborne releases, thermal effects, overpressure effects, projectiles, and exposure to low-level radiation).

The technical choices made are those that apply the principle of defence-in-depth by preventing any major dispersion of radioactive substances off-site and by limiting the exposure of members of the public. They will be set out in the Risk Control Study that will be included in the Dismantling File required by Article R. 593-67 of the Environment Code.

5. ASSESSMENT OF THE ENVIRONMENTAL IMPACTS OF PLANT OPERATION

Saint-Laurent NPP, Loir-et-Cher Department
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5.1. Approach

Section 5 presents the assessment of the environmental impact of Saint-Laurent NPP operation, both in its current state and for the next ten years.

The first subsections set out:

- the environmental impact assessment methods (Section 5.2),
- uncertainty in the impact assessment (Section 5.3),
- the data used in the assessment (Section 5.4),
- the current state of the environment (Section 5.5).

Section 5.6 presents the interactions between Saint-Laurent NPP operation and the environment, both currently and over the next ten years.
Section 5.7 sets out the impacts of Saint-Laurent NPP operation on the environment, currently and for the next ten years. The impacts of plant decommissioning are presented in Section 5.7.10.

5.2. Impact assessment methods

The impact assessment methods, presented by area, aim to establish the effects of Saint-Laurent Nuclear Power Plant operation on health and the environment, and to justify acceptability.

Air and climate factors

The analysis of the impacts of Saint-Laurent NPP operation on the climate draws on the life cycle assessment (LCA) of the nuclear kWh for EDF's current operating fleet. It was carried out by EDF using a standard method and was critically reviewed by a panel of independent experts. It is based on an inventory of material and energy flows at the different phases of the product's life cycle, from raw material extraction to waste management.
The air quality impact analysis is based on a comparison between the concentrations of released substances and the air quality standards defined in the Environment Code (Article R.221-1).

Surface water

The assessment of the impact of liquid chemical effluent discharges on surface water quality hinges on:

- a retrospective analysis of the impact of past and current liquid chemical discharges, based on data from chemical and hydroecological monitoring carried out upstream and downstream of the power plant;
- a quantitative substance-by-substance evaluation of the impacts of liquid chemical discharges, founded on a comparison between the calculated concentrations in the environment and reference values (threshholds, guidance values, ecotoxicological data, etc.).

Soil and groundwater

The assessment of impacts on soil and groundwater is based on:

- investigations of the status of soil and groundwater at the power plant, founded on an analysis of historical data and a review of the results of piezometer monitoring on site, supplemented by measurement campaigns;
- comparisons with reference data for soils: data on the quality of surrounding soils (outside the areas potentially affected by the plant), data from specific studies or national programmes;
- a comparison with groundwater quality thresholds (the decree of 11 January 2007 on quality limit values and reference values for raw water and water intended for human consumption, the decree of 17 December 2008 establishing assessment criteria and procedures for determining groundwater status, the WHO (2017) Guidelines for Drinking Water Quality, and Council Directive 2013/59/EURATOM of 5 December 2013, establishing basic standards for protection against the dangers to health arising from exposure to ionising radiation).

Radioecology

The assessment of the environmental impacts of liquid radioactive effluent discharges and radioactive effluent discharges to atmosphere draws on:

- a retrospective analysis of the impact of past discharges, factoring in the results of the initial baseline assessment, the ten-year reports and the annual follow-ups;
- a prospective (future-orientated) analysis carried out using the European ERICA (Environmental Risks from Ionising Contaminants: Assessment and management) tool, to assess the radiological risks to terrestrial and aquatic ecosystems associated with radioactive effluent discharges from Saint-Laurent power plant, taking into account the authorised discharge limits.

The principle behind this assessment is a comparison of the dose rate induced by the radioactive discharges, with a dose rate value that has no effect on each reference organism. This comparison results in the calculation of a risk index. If the risk index is less than 1, it can be concluded that the risk is negligible.

Biodiversity

The analysis of the impacts of Saint-Laurent NPP operation on biodiversity is based upon:

- the study of the natural areas, habitats, fauna, flora and ecological functionalities present within the study area (bibliographic studies and field investigations);
- the analysis of the effects of each interaction between Saint-Laurent power plant and natural areas, fauna, flora and ecological functionalities.

Population and human health

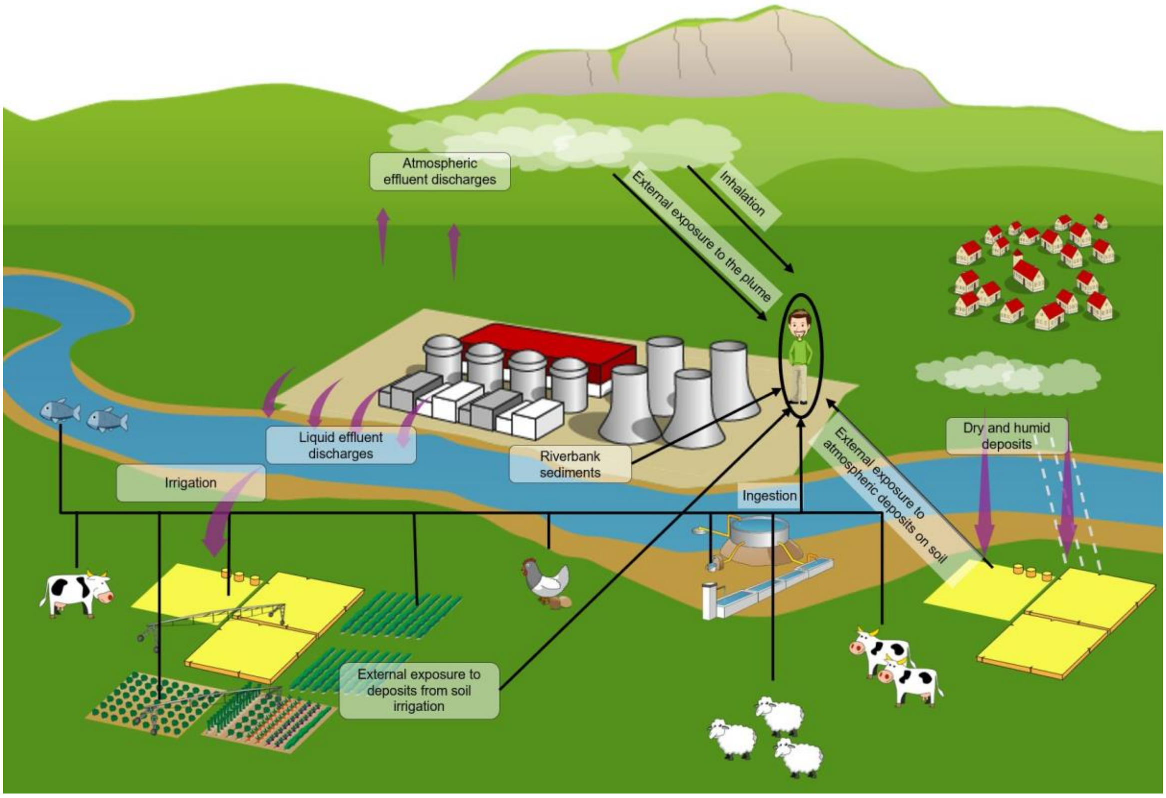
The **dosimetry impact** of radioactive effluent discharges takes into account both internal and external exposure associated with liquid radioactive effluent discharges and radioactive effluent discharges to atmosphere.
The following exposure pathways are considered (see figure below):

- external exposure to radioactive effluents discharged to atmosphere, atmospheric deposition of radioactive substances onto soil, deposition from soil irrigation, and sediments on riverbanks;
- internal exposure through inhalation and food ingestion.

To assess the dosimetric impact on the population of radioactive effluent discharges linked to the operation of nuclear power plants, EDF uses a tool developed by the Institute for Radiation Protection and Nuclear Safety [IRSN] (now the Authority for Nuclear Safety and Radiation Protection [ASNR]).

The assessment is carried out in the following stages:

- characterisation of radioactive effluent discharges;
- characterisation of the environment around the site;
- assessment of the transfers of discharged radionuclides to the various environmental compartments, up to humans: atmospheric environment, river environment, agricultural environment (plants, animals, soils);
- assessment of the exposure of local populations;
- presentation of the results, with a comparison of the total effective dose received by the representative individual, as against the regulatory limit of 1 mSv/year.



Pathways of exposure to radioactive effluent discharges ©EDF

With regard to the **assessment of the health risks** associated with liquid chemical discharges, the methodology that is used conforms to the methodological guide published by the National Institute for the Environment and Industrial Risks [INERIS] and entitled 'Assessment of the state of the environment and health risks'. It sets out a two-step approach:

- A Site Pollution Assessment [IEM], based on monitoring data and on specific measurements;
- A Prospective Health Risk Assessment [EPRS], drawn up by modelling the discharges attributable to the Saint-Laurent site. This assessment is broken down into five steps:
  - an inventory of the substances discharged,
  - an assessment of issues and exposure pathways,
  - identification of hazards, assessment of dose-response relationships, and identification of environmental health risk markers,
  - an assessment of population exposure,
  - characterisation of the risks.

The health risks associated with chemical discharges to atmosphere are assessed qualitatively, given the low quantities of chemical emissions into the atmosphere, their short duration, their low occurrence, or the absence of toxicological reference values (TRV).

The assessment of the **noise impact** of Saint-Laurent NPP operation hinges on noise measurement campaigns conducted in the environment, in the Regulated Noise Aggravation Zones and at the site boundary. These campaigns apply a methodology based on standard NF S 31-010 for the characterisation and measurement of environmental noise.

- ***Human activities***

The assessment of the impacts on human activities is based on environmental issues:

- using public, validated data (e.g. data on road traffic, land use, water use);
- using the assessments of the health impacts of the plant's discharges.

- ***Waste management***

The impact of the waste that is produced is mainly assessed through analysis of the measures implemented for waste zoning, characterisation, sorting, treatment, packaging and inspection, and through analysis of the power plant's operating experience.
The quantification of waste produced, and estimation of projected quantities of waste generated in the coming years, are based on data from the annual waste management reports prepared by the power plant. These reports provide quantitative and qualitative data on the waste generated by the plant, and specify the waste management streams that have been and will be used.

5.3. Uncertainty in the impact assessment

The impact assessment methods presented in the previous section are cutting-edge and developed using available scientific results.
Advances in science are gradually improving environmental monitoring and fostering the development of assumptions and computational tools.
Conservative assumptions are incorporated into the impact assessments. The main conservative assumption is to consider the interactions with the environment to be reasonably bounding of the interactions that will actually be observed. Other conservative assumptions are adopted in the various assessments, particularly in the exposure scenarios. For example, it is assumed that neighbouring populations consume only tap water from the nearest water source, without taking into account substance degradation phenomena.

5.4. Data used in the assessment

The data used to assess the impact of Saint-Laurent NPP operation is as follows:

- data on the plant's interactions with the environment, detailed in Section 5.6;
- data on the current state of the environment, acquired largely through environmental studies carried out by Saint-Laurent power plant. This data is presented in Section 5.5 and covers:
  - air quality;
  - meteorology;
  - surface water quality;
  - soil and groundwater status;
  - the radiological state of the environment;
  - biodiversity;
  - population and human activities.

Saint-Laurent NPP regularly publishes data from its monitoring of discharges and of the environment:

- The results of environmental monitoring around the plant are sent to the National Network for Environmental Radioactivity Measurement, developed under the umbrella of the Authority for Nuclear Safety and Radiation Protection. This data is available on the website of the National Network for Environmental Radioactivity Measurement (https://www.mesure-radioactivite.fr/).
- Every month, the power plant publishes discharge and environmental monitoring data on its website.
- An annual environmental monitoring report is also available on the website.

For further information, the guide "Nuclear power plants and the environment" sets out the interactions between nuclear power plants and the environment, and the associated monitoring arrangements.

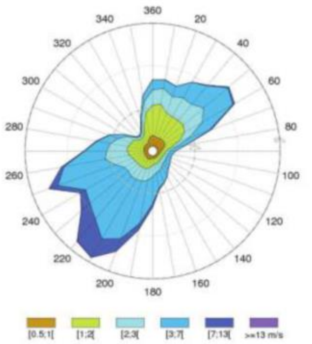
5.5. Current state of the environment

5.5.1. Air and climate factors

▪ *Climate*

The region in which Saint-Laurent NPP is sited has a temperate climate with regular episodes of intense heat in the summer and frequent frosts in the winter. Local winds blow predominantly in two directions, and are generally associated with oceanic weather systems and high-pressure conditions. However, the orographic effects of the Loire Valley must be taken into account in relation to wind patterns.

Between 2011 and 2020, the average temperature at Saint-Laurent was of the order of 11.8°C; it rains on average 185 days per year, and the prevailing winds are from the south-west and north-east.



Wind rose at 10 metres at Saint-Laurent NPP's weather station, 2011-2020

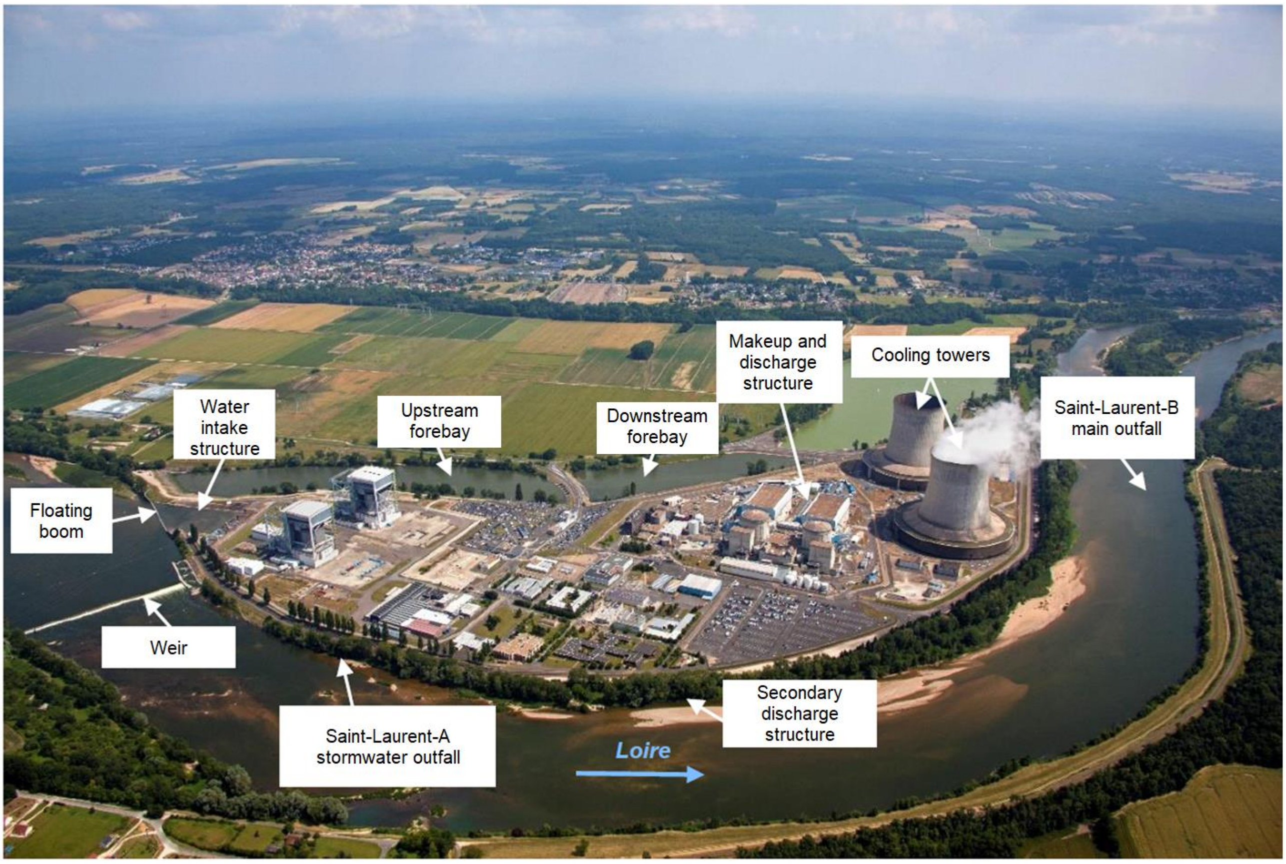
▪ *Air quality*

Air quality around the Saint-Laurent site is generally average, mainly due to higher ozone levels in the summer months and higher fine particulate matter concentrations in the winter months, resulting in particular from household heating systems. Air quality standards are met for available data.

5.5.2. Surface water

Hydrology

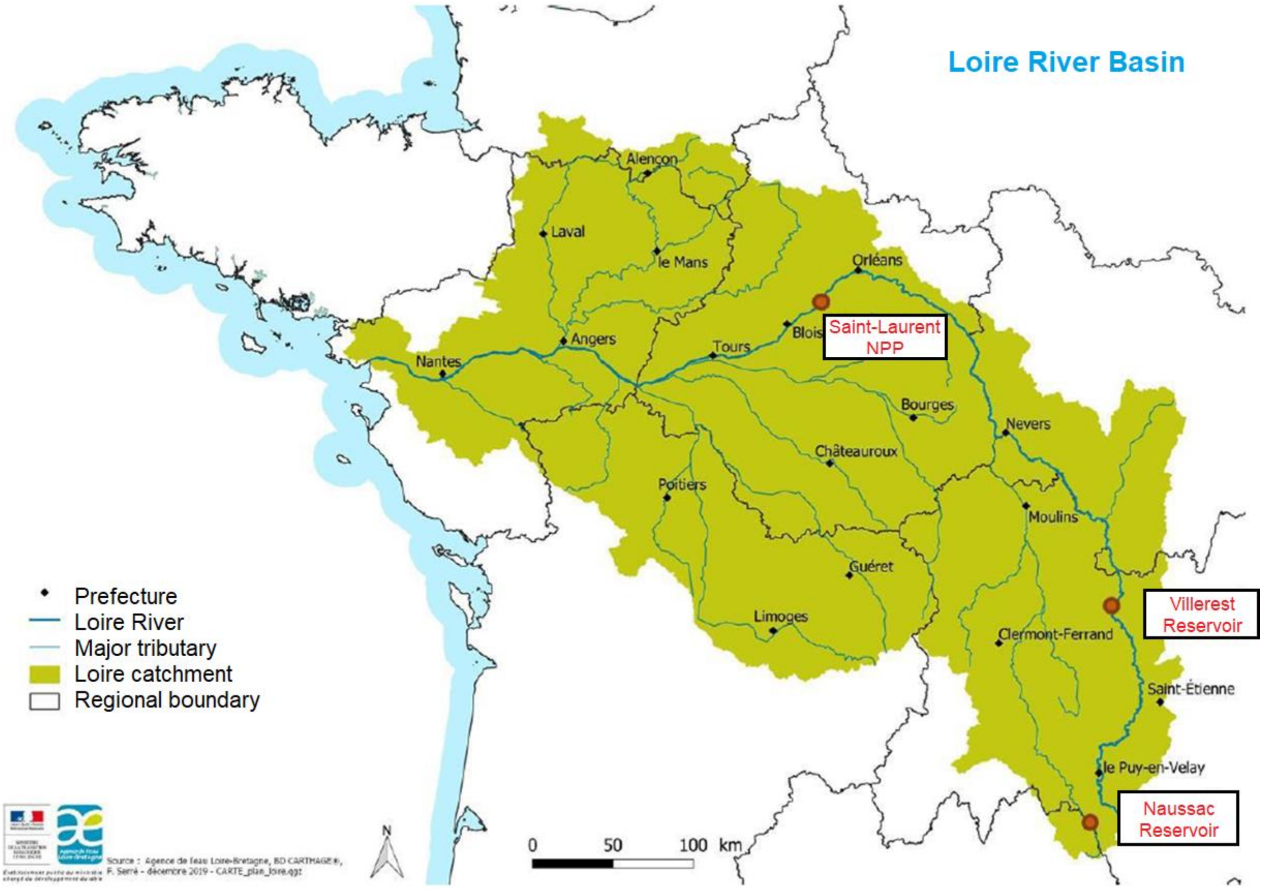
Saint-Laurent NPP is located in the Commune of Saint-Laurent-Nouan, on the left bank of the Loire River, around 30 kilometres downstream of Orléans (Department of Loiret) and approximately 28 kilometres upstream of Blois. Water for the power plant is drawn from the Loire and flows into the intake structure on the left bank, which encompasses the former Saint-Laurent-A intake as well as an opening connected to the intake channel. The latter consists of upstream and downstream forebays connected by pipes installed beneath the site access road. The pumping station for Saint-Laurent B nuclear power plant is located in the downstream forebay. A weir in the Loire downstream of the intake structure ensures adequate intake water levels at all times.



Aerial view of the Saint-Laurent site
© DIDIER MARC

The hydrological regime of the Loire is pluvial oceanic, with highly variable flows characterised by both low-water and high-water events, the latter caused by Cévennes flash-floods, oceanic flooding or mixed floods. The contribution of right-bank tributaries (the Lignon du Velay, the Arroux, the Cisse and the Maine) is significant, particularly during periods of rising waters. River flow is also affected by hydraulic structures upstream of the site.

From 1986 to 2020, the average inter-annual flow of the Loire at the Saint-Laurent site was 325 m^3/s. Flows are highest between November and May, and low-water levels are more pronounced in the summer, particularly in August.



The location of Saint-Laurent NPP in the Loire catchment area (© Agence de l'Eau Loire-Bretagne)

▪ *Thermal regime*

The analysis of the thermal regime of the Loire River upstream of Saint-Laurent NPP drew on historical records of river temperature measurements taken upstream of the plant over the period 1976-2021.

The findings of this analysis are as follows:

- Intra-day variability is greater in the summer, with average daily fluctuations of around 1.7°C. Winter sees average temperature fluctuations of around 0.7°C.
- Seasonal variability is pronounced and mainly influenced by seasonal hydrometeorological conditions, with temperatures in the Loire upstream of Saint-Laurent NPP ranging from a monthly average minimum of 5.4°C in January to a monthly average maximum of 21.9°C in July.
- The temperature of the Loire upstream of the power plant is above 25°C for 10% of the time in July and 5% of the time in August. It exceeded 28°C on six occasions between 1976 et 2021. The maximum daily temperature recorded is 28.3°C, on 27 June and 25 July 2019.
- An analysis of year-to-year variations charted since the late 1970s shows an upward trend in water temperatures. The average change is calculated at around + 0.4°C per decade over the period 1976-2021.

Physico-chemical and biological quality

Saint-Laurent NPP abstracts its water and releases its liquid discharges into surface water body 'FRGR0007c'. This natural water body marks off the section of Loire River between Saint-Denis-en-Val and the confluence of the Cher River.

A 2019 assessment by the Loire-Bretagne Water Agency of the **ecological and chemical condition** of this body of water concluded in a good ecological status and a good chemical status, excluding ubiquitous substances* (however, the chemical status including ubiquitous substances is poor).

**: the ubiquitous substances that downgrade this status, namely, benzo(a)pyrene, perfluorooctane sulfonate, mercury and its compounds, and brominated diphenyl ethers, are not substances that are released by Saint-Laurent NPP.*

The results of hydroecological and chemical monitoring over the period 2012-2021 indicated that the quality of the aquatic environment was satisfactory, in terms of physico-chemical and chemical parameters, as well as biological indicators.

Based on analyses carried out in 2017, the quality of the sediment in the water intake structure and forebay upstream of Saint-Laurent NPP generally meets the regulatory criteria for release back to the environment, in terms of particle size and chemical parameters.

What is more, the quality of the sediments in the intake channel is equivalent to that of the sediments moving along the Loire River.

The ecological status of a surface water body within the meaning of the Water Framework Directive [DCE] is defined on the basis of several criteria: general physico-chemical elements supporting biology, specific pollutants, hydro-morphological elements, and biological elements (with macroinvertebrates, fish, macrophytes and diatoms as biological indicators).

The chemical status of a surface body of water is determined by its concentration in certain pollutants (chemical substances) in different matrices (water, biota and/or sediments), compared with the Environmental Quality Standards (EQS).

Ubiquitous substances are persistent, bioaccumulative and toxic (uPBT) substances, often emitted in the past by human activities (fire retardants, pesticides, etc.), which remain present in aquatic environments at concentrations that are very often above those set by environmental quality standards. As a result, they regularly downgrade the status of water bodies and, furthermore, mask any improvements. Directive 2013/39/UE therefore authorises Member States to report separately on the impact of ubiquitous substances, in order to get a clear picture of water quality improvements in relation to the remaining substances**.**

5.5.3. Soil and groundwater

Geology

Saint-Laurent power plant is sited at the south-western edge of the Paris Basin, on the left bank of the alluvial plain of the Loire River, approximately 30 km downstream from Orléans.

The formations found beneath the natural ground at Saint-Laurent NPP are, from top to bottom: elevation fill material consisting of alluvium, ancient alluvium deposited by the Loire during the Quaternary period, marl-limestone alterations of Paleogene limestone and marl, clay-with-flints dating to the transition between the Lower Eocene and the Upper Cretaceous, and Upper Cretaceous chalk.

Hydrogeology

Three aquifer reservoirs have been identified at the Saint-Laurent site:

- alluvial deposits;
- the Beauce aquifer complex, comprising the Étampes Formation and the Middle and Upper Eocene lacustrine formation (Paleogene period marl-limestone alterations);
- chalk comprising clay-with-flints, the eluvial facies of the chalk, and pure chalk.

The construction of the power plant has anthropised the land and brought about local changes in groundwater flows (resulting from earthworks, the construction of buildings and engineered confinement structures[10], the creation of an intake and discharge channel, etc.).

There are two bodies of water at the Saint-Laurent site:

- The Level-1 groundwater body 'FRGG108, Alluvions Loire moyenne avant Blois'. Under River Basin Management Plan SDAGE 2022-2027 for the Loire-Brittany basin, the objectives for this body of water are to maintain good quantitative status and good qualitative status, which were attained in 2015 and 2021, respectively.
- The Level-4 groundwater body '2FRGG089, Craie du Séno-Turonien captive sous Beauce sous Sologne', from which the power plant draws directly for both drinking water supply and ultimate emergency makeup water. Under River Basin Management Plan SDAGE 2022-2027 for the Loire-Brittany basin, the objectives for this body of water are to maintain a good quantitative status and a good qualitative status, which were attained in 2015.

Furthermore, given that the Commune of Saint-Laurent-Nouan abstracts water from the Cenomanian aquifer system, it is classified as a Water Allocation Zone [ZRE]. Within the commune, the official elevation of the Cenomanian aquifer's groundwater table, as specified in the decree, is - 150 m NGF (levelling datum).

- ***Soil status***

The initial condition of the soil around the power plant is determined using national databases, 'control' soil samples taken within the plant boundary, outside the reach of any potential contamination linked to plant activities, and radioecological measurements in the surrounding environment

Regarding radionuclides, radiological monitoring operations take place every year and include sampling layers of surface soil near the power plant, as well as analysing these samples for the main radionuclides of artificial origin in the site's effluent discharges to the atmosphere. As the power plant has no impact on the surrounding soil, the results of this monitoring are representative of local background radiation levels.

Saint-Laurent NPP's activities may have a temporary impact on soil and groundwater as a result of operational incidents in the facilities. However, should there be any evidence of contamination, action is taken with the implementation of measures to reduce potential impacts, and to restore soil and groundwater substance-concentrations to levels that do not pose a risk to health or to the environment.

5.5.4. Radioecology

The environment surrounding Saint-Laurent NPP has been subject to radioecological studies focused, on the one hand, on identifying the main radionuclides present in the various terrestrial and aquatic environmental matrices prior to plant operation and, on the other hand, on assessing over the long term the extent to which the power plant's effluent discharges contribute to environmental radioactivity, in comparison to other known sources.

- ***Sources of environmental radioactivity***

Interpreting radioactivity measurements requires a distinction between radionuclides that occur naturally in the environment (from cosmic and telluric radiation) and those produced artificially through nuclear fission or activation reactions (atmospheric nuclear tests, nuclear accidents, radioactive effluent discharges from industry and hospitals).

- ***Radiological status of the environment***

Analysis of the results of radioecological surveys carried out in the environment around Saint-Laurent NPP over the period 2012-2021 highlights the predominantly natural sources of radioactivity, along with artificial radioactivity originating from the residual effects of the fallout from atmospheric nuclear tests and the Chernobyl accident, as well

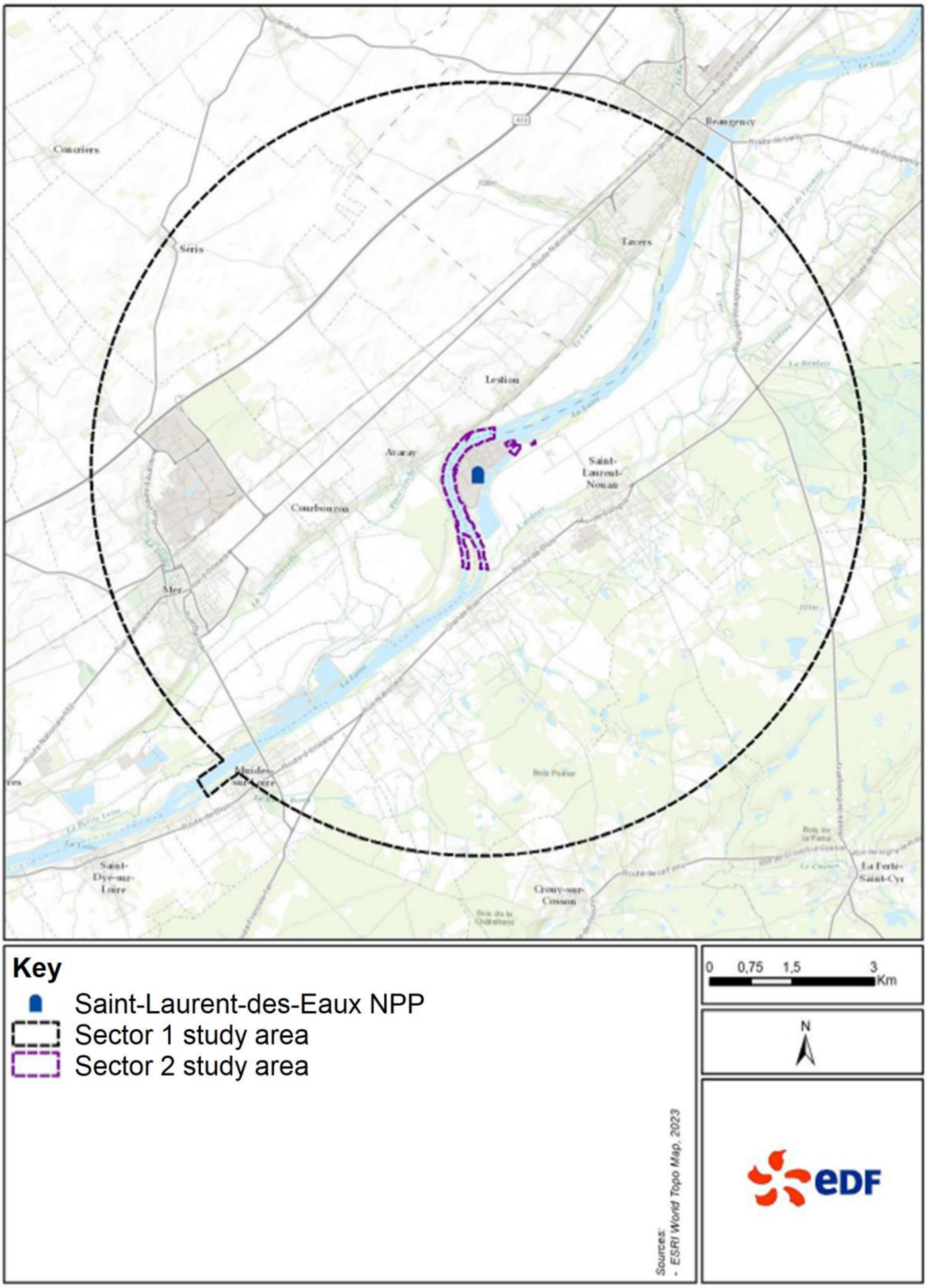
[10] These engineered confinement structures isolate the subsoil below the BNI from the rest of the alluvial aquifer.

as from the radioactive liquid effluent discharges and radioactive effluent discharges to atmosphere from Saint-Laurent NPP and from power plants upstream of the Loire (Dampierre-en-Burly and Belleville-sur-Loire).

5.5.5. Biodiversity

A review of the ecological priorities for the area around Saint-Laurent NPP was carried out:

- firstly, by detailing the areas of special interest and the ecological functionalities within a 10-km radius of the power plant;
- secondly, by conducting an impact assessment in relation to two sectors within the boundary:
- sector 1 represents the area of potential influence on terrestrial and aquatic environments associated with overall plant operation. It is defined conservatively by a radius of 7 km around the site, equivalent to the area of influence on the terrestrial environment, plus a section of the Loire River sited between the most upstream discharge point and the downstream boundary of the downriver hydroecological monitoring station, located approximately 7.5 km from the power plant, corresponding to the area of potential influence on the aquatic environment;
- sector 2 constitutes the area of potential influence on terrestrial and aquatic environments associated with the maintenance of water intake structures (dredging operations in particular).



Study sectors 1 and 2 adopted for the Saint-Laurent NPP impact assessment

Natural areas of special interest

The following natural areas of special interest have been identified within a 10-km radius of Saint-Laurent power plant:

- eight sites in the Natura 2000 protected areas network;
- seven type-1 Natural Areas of Interest for Ecology, Fauna and Flora [ZNIEFF] and three type-2 ZNIEFF;
- three sites managed by the Nature Conversation Trust [Conservatoire des Espaces Naturels];
- one National Wildlife and Hunting Reserve;
- two areas under Biotope Protection Orders (BPO) [APB].

Natural Areas of Interest for Ecology, Fauna and Flora [ZNIEFF] correspond to areas of ecological interest that are home to heritage species. They represent a source of information and knowledge on natural environments.

Natural habitats

Various habitats have been identified in the study area, under two main habitat complexes:

- Sector 1 consists mostly of croplands and anthropised habitats. Woodlands and wet meadows also feature prominently. The ecological priorities identified for this sector vary from area to area, with higher priority habitats in the south and east, as well as along the Loire River, and lower priority habitats in the west and north of the sector;
- Sector 2 is made up of seven habitats that can be grouped into four complexes, namely, aquatic and wetland habitats, woodlands, croplands and artificial surfaces, and anthropised environments. The habitats in this sector are high-priority as regards the Loire River and its riparian woodland, while the remainder of sector 2 is low to zero priority owing to the anthropised environments.

Vegetation

Around 650 terrestrial and semi-aquatic plant species have been identified in sector 1. This includes 53 species of special interest, listed as protected and/or heritage species (threatened or near-threatened species on national or regional red lists, or species that are classed as key species of high conservation value for the Centre-Val de Loire region's Natural Areas of Interest for Ecology, Fauna and Flora). 16 species are designated as invasive alien species. Given the diversity of habitats and associated plant species, sector-1 flora is categorised as being of generally high ecological significance.

415 terrestrial and semi-aquatic plant species have been recorded in sector 2, primarily in anthropised environments (across the industrial site, as well as around the upstream forebay). No species of special interest have been found. However, two protected species have been identified in the immediate vicinity of sector 2 (one semi-aquatic and one terrestrial). A non-protected heritage species has also been surveyed in the study area. Two of the species found in sector 2 are listed as invasive alien species. On this basis, the terrestrial and semi-aquatic plant species in sector 2 are deemed to be of no ecological significance.

Small fleabane (Pulicaria vulgaris Gaertn)
© EDF

Mountain parsley (Oreoselinum nigrum Delarbre)
© EDF

Protected plant species in the vicinity of sector 2

- ***Fauna***

Bibliographic data supplemented by field investigations highlighted the potential presence in sector 1 of around 240 species of special interest, classified as such due to their protected status. Five invasive species were also identified.

The sector-2 bibliographic data and field investigations revealed the potential presence of around 59 species of special interest owing to their protected status. Three invasive species have also been logged.

Alpine longhorn beetle (Rosalia Alpina)
© THEMA Environnement - 2020

Black yellow owlfly (Libelloides Longicornis)
© THEMA Environnement 2020

Species of special interest

Ecological functionalities

The main features of the ecological functionalities of the environment within a 10-km radius of the power plant may be summarised as follows:

- Three **biodiversity reservoirs** have been identified in the study area. The first biodiversity reservoir, which falls within the SRCE[11] framework, is the Loire, the second encompasses the wet meadows of Arrachis, and the third consists of two sandy-calcareous grassland areas classified as micro-reserves.
- Four **ecological corridors**, key to sustaining fully functional ecosystems in the area, have been determined: the first consists of meadow habitats, the second of woodland habitats, the third is made up of calcicolous habitats, and the fourth, comprising the entire Loire Valley, consists of acid heathland.

Biodiversity reservoirs are areas in which biodiversity is the richest or best represented, where species can complete all or part of their life cycle, and which are home to core populations of species from which individuals disperse, or which are likely to support new populations of species.

Ecological corridors are essential routes connecting biodiversity reservoirs, allowing species to move freely and complete their life cycles.

- Three landscape corridors have been identified, featuring meadow habitats, calcicolous habitats, and acid heathland.

There is also a weir in the Loire at the Saint-Laurent site, ensuring the supply of raw water to the power plant. A fish ladder in the weir helps species migrate upstream past the structure.

Natura 2000 sites

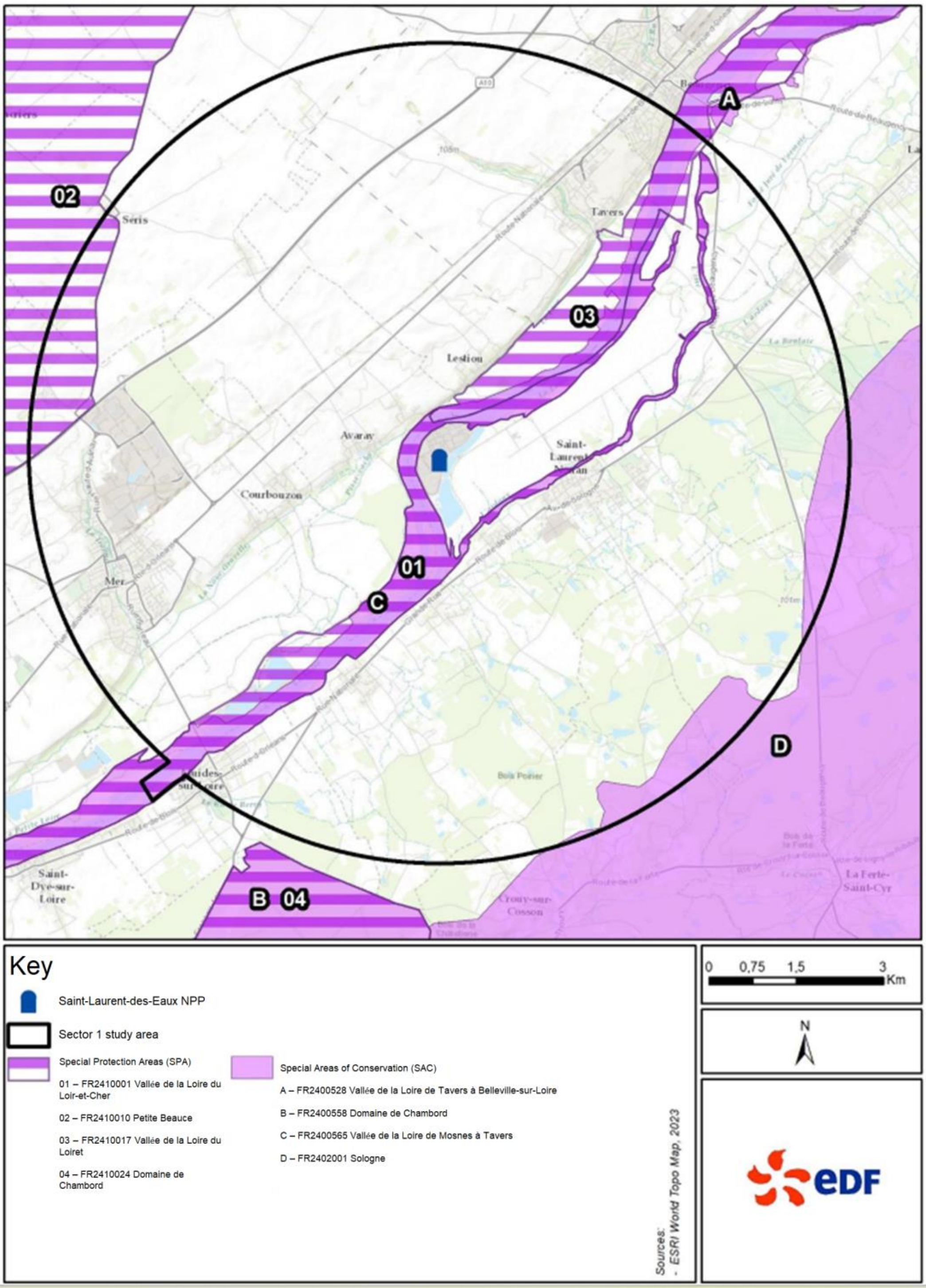
The impact assessment of the study area in relation to the Natura 2000 network has identified six Natura 2000 sites, corresponding to overlapping potential areas of influence on terrestrial and aquatic environments.
These are the three **Special Protection Areas (SPA)** and three **Special Areas of Conservation (SAC)** listed below:

- SPA FR2410001 'Vallée de la Loire du Loir-et-Cher';
- SPA FR2410010 'Petite Beauce';
- SPA FR2410017 'Vallée de la Loire du Loiret';
- SAC FR2400528 'Vallée de la Loire de Tavers à Belleville-sur-Loire';
- SAC FR2400565 'Vallée de la Loire de Mosnes à Tavers';
- SAC FR2402001 'Sologne'.

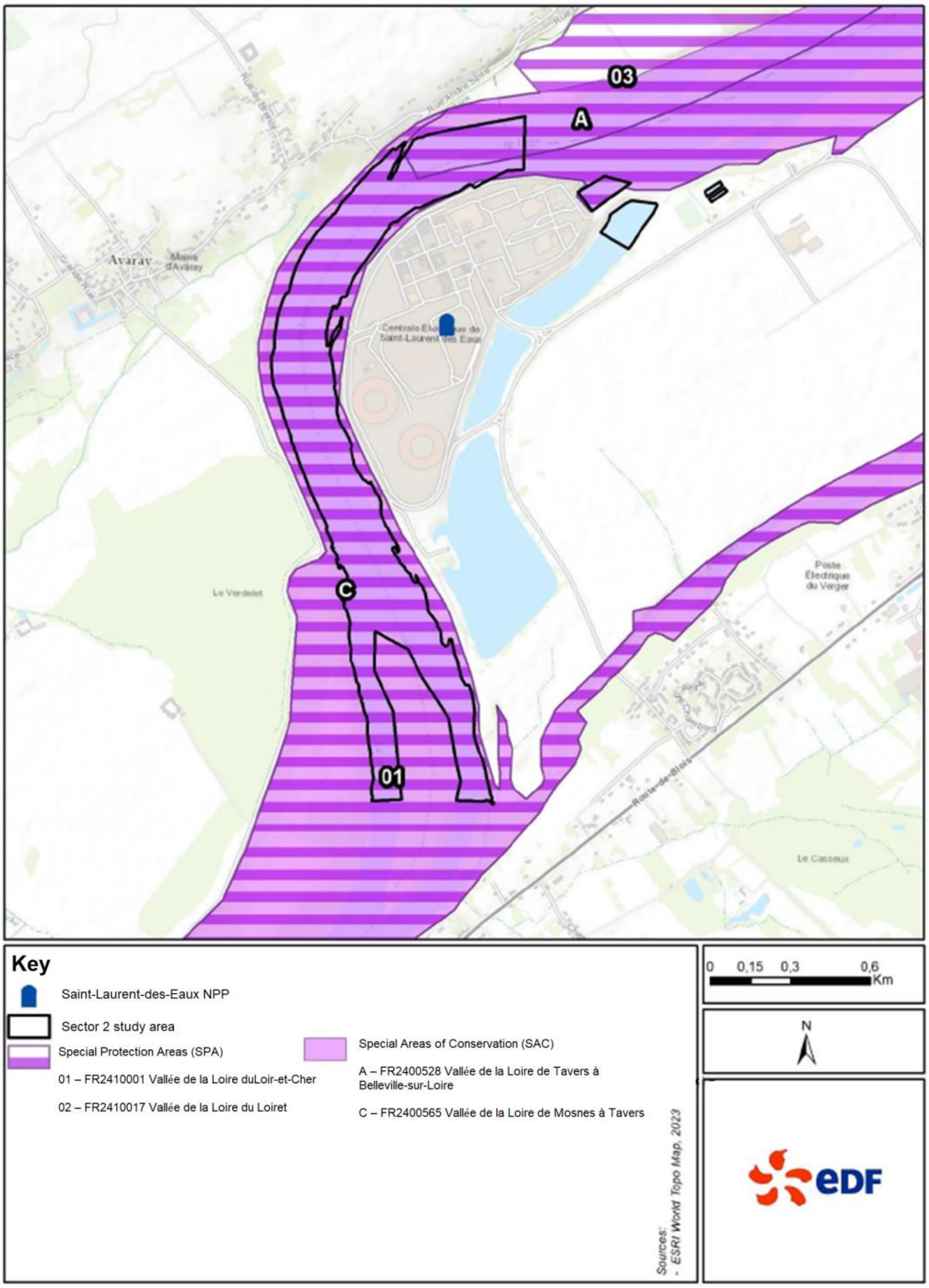
Natura 2000 is a European network of natural sites selected for their rare or fragile wild animal and plant species and habitats.
The network is made up of:

- SPA (Special Protection Areas) focusing on the conservation of wild bird species;
- SAC (Special Areas of Conservation) concentrating on protecting natural areas, as well as fauna and flora of heritage value.

[11] SRCE: Regional Ecological Coherence Protocol.



Natura 2000 sites in sector 1



Natura 2000 sites in sector 2

5.5.6. Population and human health

▪ *Population*

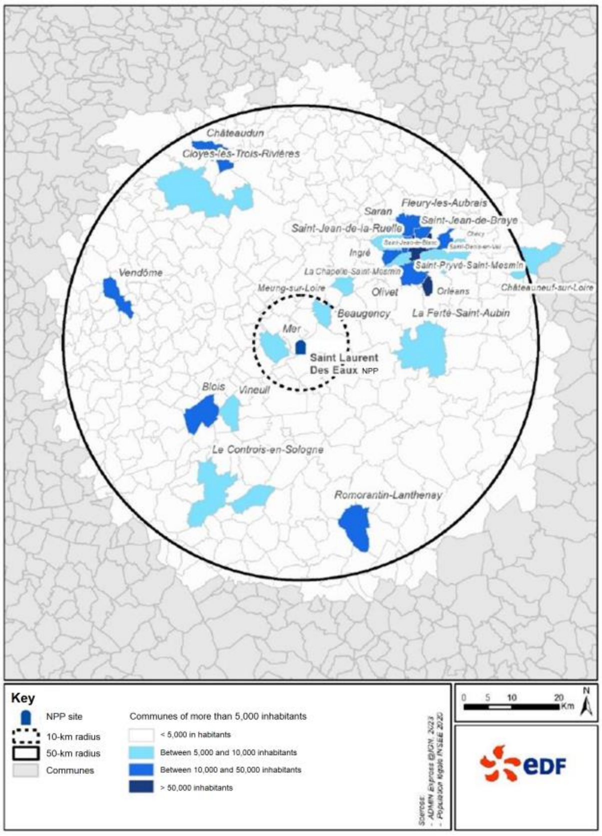
The extended 50-km-radius study area shows the distribution of the population around Saint-Laurent NPP, while the more local 10-km-radius study area focuses on identifying populations of interest.

The average population density is around 84 inhabitants/km² within the 50-km radius, and approximately 67 inhabitants/km² within the 10-km radius, which for both radii is lower than the average value for mainland France, at around 119 inhabitants/km² (2020 census).

The largest communes within a radius of 50 kilometres are Orléans (116,269 inhabitants), Blois (45,898 inhabitants) and Olivet (22,386 inhabitants). Within the narrower study area of 10 kilometres, Beaugency (7,339 inhabitants) and Mer (6,171 inhabitants) are the only communes with more than 5,000 inhabitants.

The nearest vulnerable populations (in schools, childcare facilities, healthcare centres, social services facilities and nursing homes) are located approximately 900 metres north-west of the site boundary.

The closest residential housing is situated less than one kilometre north-west, in the Commune of Avaray.



Communes of over 5,000 inhabitants within a 50-km radius of Saint-Laurent NPP (2020)

▪ *Noise and light pollution*

A noise measurement campaign was carried out in 2022 at Saint-Laurent NPP. Measurements indicated that noise levels on site comply with the targets set by regulations.

Light emissions in the vicinity of Saint-Laurent power plant mainly originate from public lighting in neighbouring communes, such as Avaray, Mer and Beaugency.

5.5.7. Human activities

▪ *Land use*

Land use within a 10-kilometre radius of Saint-Laurent power plant falls under two main categories, primarily agricultural land (around 67% of the study area), followed by forest surfaces (23% of the study area). The remainder of the study area is largely made up of artificial surfaces (around 8%) and water bodies (around 2%).

▪ *Landscape and cultural heritage*

Seven landscape units have been identified within a 10-km radius of Saint-Laurent NPP.

- the plateau of Beauce;
- the Grande Sologne region of forests and ponds;
- the section of the Loire River Valley from Mer to Blois;
- the Loire at Saint-Laurent-Nouan ;

- the Val Ouest alluvial plain and valley;
- the plateau of the Sologne forest lands within the Orléanais region;
- the mosaic-landscape plateau of Petite Beauce.

There are several protected sites and historical monuments within a 10-km radius of the power plant, the closest being:

- the Château of Avaray, the nearest historical monument, around 1 kilometre west of the plant ;
- the Church of Saint-Aignan d'Herbilly, classified as architectural heritage, located 2 kilometres west;
- the 'Eaux Bleues' (Blue Waters) natural spring and the banks of the Fontenils stream, the closest classified sites, around 5 kilometres north-east;
- the Colonel Therel house and gardens, the closest listed site, located around 8 kilometres north-east.

The archaeological sites nearest to the power plant are at Les Angelières and Cent Planches in Mer, at a distance of around 5 kilometres west-north-west of site. It should be noted that other excavation sites have been surveyed but have not yielded any finds.

Water use

The water abstracted in the communes within a 10-km radius of Saint-Laurent power plant serves three purposes:

- Drinking water: there is no public drinking water supply abstraction point downstream of the plant and within the study area. The nearest public supply abstraction point downstream of Saint-Laurent is sited around 23 km away, in the Commune of Blois (Department 41). This is a surface water abstraction site.
- Agricultural water: the first abstraction point downstream of the plant, for agricultural purposes, is sited around 2 km away, in the Commune of Avaray. This is a groundwater abstraction point.
- Industrial water: the closest abstraction point for industrial water, downstream of Saint-Laurent NPP, is located around 5 km away, in the Commune of Courbouzon. This is an underground abstraction point.

Infrastructure and transport links

The area within a 10-km radius of Saint-Laurent NPP comprises the following:

- the RD951 departmental road runs approximately 1 km south of the power plant, the RD2152 departmental road runs around 2 km north-west, and the A10 motoway runs around 4 km north-west;
- the only railway in the area is the line connecting Paris to Bordeaux, running around 2 km north-west. It serves the station of Mer, located around 5 km south-west of the plant, and Beaugency, around 7 km north-east;
- There are no navigable waterways within the 10-km study area around Saint-Laurent NPP.

Industrial environment

There are 27 facilities classified for environmental protection [ICPE] within a 10-km radius of Saint-Laurent power plant (13 listed as using substances subject to authorisation and 14 as using substances subject to registration), including one **SEVESO** classified site.

The study areas also include three industrial and commercial areas.

Since 2015, Directive 2012/18/UE of 4 July 2012, known as the 'Seveso III directive', has required European Union Members States to identify industrial sites that pose a risk of major accidents. These are classified as '**SEVESO** sites' and require a prevention policy that ensures a high level of protection.

Recreation and leisure activities

Hunting and fishing take place in the area around Saint-Laurent power plant. A permanent fishing reserve extends from 50 metres upstream of the dam at the Saint-Laurent site to 300 metres downstream of the dam, on the left bank of the Commune of Saint-Laurent and on the right bank of the Commune of Avaray.

The departments of Loir-et-Cher and Loiret offer sports and leisure activities such as hiking, cycling, horse riding, golf, and canoeing and kayaking on the Loire River. The nearest leisure facilities are water sports clubs located less than a kilometre south of the plant. There are no listed bathing sites within a 10-km radius of Saint-Laurent NPP.

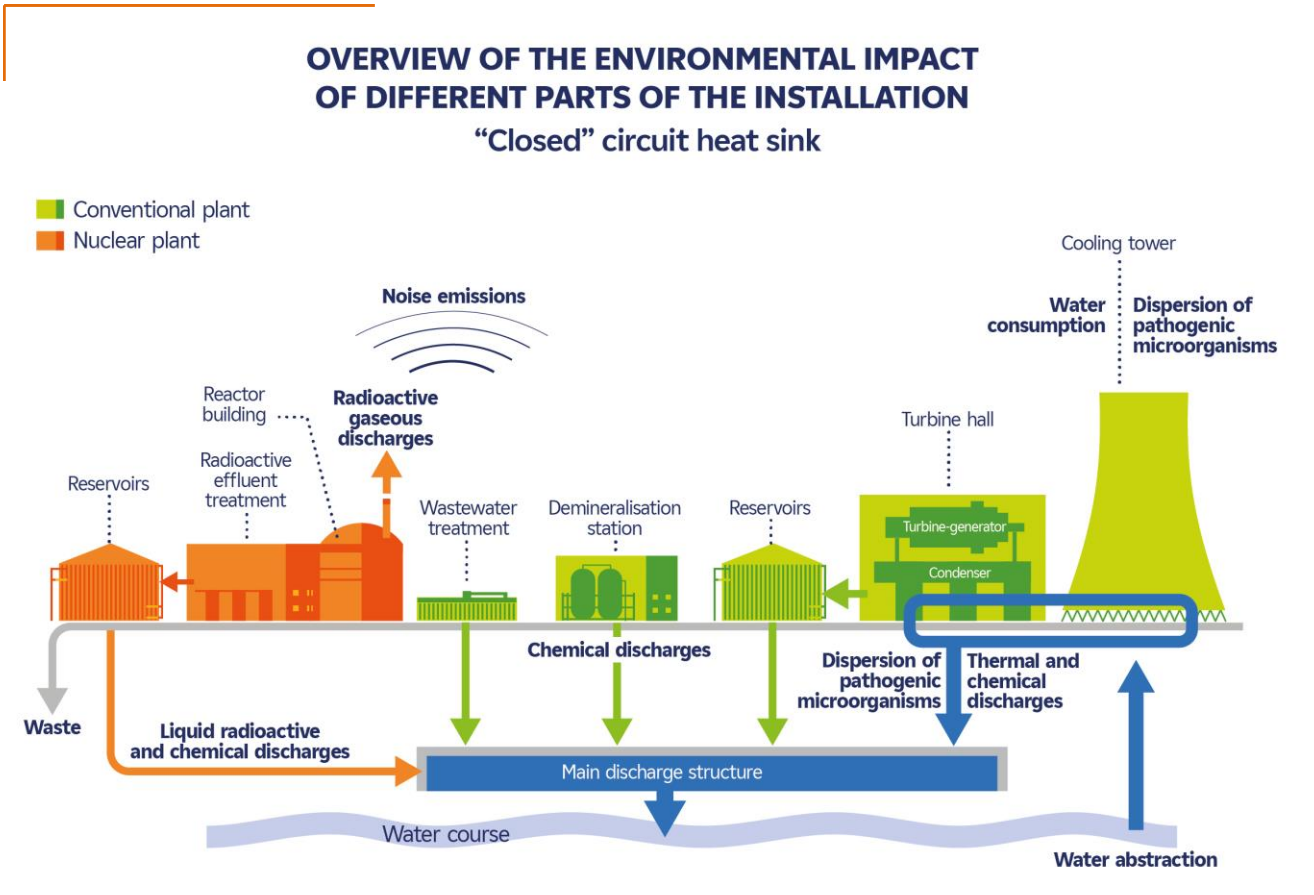
There are no freshwater aquaculture companies operating within a 10-km boundary of Saint-Laurent power plant.

- ***Energy consumption***

In 2022, Saint-Laurent Nuclear Power plant generated 9.4 billion kilowatt-hours of low-carbon electricity. The plant's annual output meets its own electricity consumption requirements and covers 100% of the electricity needs of households in the Centre-Val de Loire region.

5.6. Saint-Laurent NPP interactions with the environment

This section sets out the interactions between Saint-Laurent Nuclear Power Plant operation and the environment, both currently and over the next ten years. These interactions are illustrated in the figure below.
The different types of interactions and their characteristics are detailed in Sections 5.6.1 to 5.6.9.
Section 5.6.10 presents the changes in these interactions over the next ten years.



5.6.1. Water abstraction and consumption

Saint-Laurent's various requirements for water supplies (cooling water, demineralised water and industrial water) are met by drawing from the Loire River, the deep chalk aquifer, and the Loire alluvial aquifer.

- Water is drawn from the Loire to supply the cooling systems required for the operation of the facilities, to produce demineralised water, and to supply water to the firefighting system network.
- Water is drawn from the deep chalk aquifer to supply drinking water to site, and to operate and manage the ultimate makeup water pumping facility.
- Water may be drawn from the Loire alluvial aquifer within the power plant's engineered confinement structures. It should be noted that Saint-Laurent NPP has not yet needed to abstract water from this source.

Water abstraction limits are defined in regulations set by the Authority for Nuclear Safety and Radiation Protection. These limits are maximum values that must not be exceeded, which are determined so as to allow the plant to operate normally, taking into account some operating contingencies, and to ensure protection of the environment.

Actual volumes of abstraction therefore remain below the regulatory limits (Decision No. 2015-DC-0499[12]).
The table below details the annual water abstraction limits, along with recorded abstractions over ten years.
No changes in volumes of water abstraction are planned for the next ten years, and therefore no request to modify the regulatory limits listed below is expected.

Source of abstraction	Use	Maximum volume	
		Regulatory limit (annual volume)	Average annual volume 2012-2021
Loire River	Cooling water	127 million m^3	94,12,000 m^3
Loire River	Industrial water (demineralised water, firefighting water)		228,733 m^3
Deep chalk aquifer	Drinking water	Potable water: 145,000 m^3	58,354 m^3
	Ultimate emergency makeup water	Ultimate emergency makeup water: 3,000 m^3 (can be increased to 23,000 m^3 for tests, or for work in the ultimate emergency makeup pumping station)	2,212 m^3(*)

(*): value recorded in 2021 (test execution)

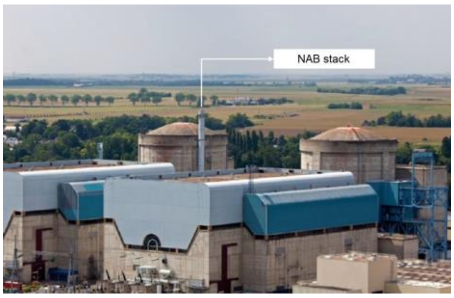
Table 1: Regulatory limits and water abstraction volumes for Saint-Laurent NPP

[12] Nuclear Safety Authority Decision No. 2015-DC-0499 dated 19 February 2015 setting out the requirements for water abstraction and consumption, for liquid and gaseous effluent discharges to the environment, and for environmental monitoring, directed at basic nuclear installations No. 46, No. 74 and No. 100, operated by Électricité de France – Société Anonyme (EDF-SA) in the Commune of Saint-Laurent-Nouan.

5.6.2. Liquid and gaseous radioactive effluent discharges

It is in the nuclear reactor that radioactive substances (radionuclides) are formed, a tiny fraction of which end up in effluents. These effluents are collected and sorted, and then transferred to the appropriate treatment and/or storage systems.

The power plant's liquid radioactive effluents are discharged into the Loire River via the site's outfalls.
Gaseous radioactive effluents are released into the atmosphere via stacks located on top of the plant's nuclear auxiliary building (NAB).



© EDF
The power plant's nuclear auxiliary building stack

The power plant discharges five categories of radionuclides:

- Carbon-14 is mainly produced by **neutron activation** of oxygen-17 and nitrogen-14 present in the primary system water, and of oxygen-17 present in the fuel. Only a small fraction of carbon-14 ends up in liquid effluent discharges; most of it is retained by the treatment systems. Any carbon-14 released in gaseous form is derived predominantly from primary-circuit water degassing operations.

Neutron activation is the process by which one of more elements contained in a substance is/are made radioactive through irradiation in a flux of neutrons.

- Tritium is produced by fission in fuel rods and by neutron activation of boron-10 and lithium-6 in the primary water, resulting from its conditioning using boric acid and lithium hydroxide. Almost all the tritium remains contained in the fuel rods. However, a small proportion may migrate into the primary circuit in the event of fuel cladding failure. The use of lithium-7-enriched lithium diminishes tritium production by neutron activation of lithium-6. At present, there are no technically and economically feasible industrial means of removing the tritium from these effluents.

The limit values for radioactive effluent discharges from Saint-Laurent NPP are defined in regulations set out by the Authority for Nuclear Safety and Radiation Protection (Decision No. 2015-DC-0498[13]).

- Iodine is a by-product of uranium fission and remains largely contained within the fuel rods. A small quantity of iodine may nevertheless migrate into the primary circuit water in the event of fuel cladding failure. Any iodine present in liquid radioactive effluents is trapped by the effluent treatment systems, and a short half-life ensures that it disappears quickly.
- The other fission or activation products ('other FPs/APs') are formed by fission, such as caesium-134 and -37, which remain contained in the fuel but may migrate into the primary circuit for the above-mentioned reasons, or by activation, such as cobalt-58 and -60, manganese-54, or antimony-124. These 'other FPs/APs' present in the form of aerosol particles in gaseous effluents are treated by transfer to storage tanks to allow for radioactive decay, and/or are captured by iodine traps (activated carbon) and high-efficiency filters. In liquid effluents, the 'other FPs/APs' are largely contained by the treatment systems (filter- or resin-based) of the reactor coolant continuous cleanup system and effluent treatment system.
- Rare gases are produced by fission and remain mostly contained within the fuel rods. A small quantity of rare gases may nevertheless migrate into the primary system water for the reasons mentioned above, and may end up in the gaseous radioactive effluents. These effluents are discharged to the atmosphere after sufficient radioactive decay in storage tanks.

[13] Nuclear Safety Authority Decision No. 2015-DC-0498 dated 19 February 2015 stipulating environmental discharge limits for the liquid and gaseous effluents produced by basic nuclear installations No. 46, No. 74, and No. 100, operated by Électricité de France – Société Anonyme (EDF-SA) in the Commune of Saint-Laurent-Nouan.

RELATIONSHIP BETWEEN DISCHARGE LIMITS AND ACTUAL DISCHARGES

Discharge limits are set in order to ensure that their impact on the environment is acceptable. They are based on best available techniques, under technically and economically acceptable conditions, factoring in the features of the installation, its geographical location and local environmental conditions. They represent maximum values that must not be exceeded. In addition, the operator draws up an optimised projection of discharges based on scheduled activities, and analyses the alignment between actual discharges and these performance objectives, with a view to extracting operating experience for continuous improvement purposes.

The assessment of the impact of the discharges, which is carried out on the basis of regulatory limits, is therefore bounding of the site's actual discharges.

The projected discharges related to the operation of Saint-Laurent NPP over the next ten years will remain of the same order of magnitude as for the previous decade, and will in all cases remain below the discharge limits.

The following tables give a summary of Saint-Laurent NPP's radioactive discharges over a 10-year period (average discharges from 2012 to 2021).

- Overview of liquid radioactive discharges between 2012 and 2021

	Annual limits (GBq/yr)	Annual average activity released GBq/yr
Tritium	45,000	22,200
Carbon-14	130	14.9
Iodine	0.2	0.0075
Other fission and activation products	20	0.319

- Overview of gaseous radioactive discharges between 2012 and 2021

	Annual limits (GBq/an)	Annual average activity released GBq/yr
Tritium	4,000	685
Carbon-14	1,100	258
Rare gases	30,000	835
Iodine	0.6	0.015
Other fission and activation products	0.4	0.002

5.6.3. Liquid and gaseous chemical effluent discharges

Operating a nuclear power plant requires the use of chemical substances and leads to liquid-borne chemical effluent discharges (from substances used for circuit conditioning, from operations in the demineralisation station and purification plant, and from **antiscaling and biocide treatments**) and, to a lesser extent, to discharges to atmosphere (derived from circuit and equipment operation).

In so-called 'closed' cooling circuits using cooling towers, as is the case for Saint-Laurent NPP, chemical treatment is required in order to:

- Minimise circuit fouling resulting from the use of Loire River water naturally loaded with suspended matter and mineral salts, by injecting a polymer-based dispersant and **antiscalant**;
- Control the risk of dispersion of pathogenic microorganisms (legionella and amoeba) through preventive maintenance of the cooling circuit and **biocide treatments** that inject monochloramine or sodium hypochlorite, as used in aquatic centres.

Liquid chemical effluents

The liquid chemical effluents from the primary and secondary circuits are collected and sorted by type and composition, filtered, treated if necessary, and then checked before being discharged into the environment.
The main chemical substances discharged in liquid form are the following:

- Boric acid and lithium hydroxide, used to condition the primary circuit in order to control the nuclear reaction and minimise corrosion of materials.
- Hydrazine, injected into the primary and secondary circuits to reduce dissolved oxygen in circuit water and thus diminish corrosion in metal components.
- Morpholine[14], ethanolamine and ammonia, used to condition the secondary circuit.
- Sodium, chlorides, ammonium, nitrates, nitrites, adsorbable organic halogens (AOX) on activated carbon, total residual chlorine, trihalomethanes and sulphates, from the biocide and antiscaling treatments of cooling circuits.
- Metals derived from corrosion in the primary and secondary circuits (aluminium, chromium, copper, iron, manganese, nickel, lead and zinc).
- Trisodium phosphate (NA_3PO_4), from the conditioning of intermediate cooling circuits and from effluents in the purification plant.
- Detergents, free of phosphates and chelating agents such as EDTA (ethylenediaminetetraacetic acid), from washing the workwear used by personnel in radiological controlled areas.
- Suspended matter (SM) and chemical oxygen demand (COD), from the effluent treatment tanks, backup tanks and inspection tanks.
- Iron, sodium, chlorides, sulphates and SM, from the demineralisation station.
- Phosphates, phosphorous, SM, nitrogen, ammonium, nitrates, COD and BOD5 (5-day biochemical oxygen demand), from the purification plant.

Just as for the radioactive discharges, maximum discharge values are set for chemical substances to ensure that their impact on the environment is acceptable, based on the best available techniques applicable to plant operation. The assessment of the impact of the discharges, carried out on the basis of these maximum values, is therefore bounding of the power plant's actual discharges.

[14] In 2016, in a drive for continuous improvement, the circuit conditioning agent for both Saint-Laurent-des-Eaux reactors was switched from morpholine to ethanolamine.

Future discharges should be of the same order of magnitude as past discharges, and in all cases below the maximum discharge values. The results of the discharge impact assessment presented in this document are therefore valid for the next ten years.

The following table shows the maximum values for discharges[15] into the Loire (as per currently applicable decisions specifying limits and conditions, or as determined from additional characterisations based on OPEX or design data), and an overview of past discharges of higher-impact chemical substances, over a 10-year period.

Substances	Annual flow (kg)	
	Maximum discharge values	Actual discharges (2012-2021 average)
Boric acid From effluent treatment tanks and backup tanks	10,000	2,320
Morpholine* From effluent treatment tanks, backup tanks, inspection tanks, And the plant sewer system	500	246
Ethanolamine** From effluent treatment tanks, backup tanks and inspection tanks, and the plant sewer system	400	21
Hydrazine From effluent treatment tanks, backup tanks and inspection tanks	16	1,4
Total nitrogen (ammonium, nitrites, nitrates) From effluent treatment tanks, backup tanks and inspection tanks	6,000	1,110
Ammonium From monochloramine treatment	70 kg/day, so 25,550 kg***	229
Nitrates From monochloramine treatment	1,470 kg/day, so 536,550 kg***	50,000
Nitrites From monochloramine treatment	70 kg/day, so 25,550 kg***	1,390
Phosphates From effluent treatment tanks, backup tanks and inspection tanks, and the plant sewer system	710	164
Total residual chlorine (TRC) From monochloramine treatment, and shock-treatment chlorination	4,500	813
AOX	1,000	233

* Morpholine was used until 2016 (5-year average)
** Ethanolamine has been in use since 2016 (6-year average)
*** Given that Decision No. 2015-DC-0498 does not stipulate an annual discharge limit for these substances, the maximum discharge values are extrapolated by multiplying the daily limit by 365.*

[15] These limit values are stipulated in Nuclear Safety Authority Decision No. 2015-DC-0498 dated 19 February 2015 stipulating environmental discharge limits for the liquid and gaseous effluents produced by basic nuclear installations No. 46, No. 74, and No. 100, operated by Électricité de France – Société Anonyme (EDF-SA) in the Commune of Saint-Laurent-Nouan.

- ***Chemical effluents discharged to atmosphere***

The main chemical substances released into the atmosphere are the following:

- exhaust gases from periodic testing of the emergency generators, mainly containing sulphur, nitrogen and carbon oxides;
- formaldehyde and carbon monoxide emissions from new glass wool insulation, produced when first heated;
- ammonia emissions from the turbine bypass system, originating from the auxiliary feedwater system and from the thermal decomposition of hydrazine in the steam generator layup solution at reactor startup;
- morpholine or ethanolamine emissions;
- ammonia from the extraction system for non-condensable gases from the secondary circuit, when the condenser is kept under vacuum, which is discharged from the nuclear auxiliary building stack;
- emissions of total residual chlorine (TRC), ammonia, hypochlorous acid (HOCl) and trihalomethanes (THM) from the cooling towers, during biocide treatment operations;
- exhaust gases from the vehicles and lorries used for waste disposal and for transport of goods and materials (delivery and dispatch). Due to the limited use of these vehicles on site and thanks to regular maintenance checks, the quantities of gases released annually are low;
- diffuse emissions of refrigerants and SF_6 used in chiller units (for the production of chilled water and for cooling technical and tertiary facilities) and in the site's power transmission switchyards, respectively. These emissions are quantified during maintenance of these installations;
- emissions of dust into the atmosphere, from mechanical workshops, in negligible quantities.

5.6.4. Thermal discharges

Thermal discharges are governed by regulations that limit water-temperature increases between intake and discharge points.

Thermal discharge limits for Saint-Laurent-des-Eaux NPP

Conditions	Average daily temperature increase (°C)
Normal conditions	≤ 1°C
Specific conditions: Loire River flow below 100 m³/s and $T°_{\text{Loire upstream}}$ < 15°C	< 1.5°C

In a nuclear power plant, as per Carnot's principle of thermodynamics, around one-third of the thermal energy that is produced by the reactor is converted into electricity. The remainder, so around two-thirds of this energy, is transferred as heat through the condenser to a heat sink, which can be a body of water (a so-called 'open circuit' heat sink) or the atmosphere (via cooling towers, a so-called 'closed-circuit' heat sink). This results in thermal discharges into the environment.

At Saint-Laurent NPP, the condensers are cooled by way of a 'closed' circuit: the raw water flowing through the cooling circuits is reheated in the condensers, and then cooled on contact with the heat transfer packing in the cooling towers. Most of the thermal energy is transferred to the atmosphere through evaporation and convection. The thermal discharges into the Loire originate from the continuous blowdown from the cold basins of the cooling towers, aimed at controlling the cycle of concentration.

Between 2012 and 2021, the power plant increased the temperature of the water between intake and discharge points by an average 0.09°C, with a maximum recorded value of 0.47°C.

5.6.5. Management of sediment from discharge and intake channel maintenance

In order to ensure a supply of raw water for its facilities and thus maintain them in a safe state, Saint-Laurent NPP has to conduct dredging operations around the floating boom, the upstream forebay and the upstream forebay's settling basin. This involves removing accumulated sediment using a suction dredger equipped with a powerful high-flow pump and a filtration system.

Dredged sediments are returned to the river in accordance with their characteristics, and in compliance with the ten-year order authorising dredging activities. Sediments that are unsuitable for return to the river are managed in accordance with current regulations.

If it is not possible to return the sediments to the Loire River and there is urgent need for cleanup, this is carried out by collecting the sediments with an excavator. The sediments are then transferred to the power plant's two settling ponds, and can subsequently be restored to the river, in line with the criteria defined for sediment return, or be sent to a suitable disposal facility.

5.6.6. Waste production

The operation of Saint-Laurent NPP generates both radioactive and conventional waste.

Radioactive waste is derived mainly from the treatment of radioactive effluents (filters, activated carbon, evaporation concentrates, ion exchange resins, sludge, etc.), from routine maintenance operations (discarded radioactive mechanical parts, laundry waste, etc.), from fuel handling operations (clusters, fuel rod capsule-canisters, skeleton assemblies, etc.), and from Saint-Laurent-A dismantling activities.

Conventional waste is waste that is produced in areas that do not contain any radioactive material. It is made up of inert waste (rubble, soil, etc.), non-hazardous waste (wood, packaging, paper, cardboard, glass, plastic, metal, etc.) and hazardous waste (explosive, oxidising, flammable, irritant, infectious, mutagenic, ecotoxic, etc.).

Radioactive waste categories and associated disposal routes

Half-life* / Radioactivity**	Very Short Lived (VSL) (period < 100 days)	Primarily Short Lived (P-SL) (period ≤ 31 years)	Primarily Long Lived (P-LL) (period > 31 years)
Very Low Level Waste (VLLW) < 100 Bq/g	VTC VSL Management by decay	TFA VLLW Surface disposal (CIRES - Industrial Facility for Waste Collection, Sorting and Storage)	
Low Level Waste (LLW) a few hundred Bq/g to a million Bq/g		FMA-VC LILW-SL Surface disposal (Centre de l'Aube and Centre de la Manche disposal facilities)	FA-VL LLW-LL Near-surface disposal under examination
Intermediate Level Waste (ILW) a million Bq/g to a billion Bq/g			MA-VL ILW-LL Deep geological repository under development (Cigéo project)
High Level Waste (HLW) several billion Bq/g	Not applicable	HA HLW Deep geological repository under development (Cigéo project)	

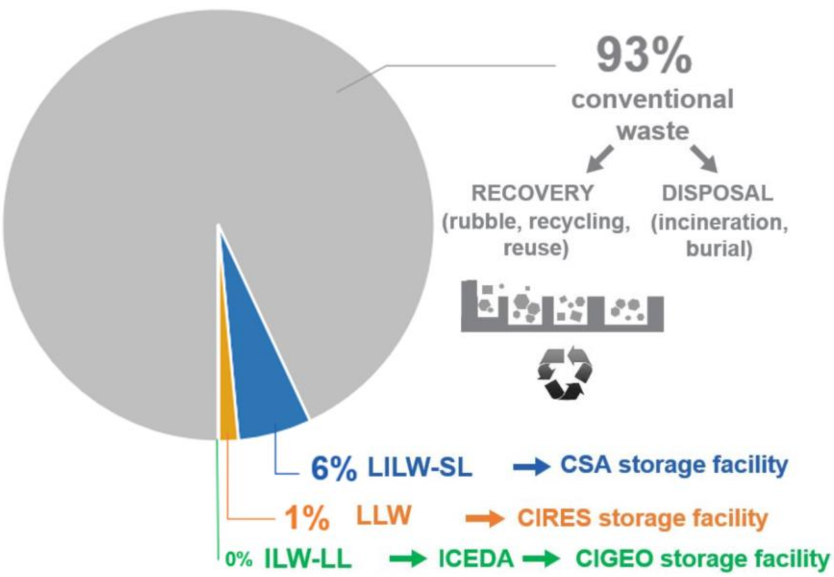
* The half-life of the radioactive material (radionuclides) in the waste to decay.
** The level of radioactivity of the radioactive waste.

Waste can sometimes be classified under one category but managed through a different disposal route if it has other characteristics (e.g. in terms of its chemical composition or physical properties).

In France, radioactive waste is classified according to two criteria:

- its level of radioactivity: High Level Waste (HLW), Intermediate Level Waste (ILW), Low Level Waste (LLW), and Very Low Level Waste (VLLW);
- its half-life, which is the time it takes for half of the radioactive material to decay: Very Short Lived (VSL); Short Lived (SL); Long Lived (LL).

Activities related to the operation of Saint-Laurent NPP generate conventional waste (92% of total waste produced) and radioactive waste (7% of total waste produced).



Breakdown of waste categories and waste disposal routes for waste generated by Saint-Laurent NPP operation

The following table presents an overview of the radioactive waste produced by Saint-Laurent power plant over a ten-year period, along with a projection of waste production in the coming years.

Overall, the volume of radioactive waste generated by Saint-Laurent NPP over the next ten years is of the same order of magnitude as that produced over the reference period. Nevertheless, fluctuations have already been identified for some types of waste in connection with the ten-year outages. No significant changes are expected in either waste categories or disposal routes.

Radioactive waste	Average annual waste-package volume (m^3) (average for 2012-2021)	Projected average annual waste-package volume (m^3) (average for 2025-2028)
Solid VLLW for storage at CIRES*	65	71
Solid SL-ILW for storage at CSA**	180	130
Solid SL-LLW for direct storage at CSA	63	30
Solid SL-LLW for processing (melting)	142[16]	63
Solid SL-LLW for processing (incineration)	165	180
Liquid SL-LLW for processing (incineration)	130[17]	2

5.6.7. Noise and vibration emissions

Saint-Laurent NPP conducts a noise emission measurement campaign every ten years. The noise emission measurement campaign carried out in 2022 concluded that recorded noise levels complied with the targets set by regulations.
Saint-Laurent power plant may generate vibrations related to its industrial activities (from rotating machinery, construction equipment, vehicles, etc.). Owing to the design of the buildings and the composition of the soil, these vibrations are felt inside site facilities but are not perceptible off-site.
Certain dismantling operations may give rise to intermittent vibrations due to the use of certain construction equipment, particularly during the building-demolition phase. These operations will be carried out during the day.

5.6.8. Land use

Saint-Laurent power plant covers an area of 60 hectares in which a range of industrial activities take place. Most of the land is anthropised (buildings, roads, man-made green spaces).
There are no plans for any changes in the land surface required for operating Saint-Laurent NPP's 2 reactors over the next ten years.

[16] The difference between the average annual volume of solid waste processed by melting over the period (2012-2021) and the projected figure (2025-2028) is attributable to the volumes of waste generated by operations to clear out waste storage areas, which were added to the historical figures. This project aimed to free up storage capacity prior to the launch of the Grand Carénage plant refurbishment programme, by dismantling the contents of waste containers in either the Hot Bases or at CENTRACO. Excluding these particular volumes of waste, the average annual volume of waste for this category was around 55 m^3 over the period 2012-2021.
[17] The difference between the average annual volume for the period (2012-2021) and the projected figure (2025-2028) results from the inclusion, in the historical data, of effluents derived from preventive steam generator cleaning operations. Excluding these isolated additional volumes, the average annual volume for 2012-2021 was around 3.5 m^3. What is more, no such operations are scheduled until 2030.

5.6.9. Other interactions

Other interactions between Saint-Laurent NPP and the environment that were examined include: odours, light emissions, road and rail traffic, energy consumption, heat and radiation. No changes in these interactions are expected over the next ten years.

5.6.10. Ten-year projection of interactions between Saint-Laurent NPP and the environment

The past and current interactions between Saint-Laurent NPP operation and the environment were presented in Sections 5.6.1 to 5.6.9.
As shown in the table below, the interactions between Saint-Laurent power plant operation and the environment will remain similar over the next ten years to those of the previous decade.

Interaction with the environment	Past operation	Ten-year projection
Water abstraction and consumption	Saint-Laurent NPP's various requirements are covered by Loire River water and groundwater abstraction. Regulated abstraction (of surface water and groundwater) has always remained below stipulated limits (Decision No. 2015-DC-0499).	There are no plans to change the sources of water supplies. Over the next ten years, the projected volumes abstracted for purposes of Saint-Laurent plant operation will remain of the same order of magnitude as during the previous decade, and within regulatory limits.
Liquid radioactive effluent discharges	Radioactive effluents are discharged into Loire River water, via the liquid effluent outfalls. These discharges are regulated by Decision No. 2015-DC-0498.	There are no plans to change the discharge points in the Loire. Over the next ten years, the projected volumes discharged for purposes of Saint-Laurent plant operation will remain of the same order of magnitude as during the previous decade, and within regulatory limits.
Radioactive effluent discharges to atmosphere	Radioactive effluents are discharged to atmosphere from the stacks on top of the nuclear auxiliary buildings. These discharges are regulated by Decisions Nos. 2015-DC-0498 and 2015-DC-0499.	There are no plans to change the sites of discharges to atmosphere. Over the next ten years, the projected discharges for purposes of Saint-Laurent NPP operation will remain of the same order of magnitude as during the previous decade, and within regulatory limits.

Interaction with the environment	Past operation	Ten-year projection
Chemical effluent discharges	Liquid chemical effluent discharges are regulated by Decisions Nos. 2015-DC-0498 and 2015-DC-0499.	Over the next ten years, the projected liquid chemical effluent discharges for purposes of Saint-Laurent plant operation will remain of the same order of magnitude as during the previous decade, and within regulatory limits.
Thermal discharges	Thermal discharges are governed by regulations that limit the temperature increase of water between the intake and discharge structures.	There are no plans for changes to thermal discharges, which will remain within regulatory limits.
Radioactive waste production	Annual volumes of waste (in m^3) Very low level waste: 65 Low level waste: 500 Intermediate level waste: 180	Overall, the volumes of radioactive waste generated over the next 10 years will be comparable to those produced during the reference period. Any differences are the result of standalone projects, such as the activities to clear out waste storage areas and the preventive steam generator cleaning operations over the period in question.
Noise emissions	Saint-Laurent NPP conducts a noise emission measurement campaign every ten years. The last noise emission measurement campaign concluded that noise levels comply with the targets set by regulations.	No major changes, though temporary noise and vibrations may be caused by possible modification and construction work.
Land use	Saint-Laurent NPP covers an area of 60 hectares.	There are no plans for any changes to the land surface required for operating Saint-Laurent NPP's 2 reactors in the next ten years.
Other interactions	Other interactions with the environment include odours, light emissions, road and rail traffic, energy consumption, heat and radiation.	No changes in these interactions are expected over the next ten years.

5.7. Ten-year projection of environmental impacts

This section deals with the actual and potential health and environmental impacts that Saint-Laurent NPP may present during normal operation, over the next ten years, as a result of water abstraction, discharges and waste, as well as the other impacts it is likely to generate (noise, light emissions, energy consumption, heat and radiation emission, road and rail traffic, vibrations, odours or airborne dust). The analysis also covers the measures taken to improve the protection of interests in the context of the 4th periodic review.
As shown in Section 5.6, the interactions between the operation of Saint-Laurent power plant and the environment will remain similar in the next ten years to those of the previous decade.

The environmental effects of Saint-Laurent NPP operation are presented by area (Sections 5.7.1 to 5.7.8); these are local effects, primarily in the vicinity of the power plant, as per the scope of the study presented in Section 5.5.5. The normal operation of the plant produces no transboundary effects (see the section on the transboundary effects of accidents). A comparison of the climate change impacts of continued operation and decommissioning is set out in Section 5.7.10.

5.7.1. Air and climate factors

- ***Impact on climate***

Nuclear power generation produces very little carbon dioxide (CO_2), the main **greenhouse gas**.
According to a 'life cycle analysis' by EDF R&D, each kWh produced by EDF's nuclear fleet emits the equivalent of **4 grammes of CO_2**. This figure substantiates the fact that nuclear power is a very low carbon energy source: ACV du kWh nucléaire (LCA of a nuclear kWh).
The gaseous discharges linked to Saint-Laurent NPP operation therefore do not change the present situation in regard to the climate.
The climate change sensitivity assessment (see next page) concluded that the climate-impact of the gaseous releases linked to plant operation can also be considered as negligible for the next ten years.

> Human-induced **greenhouse gases** are responsible for the increase in the greenhouse effect.
> This natural phenomenon is created by the presence of greenhouse gases, which trap some of the heat emitted by Earth in the lowest layer of the atmosphere.

- ***Impact on air quality***

The Environment Code specifies air quality standards aimed at ensuring effective protection of human health and of the environment as a whole. These standards target substances in the atmosphere, that are present in outdoor ambient air and pose a challenge to air quality: sulphur and nitrogen oxides, ozone, carbon monoxide, particulate matter, lead, benzene and heavy metals. These substances are mainly found in urban areas due to road traffic and other human activities (heating, industrial emissions).
Among the chemical discharges to atmosphere from Saint-Laurent NPP, during normal operation, only the discharges of nitrogen oxide and sulphur oxide and the emissions of carbon monoxide are subject to an air quality standard. The assessment of the impact of these emissions on air quality shows that the power plant has no air-quality impact.
With regard to those substances that are not regulated by an air quality standard (such as formaldehyde, ammonia, ethanolamine, refrigerants, SF6, hypochlorous acid, and trihalomethanes (THM)), their concentrations in the environment attributable to Saint-Laurent power plant are not likely to degrade air quality.
Saint-Laurent NPP is not covered by an Air Protection Plan (APP) [PPA].

AIR PROTECTION PLAN (APP) [PPA]

Air Protection Plans (APP) [PPA] were introduced by Law No. 96-1236 of 30 December 1996, amended on 14 June 2006, governing air and the rational use of energy (known as 'loi LAURE'). These plans must be drawn up in three specific cases:
- the area has exceeded air quality limit values and/or target values;
- the area is at risk of exceeding these values;
- the area has one or more built-up areas with a population of over 250,000 inhabitants.

APPs set out the measures to be taken to ensure compliance with limit values, as well as the emergency measures to be implemented if there is a risk of exceeding alert thresholds. They must be compatible with regional air quality objectives [SRADDET].

REGIONAL BLUEPRINT FOR PLANNING, SUSTAINABLE DEVELOPMENT, AND REGIONAL BALANCE AND EQUALITY [SRADDET]

The law NOTRE (Nouvelle Organisation Territoriale de la République) of 7 August 2015, reforming the country's regional structure, creates a new framework for planning, which is now entrusted to each region: the 'Regional Blueprint for Planning, Sustainable Development, and Regional Balance and Equality [SRADDET].
This blueprint must comply with the general rules of land use and urban planning, which are mandatory, and with public interest land use restrictions. It must be compatible with Water Development and Management Plans [SDAGE] and Flood Risk Management Plans [PGRI]. It must take into account land development projects of public interest, balanced water resource management, planned infrastructure and facilities, economic activities, the charters of national parks, and mountain development plans. It thus replaces existing schemes, such as the Regional Blueprints for Climate, Air and Energy [SRCAE], the Regional Multimodal Transport Strategy, the Regional Waste Prevention and Management Plan [PRPGD] and the Regional Ecological Coherence Protocol [SRCE].
SRADDET Centre-Val de Loire was adopted by resolution of the Regional Council on 19 December 2019, and was approved by the Prefect of the Region on 4 February 2020. SRADDET Centre-Val de Loire comprises 4 strategic priorities, broken down into 20 structured objectives that set out the aims and rules of SRADDET.

- ***Climate change sensitivity***

Local projections of key climate factors, produced by Météo-France, show an upward trend in annual average air temperatures, which, depending on the climate scenario, are projected to range from + 0.9°C to + 1.2°C, on average, by 2035 (for the period 2020-2050), compared with the historical period considered (1986-2016).
Apart from a slightly greater need for cooling in tertiary and industrial premises, the climate changes presented above do not alter the analysis of the impact on air quality and climate of Saint-Laurent NPP's discharges to atmosphere.

5.7.2. Surface water

- ***Impact on hydrology***

Given that the power plant's cooling system operates as a closed circuit, most of the water abstracted from the Loire is returned to the river. However, part of the flow evaporates via the cooling towers. The average rate of evaporation at Saint-Laurent NPP is around 1.2 m^3/s for the two reactors, in normal operating conditions, which corresponds to about 0.4% of Loire average flow and around 2.2% of Loire minimum average flow over three consecutive days. The rates of evaporated flows are therefore low compared to the average flow rate of the Loire and do not affect continuity with regard to river uses.
Two engineered features with potential direct impacts on flow have been built in the Loire River for purposes of plant operation (the weir in the river and the weir in the water intake structure). The weir in the Loire is the only feature that may in fact affect river flow. However, the structure is fitted with a fish ladder, installed at the left-bank end of the weir barrier, thereby maintaining ecological continuity for fish species.

Dredging operations are carried out to safeguard the supply of raw water to the facilities, and are conducted in the water intake structure, immediately upstream of the floating boom on the Loire side, and in the northern section of the upstream forebay. The engineered features, the dredging operations, and the water abstraction for Saint-Laurent NPP operation are not likely to alter the hydrology of the Loire.

- ***Impact on surface water temperature***

Surface temperature variations caused by the discharges from Saint-Laurent NPP were analysed by way of infrared thermography surveys and digital modelling.
At the local level, water temperature measurements indicate that the thermal plume is fully mixed 5 km downstream of the discharge points, regardless of flow rate. At the regional level, the residual warming associated with the operation of Saint-Laurent power plant is quickly undetectable by instrumentation and indistinguishable from the natural temperature variations of the Loire River.

- ***Impact on surface water quality***

Analysis of the results of hydroecological and chemical monitoring of the environment shows that the physico-chemical, chemical and biological parameters of the surveyed environment upstream and downstream of Saint-Laurent NPP are not linked to past or current discharges from the plant.
The substance-by-substance assessment of the impact of liquid chemical discharges at average and maximum levels does not reveal any impact on the Loire ecosystem downstream of Saint-Laurent NPP, for aluminium, chromium, manganese, nickel, titanium, zinc, chlorides, BOD5, COD, lithium, SM, sodium, ammonium, nitrites, nitrates, phosphates, sulphates, copper, iron, boric acid, ethanolamine, methylamine, pyrrolidine, ethylamine, acetates, formates, glycolates, oxalates, chlorates and chloroform.
In addition, based on the operating experience of dredging operations in recent years, the return to the Loire of sediments dredged from the intake channel has no significant impact on the physico-chemical quality of Loire River water.

Note: the assessment of the effects of radioactive discharges is presented in Section 5.7.4.

- ***Impact on morphology-sedimentology***

During the dredging season, the focal potential impact stems from sediment return to the Loire, on the left riverbank and downstream of the power plant's weir.
The maximum annual volume of sediment returned from dredging operations (6,000 m^3) represents approximately 1% of annual natural sediment transport.
It should also be noted that the period for dredging operations (November to March) is one in which average flows are higher than the Loire's 'module' (inter-annual average flow), thereby ensuring the remobilisation of the dredged sediments. Should hydrological conditions in the Loire disallow the direct return of materials to the river, the sediments are stored in two settling ponds. The impact of the return of dredged sediments on the hydrology and morphology of the Loire is therefore considered to be minimal and temporary.

- ***Climate change sensitivity***

The climate change developments that may have a bearing on the results of this study are tied to increases in the water temperature and changes in the flow rate of the Loire River. The study of the local impacts of climate change is a topic of extensive ongoing research aimed at establishing methodologies for generating climate projections at a local scale, factoring in notably the changes in watercourse temperature and flow.
Among the different climate variables that are likely to influence changes in the aquatic environment, water temperatures are one for which a trend has been observed, particularly in the summer, associated with changes in air temperatures.
Measurements taken since the late 1970s establish an overall increase in Loire River temperature, as evidenced by a number of statistical parameters.
What is more, EDF's projections for future climate conditions confirm the upward trend in average annual Loire temperatures, with increases of between + 0.8 to + 0.9°C on average, over the period 2020-2050, compared with the historical period selected (1986-2016).
Past observations and 30-year projections thus estimate the climate-change related increase in average annual Loire water temperature at around + 0.3°C per decade.

However, given the scenarios adopted in this study (water temperature is not used directly in assessments of impacts on the aquatic environment) and this slight increase over the next decade (in light of the interannual variability), it is considered that this change will not alter the conclusions of this study.
With regard to Loire River flow rates, the trends, including for the longer term, are less clear-cut than those for temperatures, with greater uncertainty owing to the more complex modelling of a river basin's hydrological cycle.
EDF projections for future climate show that the Loire River's average annual flows would be lower on average over the period 2020-2050, with a decrease of around 8% to 10% compared to the 1986-2016 reference period, and a more pronounced seasonal pattern in flow rates (slightly higher flow rates in winter and lower flow rates in summer).
These results are associated with significant inherent uncertainty in the model chain, due in particular to the spread of global climate model results, but also to the complexity of flow modelling for the Loire basin. Although developed using cutting-edge methods, these results should therefore be considered as trends. It is therefore considered that potential decreases in flow over the study period (ten years) will be relatively small compared to the seasonal and inter-annual variations already observed in the Loire River.

↘ CUMULATIVE IMPACT STUDY OF THE COMBINED EFFECTS OF NUCLEAR POWER PLANTS SITED ON THE LOIRE

In 2023, EDF carried out a study of the cumulative impact of all the nuclear power plants sited on the Loire River. The study was based on two complementary approaches:

- a qualitative method, using environmental monitoring data upstream and downstream of the sites to identify any changes in the river;
- a quantitative method of assessing the environmental and health impacts by modelling the cumulative impact of actual discharges from the facilities and actual river flows in 2016 and 2018, which represented an average year and a year with pronounced low water levels, respectively.

The qualitative approach showed that liquid chemical discharges had no significant influence on chemistry, physico-chemistry, or biology. The quantitative approach did not reveal any significant impact on the Loire ecosystem at the four assessment points that were studied. These four points were distributed along the river so as to provide insight into any combined incremental effects up to the Loire estuary.

5.7.3. Soil and groundwater

- ***Impact on soil***

The development of the power plant has altered site topography and geology, and has anthropised the entire surface area.

A study of historical and environmental data for Saint-Laurent-B NPP, and for the Saint-Laurent-A site and silos, made it possible to draw up an inventory of historical and current activities, to locate these activities, and to assess their level of risk to the soil and groundwater.
With regard to the Saint-Laurent B power plant, only the liquid effluent treatment facility was identified at the time as having caused verified soil contamination, owing to legacy leakage from tanks containing liquid radioactive effluents from the Saint-Laurent A facilities, and incidents during unloading. However, following a clean-up in 2000, the entire contaminated area has been remediated (residual gamma activity below 10 Bq/kg and no artificial alpha-emitting radionuclides above laboratory detection limits).
Furthermore, in 2019, ultimate-emergency-makeup well drilling operations in a car park on the north-western edge of the nuclear island uncovered buried construction materials (concrete, metal cables, sheet metal, wood, pieces of plastic, etc.) at a depth of 5 metres or more.

Further soil investigations were carried out between November 2019 and January 2020, so as to gain a better understanding of the status of the soil within the two areas mentioned above, as well as within - or in the immediate vicinity of, as regards operating facilities - certain areas flagged up as at risk of soil contamination in a review of historical and environmental data. The results of four additional soil survey campaigns performed between 2017 and 2022 as part of the power plant's site development projects, and the results of supplementary investigations conducted in 2022 around the ultimate-emergency-makeup well, were also analysed.

An analysis of all these investigations confirmed that, aside from the area around the ultimate-emergency-makeup well, there were no traces of chemical or radiological contamination linked to site activities, and only isolated abnormal readings for ions and trace metals, associated with the background radiation of existing fill and alluvial deposits, and did not require the implementation of special management measures. As for the area near the ultimate-emergency-makeup well, where construction materials were found at a maximum depth of 8 m below platform level, the presence nearby of operating facilities prevented any further exploration to establish the horizontal spread of the waste. At the same time, hydrocarbons, PCBs[18], and trace metals were detected in the soil of this area, at concentrations exceeding adopted reference values. This area will be subject to a management strategy, which will be submitted to ASNR for appraisal.

- ***Impact on groundwater***

The construction of installations and facilities has locally altered groundwater flows (deep foundations, engineered confinement structures, hydraulic structures, etc.).

In addition, the use of groundwater for drinking water supplies, as well as for test phases and maintenance of the ultimate-emergency-makeup well, means that water is abstracted from the deep chalk aquifer, but in small volumes relative to the aquifer's yield.

Saint-Laurent NPP also monitors the quality of the groundwater beneath its footprint. The data from this monitoring programme, collected between June 2015 and December 2021, was reviewed. With the exception of one-off cases where reference thresholds applicable to nuclear site groundwater monitoring were exceeded – giving rise to the required measures to limit or eliminate the environmental consequences of these overruns – the results of this monitoring programme confirm that there are no health or environmental impacts relating to groundwater quality either at the Saint-Laurent site or in the aquifer downgradient.

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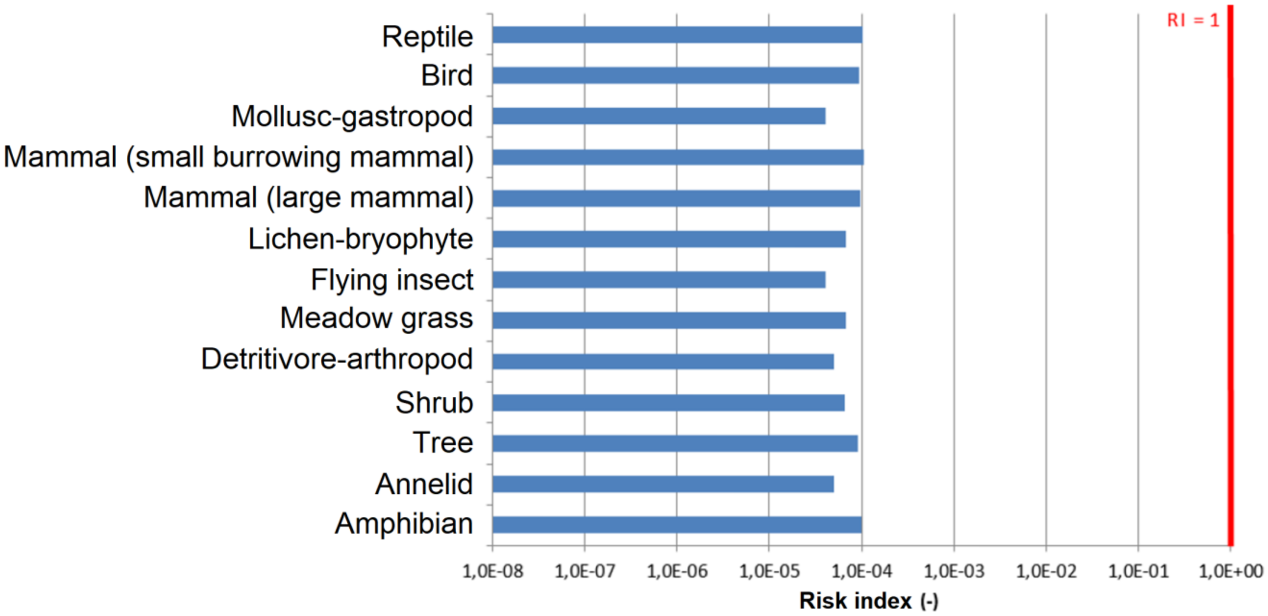
[18] PCBs: Polychlorinated biphenyls.

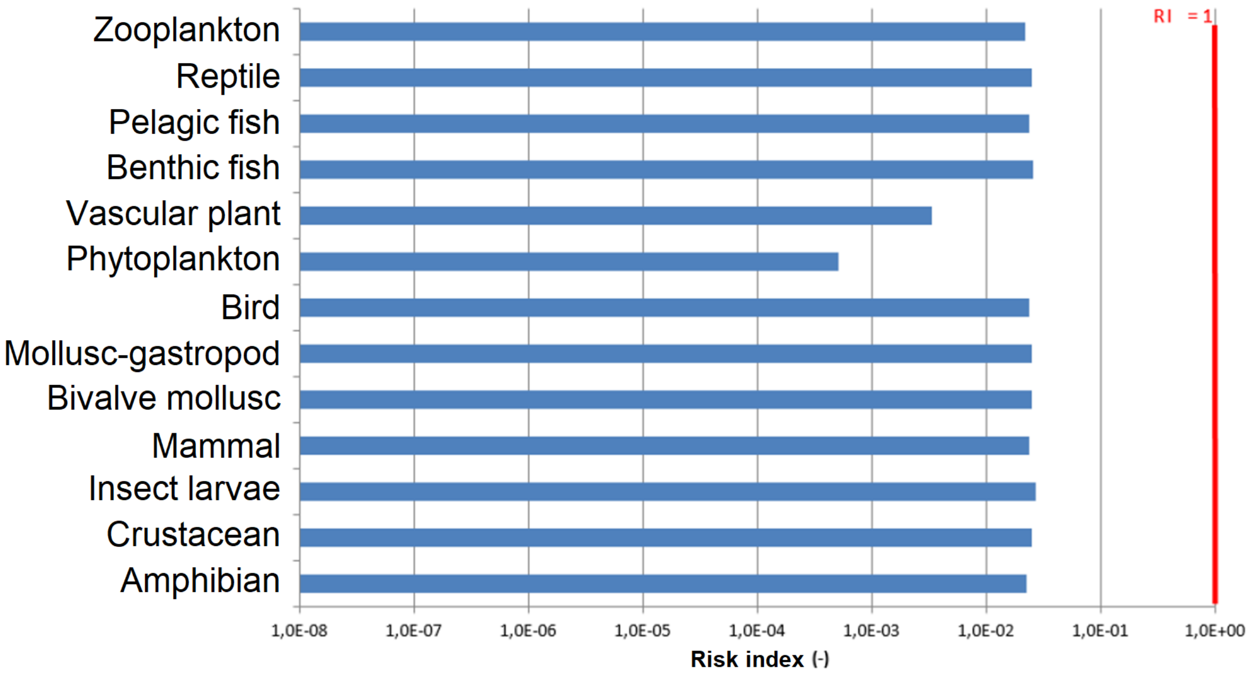
5.7.4. Radioecology

As specified in Section 5.2, the environmental impact assessment of radioactive discharges is based on a comparison of the dose rate induced by the radioactive discharges with a dose rate value that has no effect for each reference organism. This comparison gives rise to a risk index. If the risk index is less than 1, it can be concluded that the risk is negligible.

The graphs below show the risk indices determined for reference organisms in terrestrial and aquatic compartments.



Risk indices for terrestrial ecosystem reference organisms



Risk indices for marine aquatic ecosystem reference organisms

As the index is consistently below 1, the environmental risk associated with liquid radioactive effluent discharges and radioactive effluent discharges to atmosphere from Saint-Laurent power plant is negligible, both now and for the next ten years.

CUMULATIVE IMPACT STUDY OF THE COMBINED EFFECTS OF NUCLEAR POWER PLANTS SITED ON THE LOIRE

In 2023, EDF carried out a study of the cumulative impact of all the nuclear power plants sited on the Loire River. The study was based on two complementary approaches:

- a qualitative method, using environmental monitoring data upstream and downstream of the sites to identify any changes in the river;
- a quantitative method of assessing the environmental and health impacts by modelling the cumulative impact of actual discharges from the facilities and actual river flows in 2016 and 2018, which represented an average year and a year with pronounced low water levels, respectively.

The qualitative approach showed that the radioactivity present in the Loire was mainly of natural origin. In certain aquatic matrices, the effects of liquid radioactive discharges could be observed, primarily downstream, close to the discharge points. Regarding tritium and carbon-14, a gradual increase in activity levels was visible in certain matrices between Belleville-sur-Loire NPP and the downstream section of Dampierre-en-Burly NPP, but stabilised thereafter. This effect is due to the cumulative liquid radioactive discharges from the various sites on the Loire, which are not entirely offset by dilution from the Loire's tributaries. The quantitative approach showed that the risk indices for reference organisms were well below the reference value, and that the environmental risk associated with liquid radioactive discharges was therefore negligible.

5.7.5. Biodiversity

The analysis of the impacts of Saint-Laurent NPP operation on air, climate factors, surface water and the radiological status of the environment, as presented above, does not indicate any significant plant impact on the ecological characteristics of the environment, which are required to foster biodiversity in the study area.
The operation of Saint-Laurent power plant therefore has no tangible impact on the natural areas of special interest, and does not jeopardise the ability of plant species (aquatic, semi-aquatic, or terrestrial) and animal species (invertebrates, fish, amphibians, reptiles, birds, mammals) to successfully complete their biological life cycle, or compromise the ecological functionalities of the habitats present in the study area.
What is more, plant operation has no effect on species that may move within or migrate to the study area (migrating and nesting birds, bats, etc.).
Out of all the habitats and species that gave rise to the designation of the six Natura 2000 sites identified in the study area, the habitats and species that are potentially affected, directly or indirectly, temporarily or permanently, by the operation of Saint-Laurent NPP are: 14 habitats, 7 insect species, 6 mammal species, 5 fish species, and 37 bird species.
The assessments of the effects of water-abstraction, discharges and impacts, set out in the sections above, indicate that plant operation and maintenance work in the water abstraction facilities have no significant environmental consequences. Thus, the ecological characteristics of the environment, which determine the ecological richness of the habitats studied, are not compromised.
Furthermore, the parameters for the atmospheric and aquatic environments, which determine the ecological characteristics of the habitats of the species studied, are not compromised by the operation of the power plant.
The analysis therefore confirms that the direct and indirect, temporary and permanent impacts of Saint-Laurent NPP operating and dredging activities do not challenge the conservation status of the priority habitats and species, or of the habitats and species of community interest, that were established at the time the Natura 2000 sites in the study area were designated.
Lastly, the operation of Saint-Laurent power plant does not call into question the management objectives defined in the Documents of Objectives (DOCOB) for Natura 2000 sites and, more broadly, does not have an impact on the Natura 2000 protected areas network.

5.7.6. Population and human health

▪ *Evaluation of the dose impact on humans*

The **effective dose** measures the biological effect of radioactivity. It is expressed in sieverts (Sv), or more commonly in millisieverts (mSv) or microsieverts (µSv).

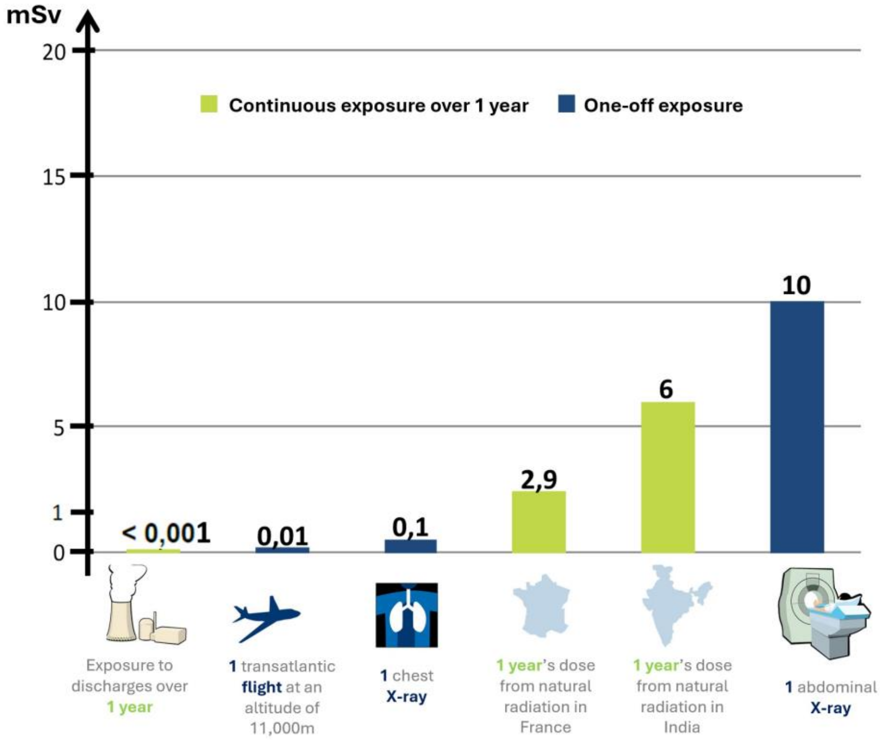
The overall impact on the general public of radioactive effluent discharges from Saint-Laurent NPP factors in the internal and external exposure associated with both liquid effluent discharges and effluent discharges to atmosphere. It is determined for a set of representative individuals, that is to say, for those likely to be most exposed, living within a 5-km radius of the power plant.

The total annual **effective dose** associated with internal and external exposure to radioactive effluent discharges from the site is estimated to be:

- for an adult, at $9.7.10^{-7}$ Sv/year, in other words, below 1 µSv/year;
- for a 10-year old child, at 6.4.10-7 Sv/year, in other words, below 1 µSv/year;
- for a 1-year old child, at 7.0.10-7 Sv/year, in other words, below 1 µSv/year.

Each of these doses represents less than 1/1,000th of the annual exposure limit for members of the public, which is set at 1 mSv under Article R. 1333-11 of the Public Health Code

In order to put these doses into perspective, in relation to other modes of exposure, the illustration below shows the orders of magnitude for doses resulting from common sources.



Scale of radiation exposure

▪ *Evaluation of the health risks linked to chemical discharges*

It has been demonstrated that the current discharges from Saint-Laurent NPP have no impact on the chemical status of the Loire River.

The Prospective Assessment of Health Risks ([EPRS], see Section 5.2) does not identify any health risk, resulting from the liquid chemical discharges attributable to Saint-Laurent power plant, for neighbouring populations potentially

exposed to substances through the consumption of Loire River water, land-based foods (vegetables, meat and milk) and fish caught in the Loire downstream of the plant.
Likewise, the assessment does not indicate any health risk, due to chemical discharges to the environment linked to Saint-Laurent plant operation, for neighbouring populations potentially exposed to the substances through inhalation.

CUMULATIVE IMPACT STUDY OF THE COMBINED EFFECTS OF NUCLEAR POWER PLANTS SITED ON THE LOIRE

In 2023, EDF carried out a study of the cumulative impact of all the nuclear power plants sited on the Loire River. The study was based on two complementary approaches:

- a qualitative method, using environmental monitoring data upstream and downstream of the sites to identify any changes in the river;
- a quantitative method of assessing the environmental and health impacts by modelling the cumulative impact of actual discharges from the facilities and actual river flows in 2016 and 2018, which represented an average year and a year with pronounced low water levels, respectively.

Radiological impact on the population*:* the total effective doses linked to cumulative radioactive effluent discharges represented less than 0.1% of the regulatory dose limit for the public, set at 1 mSv/year.
Health impact on the population: the analysis of the environmental status concluded that cumulative discharges into the Loire had no impact on the river's chemistry and therefore did not alter the water's suitability for the identified uses. The quantitative health risk assessment did not identify any health risk, resulting from the liquid chemical discharges attributable to nuclear power plants located on the Loire and Vienne rivers, for neighbouring populations potentially exposed to the substances.

Justification of microbiological risk control measures

The prevention, monitoring and control measures implemented by Saint-Laurent NPP to minimise the proliferation and spread of amoebae and legionella bacteria comply with regulatory requirements.
Monitoring of amoebae and legionella concentrations shows that the preventive water treatment strategy delivers effective control of microbiological health risks.

Evaluation of the impact of noise and vibration

A noise measurement campaign was carried out in 2022 at the Saint-Laurent NPP site. The results of the compliance analysis show that noise levels on site conform to the limits set by regulations.
In addition, plant operation gives rise to vibrations (mainly from rotating machinery) that are only felt inside the facilities thanks to the design of the buildings and the composition of the soil.
As regards any civil engineering works, and road and utility works, which are sources of vibration, these are carried out within the boundary of the power plant, for a limited period of time, and take place during daytime working hours on working days, thus restricting any potential disturbance.
The existing facilities therefore do not cause any disturbance for neighbouring populations.

Evaluation of the impact of light emissions

Current light emissions are mainly related to site security lighting (intruder protection system, aviation obstruction lighting, etc.). The impact of these light emissions is negligible.

5.7.7. Human activities

- ***Evaluation of impacts on land use***

The assessment of the health impact of radioactive and chemical discharges from Saint-Laurent NPP does not reveal any health risk, attributable to the operation of the power plant, for potentially exposed neighbouring populations.
Thus, the evaluation of human environmental exposure to radioactive and chemical effluent discharges from Saint-Laurent power plant leads to the conclusion that there is no significant impact on land use, in particular regarding agricultural land and tangible assets (residential areas, industrial estates, etc.).

- ***Evaluation of impacts on landscape and cultural heritage***

The Saint-Laurent plant, made up of three BNI (Basic Nuclear Installations), was built between 1963 and 1980. These installations have therefore been in situ for around 40 years and are now firmly embedded in the landscape. Their current operation has no impact on the landscape or cultural heritage.
As indicated in Section 5.6, there are no site development plans that would call these conclusions into question over the next ten years.

- ***Evaluation of impacts on water use***

Saint-Laurent NPP operation gives rise to various requirements for water supplies, the most important of which is for condenser cooling. The two reactors are equipped with a so-called closed-circuit condenser cooling system. The use of cooling towers limits the volume of water drawn from the Loire River for condenser cooling. Aside from the water that is evaporated in the cooling towers of reactors No. 1 and No. 2, the water taken from the Loire is returned to the river.

The health impact assessment of radioactive and non-radioactive discharges (through consumption of water and ingestion of food, considering in particular the pathways of irrigation water, bathing water, and the ingestion of fish and other aquatic species) does not reveal any health risk, attributable to the operation of Saint-Laurent NPP, for potentially exposed neighbouring populations.

Consequently, Saint-Laurent plant operation has no impact on the availability of water resources, and the discharges do not compromise water use in the vicinity of the plant.

- ***Evaluation of impacts on infrastructure and transport links***

Saint-Laurent NPP operation gives rise to the daily movement of around 2,000 light and heavy-goods vehicles, the majority of which are staff vehicles. The total volume of traffic created by the power plant accounts for 36%, 31% and 6% of the overall volume of traffic on departmental road RD951 (5,591 vehicles), departmental road RD2152 (6,451 vehicles) and the A10 motorway (33,171 vehicles), respectively. The volume of traffic generated by the plant can be seen as limited in relation to the volume of traffic on nearby road infrastructure.
Saint-Laurent power plant does not have a railway line for fuel delivery and unloading. Transport operations are carried out by road, from a depot located a few kilometres from site. The plant therefore has no impact on railway traffic.
The power plant does not generate any river traffic. Four dredging operations have been carried out, in 2014, 2015, 2016 and 2020. It should be noted that dredging improves the river's flow rate.
Saint-Laurent NPP has a limited impact on infrastructure and transport links.

- ***Evaluation of impacts on the industrial environment***

EDF has signed an agreement with local market gardeners based near Saint-Laurent NPP for the supply of hot water to heat greenhouses.
The power plant has no interaction with other industrial facilities in the study area.
Saint-Laurent plant operation therefore has a positive impact on the industrial environment, further enhanced by the aforementioned limited impact on infrastructure.

- ***Evaluation of impacts on recreation and leisure activities***

The health impact assessment of radioactive and non-radioactive discharges (including through water consumption, food ingestion, fishing, bathing, etc.) linked to plant operation does not reveal any health risk, attributable to Saint-Laurent NPP, for potentially exposed neighbouring populations.
Consequently, Saint-Laurent plant operation has no impact on recreation areas and leisure activities.

- ***Evaluation of impacts on energy consumption***

Saint-Laurent NPP meets its own electricity requirements and, as a rule, 100% of the household electricity needs in the Centre-Val de Loire region (9.4 billion kWh of electricity generated in 2022).
The power plant's electricity consumption amounted to 84 GWh, 73 GWh and 108 GWh in 2019, 2020 and 2021, respectively, representing 0.8%, 0.6% and 1.2% of its output.
It should be noted that Saint-Laurent NPP has emergency diesel generators, which undergo periodic operability testing. Off-road-diesel consumption for these surveillance tests amounts to around 55 m^3 a year.
Plant activities therefore have no impact on energy consumption.

5.7.8. Waste management

5.7.8.1. Waste generation

In the course of its electricity production, plant maintenance, waste storage and logistics activities, Saint-Laurent NPP generates two categories of waste: radioactive waste and conventional waste.

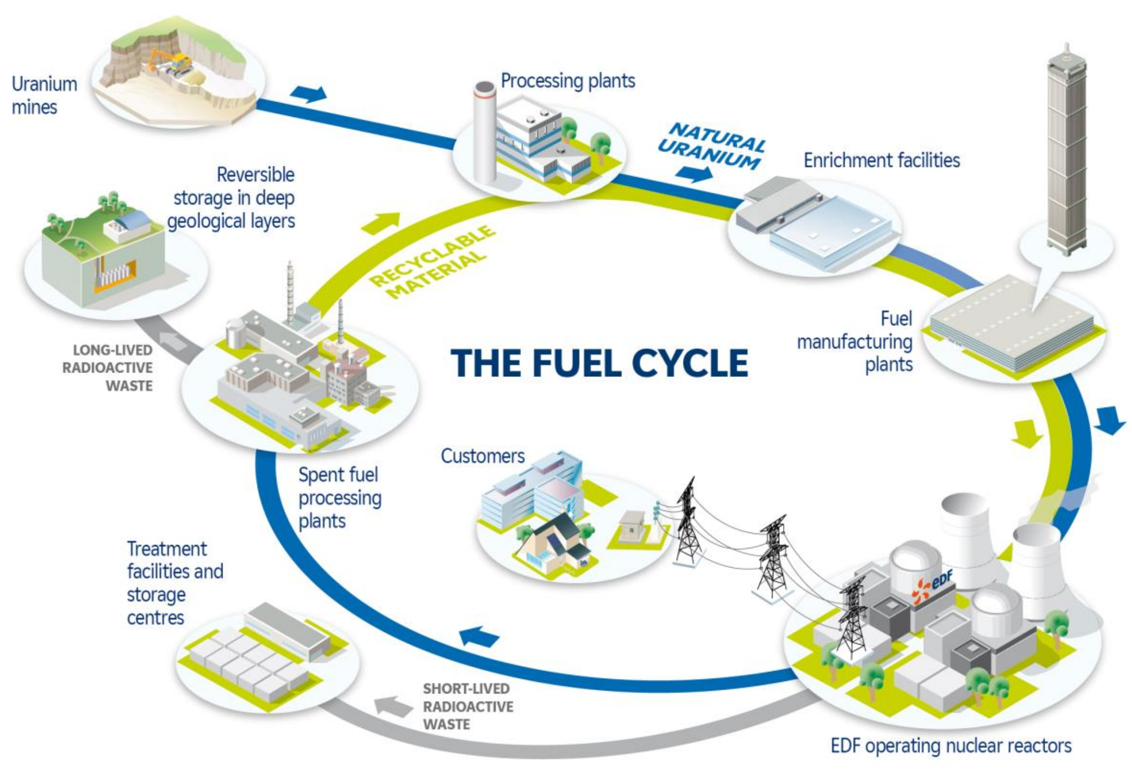
- Radioactive waste is classified by its level of activity and by the lifespan of the radionuclides it contains. It may be derived from:
  - the treatment of radioactive effluents: filters, activated carbon, evaporation concentrates, water filters, ion exchange resin sludge, etc.;
  - fuel handling operations: clusters, fuel rod capsule-canisters, skeleton assemblies, etc.;
  - routine maintenance operations: discarded radioactive mechanical parts, tooling, laundry waste, etc.
- Conventional waste is waste produced in areas that do not contain any radioactive material. It consists of inert waste (rubble, soil, etc.), non-hazardous non-inert waste (wood, packaging, paper, cardboard, glass, plastic, metal, etc.) and hazardous waste (paint, oil waste, asbestos, etc.).

FIND OUT MORE: THE NUCLEAR FUEL CYCLE IN FRANCE

A nuclear reactor uses uranium, a natural resource, as its main fuel. The ‘fuel cycle’ refers to all the industrial steps associated with fuel operations, from the extraction of the ore to the storage of radioactive waste from spent fuel.
The fuel cycle can be broken down into three stages:

- The front end of the cycle: uranium ore is extracted from the ground, converted into a gaseous form by way of a chemical process, and then enriched. This material is incorporated in the form of pellets into sealed metal tubes, which are assembled to form ENU (enriched natural uranium) fuel assemblies.
- The core of the cycle: these assemblies are loaded into the reactor and used for four to five years to produce electricity.
- The back end of the cycle: after this period, the assemblies are unloaded and stored in the spent fuel pool located in the plant's fuel building for an initial phase of heat decay and radioactive decay. The assemblies are then recycled after treatment, in a ‘closed cycle’ where the recyclable energy materials are extracted from the spent fuel (plutonium and uranium). It is only what cannot be recovered that is considered as waste.

France’s choice of ‘closed cycle’ recycling saves resources and reduces the volumes of waste produced.



5.7.8.2. Waste management strategies and streams

The various stages of waste management are designed to ensure that waste is acceptable to the stream(s) for which it is intended, and to limit its impact, particularly regarding radioactive waste earmarked for the storage facilities operated by ANDRA (National Agency for Radioactive Waste Management) and Cyclife France (the company running CENTRACO). These different stages are sorting at source, collection, checking, packaging and shipment.

- ***Radioactive waste***

Radioactive waste is sorted at source according to its dose equivalent rate (DER), below or above 2 mSv/hr on contact, its physical state (solid or liquid), its type, and its source of production.
It is collected at various locations, checked, and then packaged in compliance with the requirements of the specifications governing the waste stream it will be directed to (packaging in concrete shells, metal or plastic drums for low activity technological waste, in big-bags or crates for very low activity technological waste, for example).
The radioactive waste storage areas and facilities, as well as the reference storage times for radioactive waste, take into account the nature and activity of the waste, and the specifications of the associated storage facilities and areas.

After storage, waste from the site is disposed of by category, via dedicated streams operated by the National Agency for Radioactive Waste Management (ANDRA) and Cyclife France (CENTRACO), namely:

- Cyclife France's incineration facility (**CENTRACO**), which processes technological waste (vinyl, paper, rags, etc.), ion exchange resins, aqueous effluents, boron concentrates, oils and solvents;
- Cyclife France's melting facility (CENTRACO), which processes ferrous and mixed-metal waste, as well as certain large components subject to approval on a case-by-case basis;
- Storage facilities operated by ANDRA (the Aube Disposal Facility [CSA] or the Industrial Facility for Waste Collection, Sorting and Storage [CIRES]), which receive, process and if necessary store very-low-level to intermediate-level radioactive waste.

CENTRACO (Waste Treatment and Conditioning Centre) is an industrial facility dedicated to the treatment of short-lived very-low-level to intermediate-level radioactive waste.

©EDF
CENTRACO Cyclife – Thermal cutting prior to melting

- ***Conventional waste***

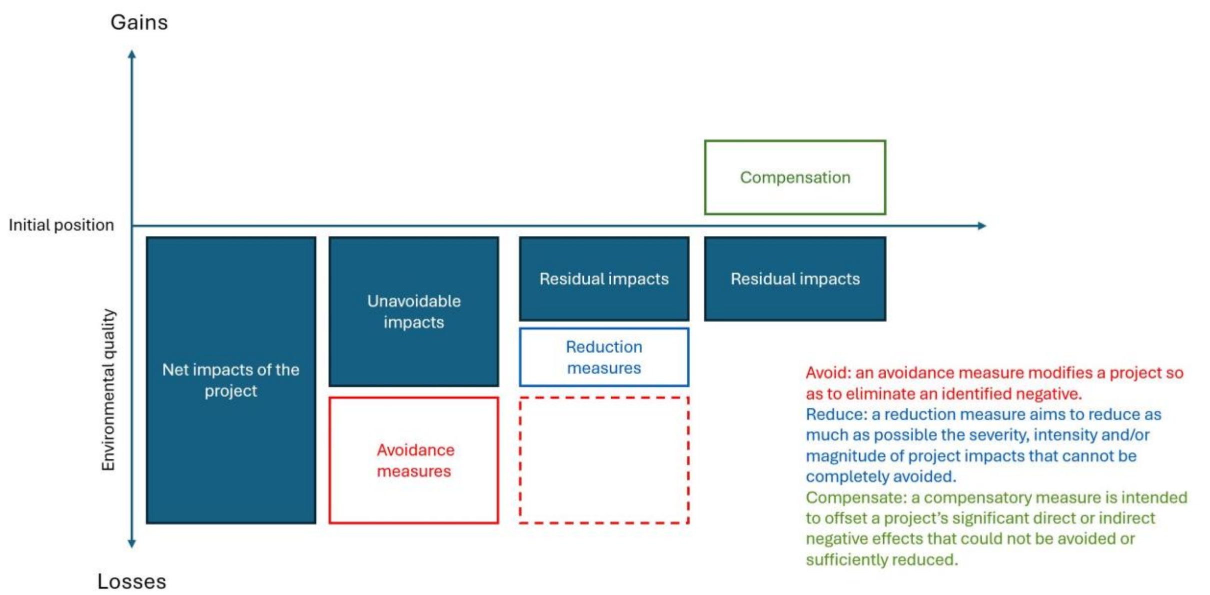
Conventional waste is collected as close as possible to the production premises. Some of it is grouped together and stored in the power plant's conventional waste transit area, and then removed after being checked at the C3 vehicle monitors (radiological monitoring equipment at site exit points, used to check for contamination).
Saint-Laurent NPP uses two types of waste streams for conventional waste: disposal and recovery.
The choice of stream takes into account the following three principles:

- hierarchy of waste treatment methods, which gives priority, in this order, to reuse, recycling, any other form of recovery (in particular energy recovery), and then disposal;
- proximity;
- compliance with local/regional/national waste prevention and management plans.

5.7.9. Impact avoidance, reduction and compensation measures

ARC MEASURES

The mitigation hierarchy consists of a three-step sequence - avoid, reduce, compensate - which aims to prevent environmental damage, reduce damage that cannot adequately be avoided and, where possible, compensate for significant effects that cannot be avoided or sufficiently reduced.



The ARC sequence in French law (Source: environnement.gouv.fr)

Air and climate factors

Saint-Laurent NPP has deployed several measures to prevent and reduce gas emissions:

- An action plan to limit greenhouse gas emissions (releases of SF6 gas);
- Actions to reduce sulphur oxide and nitrogen oxide emissions;
- A series of measures in relation to staff transport on site (emissions of CO_2):
  - company fleet vehicles have been replaced by electric or hybrid models;
  - charging stations have been installed within the inner and outer site boundary, for service vehicles used on site;
  - bus services have been made available for staff transport.

Surface water

Saint-Laurent NPP has taken steps to optimise its management of non-radioactive effluent discharges into surface water. It has done so:

- by reducing liquid effluent production at source and by lowering effluent toxicity (the concentrations of chemical substances in these effluents, for example);
- by collecting and separating effluents, so that each type of effluent can be treated as efficiently as possible and, in some cases, reused;
- by maintaining high-performance effluent treatment facilities;
- by optimising circuit conditioning with a view to keeping chemical discharges to the absolute minimum, for example through the use of substances that are less harmful to the environment but preserve the designed efficacy of treatment processes.

What is more, Saint-Laurent NPP is implementing measures aimed at reducing its water consumption and, consequently, the amount of water it draws from the Loire River.

Soil and groundwater

The main soil and groundwater impact avoidance and reduction measures implemented by Saint-Laurent power plant focus on minimising "artificialisation" (or land take) and ensuring on-site reuse of excavated soil.
The assessment of impacts on soil and groundwater did not flag up any notable adverse impacts and, on this basis, no additional compensation measures have been put forward.

Radioecology

The design and operation provisions that have been implemented ensure effective control of radiological effluent discharges:

- by reducing at source the volume of effluents (by improving the integrity of fuel cladding and of circuits carrying radioactive gases, by installing continuous primary coolant cleaning systems that trap activation products as close as possible to the source, etc.);
- by carrying out **filtration** or targeted treatment prior to discharge (ion exchange resins, for example);
- by optimising the activity concentration of the radionuclides present in effluents, through the **radioactive decay** of these radionuclides;
- by checking discharges.

Filtration traps most of the radionuclides prior to discharge. EDF's nuclear power plants are equipped with very high efficiency (VHE) filters.

Radioactive decay describes the spontaneous disintegration over time of the atomic nuclei in a radioactive material.

Biodiversity

In addition to the measures set out above, specific provisions are in place for fauna and flora, in relation to maintenance work in the intake structures.
Water intake dredging operations take place during the authorised environmental window, from November to January, thus avoiding critical periods in the lifecycles of species.

Population and human health

The impact avoidance and reduction measures for discharges to atmosphere and surface water are detailed above.
With regard to noise pollution, provisions were made at the design stage to reduce noise emission at source, and noise measurement campaigns are conducted for certain equipment and installations, in accordance with regulations. Action is taken to limit potential noise impacts from temporary installations or tests (by selecting the least disruptive time slots, the most suitable locations, processes or equipment, and by installing noise barriers).
As for light emissions, measures are in place to reduce any light pollution (projector beams are angled towards the power plant and towards the ground, and lighting is limited to the strict minimum needed for site perimeter security, outside of working hours).

Human activities

The assessment of impacts on human activities did not identify any notable adverse effects. Accordingly, no measures have been put forward to avoid, reduce, or compensate for significant negative effects.

Waste management

Saint-Laurent NPP is structured to ensure optimised waste management based on:

- a reduction at source of waste volume and harmfulness;
- separate collection and sorting;
- the implementation of efficient treatment and conditioning processes that meet the acceptance specifications of the stream(s) for which the waste is intended.

- This assessment did not identify any notable impacts and, on this basis, no additional measures have been put forward to avoid, reduce, or compensate for significant adverse effects.

5.7.10. Climate change impacts of decommissioning

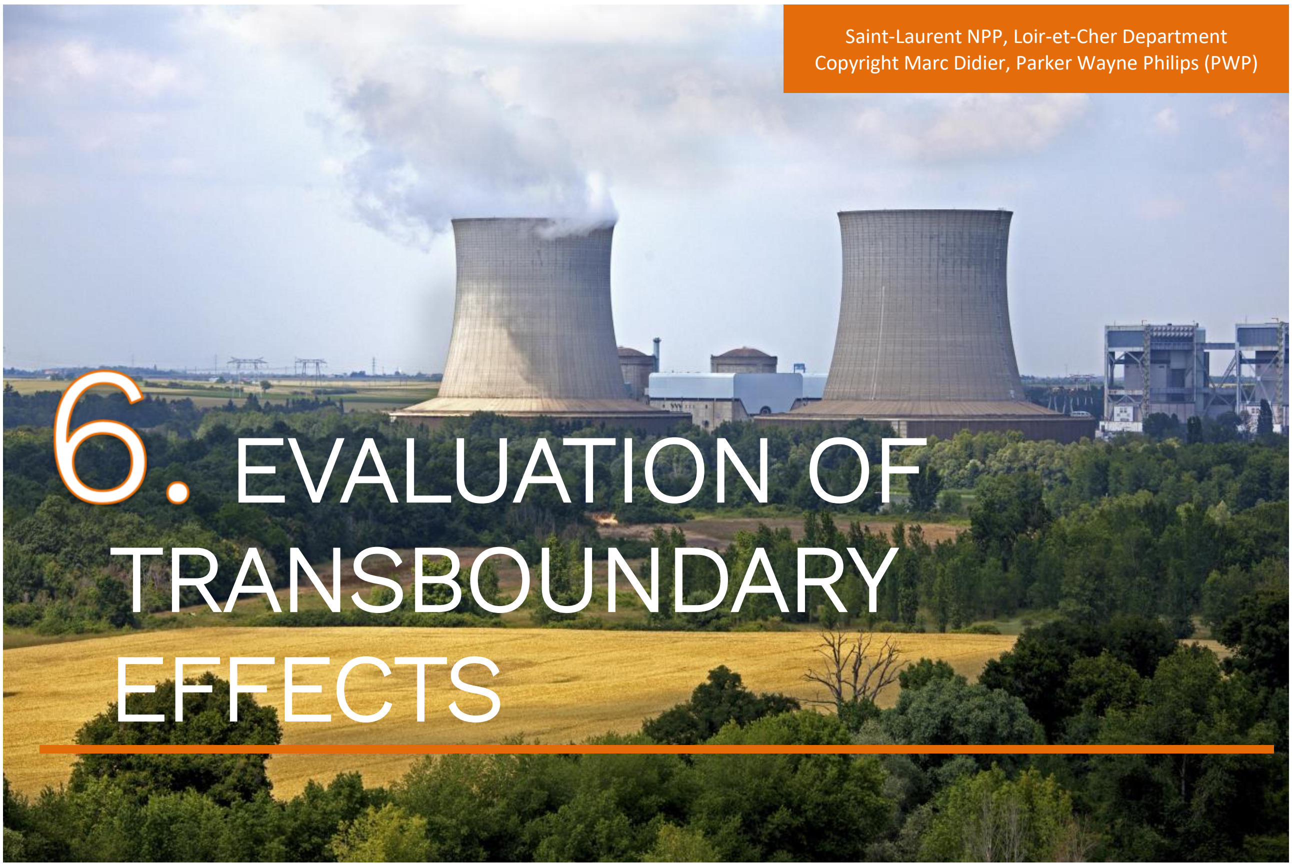
Should the plant be decommissioned, its interactions with the environment would be reduced, owing in particular to lower water abstraction and fewer discharges. As previously noted, the design, the continuous improvements made over forty years of electricity generation, the effective management of operations, and the measures to promote biodiversity, all mean that normal plant operation does not have any significant adverse effects on the environment. Decommissioning would therefore not bring any significant benefits to the environment. On the other hand, the decommissioning of the plant would lead to a significant increase in greenhouse gas emissions.

Nuclear power generation emits very little greenhouse gas: the equivalent of 4 grammes of CO_2 per kWh for the current French nuclear fleet, according to EDF's ACV du kWh nucléaire (LCA of a nuclear kWh), compared to an average 275 grammes of CO_2 for the European electricity mix (https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/chiffres-cles-du-climat-2025/fr/livre).

Saint-Laurent power plant produces on average around 12.2 TWh/year of electricity, emitting around 38,000 tonnes of CO_2.

Should Saint-Laurent NPP be decommissioned, producing the same amount of electricity using the European energy mix would increase CO_2 emissions by more than 2 million tonnes of CO_2[19].

[19] Based on the CO_2-absorbtion capacity of a deciduous forest of around 4 tonnes of CO_2/ha/yr. A forest area of around 500,000 hectares (50 km by 100 km) would need to be planted to offset this additional CO_2 in the atmosphere.



Saint-Laurent NPP, Loir-et-Cher Department
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6. EVALUATION OF TRANSBOUNDARY EFFECTS

In the event of a nuclear accident, radioactive material that could be harmful to health may be released into the environment.

This section sets out the environmental and human impacts of potential radiological incidents and accidents. In France,
in order to test the design of nuclear installations, the dose values associated with the worst-case radiological consequences, or maximum doses, are defined according to the frequency of occurrence of accidents. For example, the incidents with a moderate frequency of occurrence (1 accident in a maximum 100 years of operation) comply with the doses set by the Public Health Code. What is more, for the most severe accidents, those involving core meltdown, which are the most hypothetical scenarios, the consequences must remain limited in scope and duration, and must remain aligned with the accident management arrangements of the public authorities, so that the population can be protected. Incidents and accidents, including accidents involving core meltdown, are therefore taken into account in the design and operation of the power plant with a view to reducing and limiting the consequences.

Transboundary effects are only likely to occur in the event of an accident involving core meltdown. In fact, these effects are negligible for normal operation and for other accidents. Such a core-melt accident is a highly unlikely event, which could only occur after multiple failures of reactor protection and control systems. The consequences of a dispersion of radioactive substances up to 1,000 km around the plant have been studied for the worst-case scenario of an accident involving core meltdown.

Once the reactor has been decommissioned, the spent fuel will be removed from the reactor and transferred to the spent fuel pool during the dismantling preparation phase, after which a core-melt accident will no longer be possible (see Section 4.4).

6.1. Requirements governing radiological consequences

6.1.1. Radiological consequences assessment process

In order to verify that design basis incidents and accidents (divided into four categories) or beyond-design-basis accidents or indeed core-meltdown accidents lead to limited radiological consequences for the population, including across borders, the results of dose calculations are compared with dose limits for each situation under consideration. Since the possible initiators in a nuclear installation do not all have the same likelihood of occurrence, the higher the likelihood of the accident occurring, the lower the radiological consequences must be.

Furthermore, the following dose limits are also considered in relation to the time period under review:

- the dose associated with the short-term phase of the accident, calculated after 24 hours and then 7 days,
- and the long-term dose, calculated for the most radiation-sensitive population over a period of 50 years.

These doses are calculated for a distance corresponding to the residential housing closest to the reactors, for all the 900 MWe series plants (which is 650 metres), or for the standard distances of 2.5 km and 10 km. The closest residential housing is sited 650 metres from the Saint-Laurent reactors.

The evaluation of the radiological consequences of accidents is based on a reasonably pessimistic assessment of releases into the environment, taking into account all the transfer pathways from the fuel to the boundaries of the facility. The doses resulting from releases of activity are then assessed on the basis of realistic scenarios, without factoring in any protective measures. These doses include, in particular:

- the total effective dose (or whole body dose), short-term or long-term,
- the equivalent dose to the thyroid, estimated for the short-term phase.

The assessment of effective doses considers all internal and external exposure pathways (plume, deposited material, inhalation and ingestion).

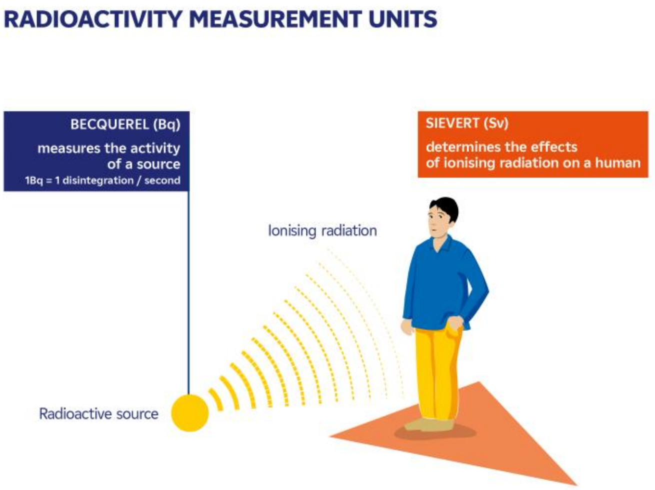
In order to obtain a more comprehensive understanding of the impact of radioactive discharges on humans and the environment, the dose calculations are supplemented by an assessment of the distance below which contamination of food items (milk and vegetables in particular) exceeds the limits for marketed foods (Maximum Permissible Levels or MPLs) in force in the European Union.

All these dose assessments take into account uncertainties in knowledge. No gaps in knowledge have emerged that would prevent a relevant determination of these doses, the main results of which are presented below.

6.1.2. Requirements governing results

The reference values for radiological consequences are as follows:

- Category 1 – normal operation: compliance with the dose limits set by the Public Health Code. Compliance with these values is guaranteed by compliance with the radioactive discharge limits specified in the decisions of the Authority for Nuclear Safety and Radiation Protection.
- Category 2 – incidents with a moderate frequency of occurrence: compliance with the NPP's authorisations for annual discharges for each of the category-2 incidents. The effects of these discharges do not exceed 1 mSv/yr of effective dose at the site boundary.
- Category 3 (accidents with a very low frequency of occurrence): short-term effective dose < 10 mSv.
- Category 4 (hypothetical accidents): short-term effective dose < 50 mSv.
- Beyond design basis: short-term effective dose < 50 mSv.



Only the two most commonly used units are shown here:

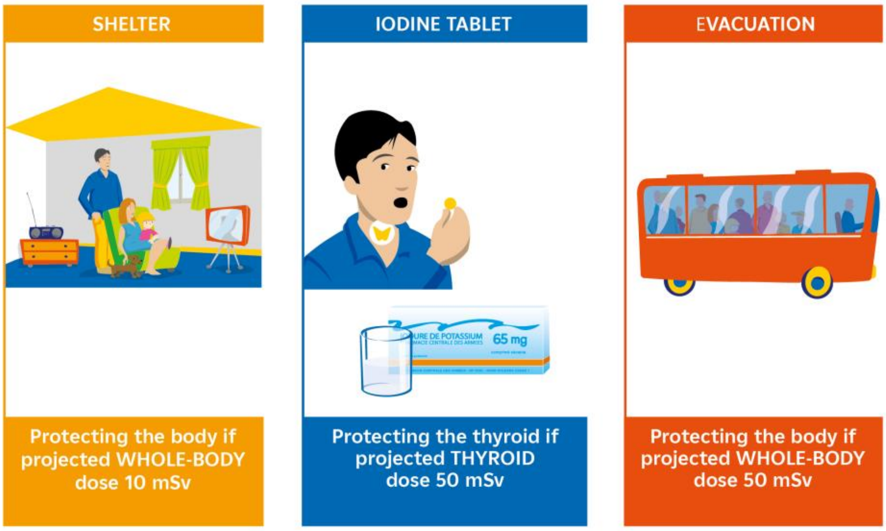
- **The Becquerel (Bq)** measures the activity of a radioactive source, in other words, the number of disintegrations per second. It is an extremely small unit: granite, for example, has an activity per unit mass of 1,000 Bq/kg.
- **The Sievert (Sv)** determines the effects of ionising radiation on humans. Exposure is generally expressed in millisieverts (mSv) or microsieverts (µSv).

To illustrate: in France, an individual's exposure to natural radioactivity averages 3 mSv per year.

In terms of **continuous improvement**, the objectives of the 4th periodic review are to move towards enhanced safety features that eliminate the need for population protection measures (shelter, evacuation, administration of stable iodine) for all design basis or beyond-design-basis accidents. The results are therefore compared with reference values that are aligned with the intervention levels in a radiological emergency:

- an effective dose of 10 mSv for sheltering;
- an effective dose of 50 mSv for evacuation;

a thyroid equivalent dose of 50 mSv for the administration of stable iodine.

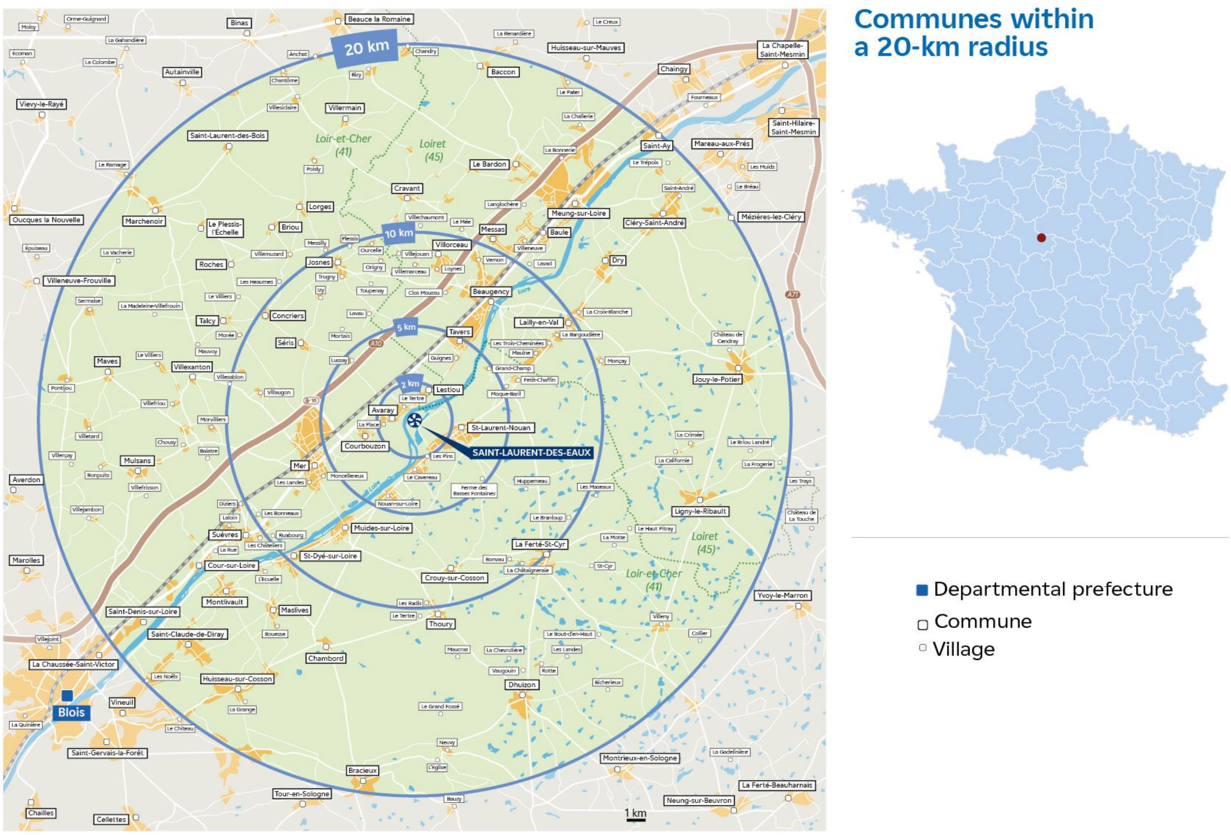


As regards the **long-term total effective doses** resulting from accidents, the reference value adopted is the dose limit specified in the Labour Code, that is to say, 1 Sv (limit for the total effective dose received by a worker over a lifetime in the event of a radiological emergency, Article R4451-9).

6.2. Radiological consequences

The map below shows the areas covered by the distances mentioned in this section.

SAINT-LAURENT-DES-EAUX NUCLEAR POWER PLANT (LOIR-ET-CHER)



6.2.1. Radiological consequences of design-basis accidents

Results for category-2 incidents

Category-2 incidents correspond to initiating events with a moderate annual frequency of occurrence during the lifetime of the plant (1 incident per 100 years of operation at most), which lead to the activation of a protection system. In these scenarios, the integrity of the containment barriers is guaranteed.

The total effective doses and short-term thyroid equivalent doses for the most radiation-sensitive populations at a distance of 650 m (the closest residential housing in the fleet of 900 MWe series plants) are of the order of a few tens of µSv, so well below the category-2 reference value. The short-term results of studies of the radiological consequences of category-2 accidents are summarised below for the bounding scenarios in this category:

	Short-term total effective dose (mSv)
Reference values	1 mSv
Total loss of off-site power	$5.0\ 10^{-4}$ mSv
Inadvertent opening of a secondary-side relief valve or steam line break	$1.5\ 10^{-3}$ mSv

For category-2 incidents, the total effective dose for populations in the closest residential housing in the fleet of 900 MWe series plants is limited to 5.3×10^{-2} mSv/year.

Results for category-3 accidents

Category-3 accidents correspond to initiating events with a low annual frequency of occurrence during the lifetime of the plant (1 accident per 100 to 10,000 years of operation), which may cause limited damage to a small percentage of the fuel assemblies. The geometry of the core is preserved, ensuring continued core cooling. The integrity of the containment building is preserved; only the rupture of a steam generator tube leads to bypass of the 3rd barrier.

The short-term radiological consequences of these category-3 accidents for the most radiation-sensitive populations at a distance of 650 m (the closest residential housing in the fleet of 900 MWe series plants) are as follows:

	Total effective dose (mSv)	Thyroid equivalent dose (mSv)
Reference values	10 mSv	50 mSv
Loss of coolant (small-diameter break less than or equal to 25 mm)	$5.7\ 10^{-3}$ mSv	$1.0\ 10^{-1}$ mSv
Withdrawal of only one power control rod	$9.1\ 10^{-1}$ mSv	6.9 mSv
Failure of the chemical and volume control system tank	$3.1\ 10^{-2}$ mSv	$3.0\ 10^{-4}$ mSv
Failure of the gaseous effluent storage tank	$1.9\ 10^{-1}$ mSv	$2.0\ 10^{-2}$ mSv
Steam generator tube rupture (SGTR)	$8.9\ 10^{-1}$ mSv	7.9 mSv

In addition, the long-term radiological consequences over a period of 50 years after the accident are assessed for adults 2 km from the point of release. The doses obtained for the worst-case category-3 accident comply with the reference values: in the event of a category-3 steam generator tube rupture, the total effective dose is estimated at approximately 4 mSv.

Results for category-4 accidents

Category-4 accidents involved hypothetical initiating events (1 accident per 10,000 to 1,000,000 years of operation). These accidents represent the bounding design-basis accidents that could lead to fuel assembly damage. However, the geometry of the core is not damaged, so core cooling remains adequately ensured, and the systems designed to limit the consequences of the accident remain operable.

The short-term radiological consequences of these accidents for the most radiation-sensitive populations at a distance of 650 m (the closest residential housing in the fleet of 900 MWe series plants) are the following:

	Total effective dose (mSv)	Thyroid equivalent dose (mSv)
Reference values	50 mSv	50 mSv
Fuel handling accident	2.6 mSv	1.3 mSv
Major steam line break	$2.0\ 10^{-2}$ mSv	$1.4\ 10^{-1}$ mSv
Blocked rotor on a reactor coolant pump	$4.0\ 10^{-1}$ mSv	3.6 mSv
Control rod ejection	1.2 mSv	10 mSv
Steam generator tube rupture combined with a relief valve stuck in the open position blocked open (category-4 SGTR)	7.2 mSv	100 mSv
Loss of coolant accident (LOCA)	3.5 mSv	35 mSv

The steam generator tube rupture accident leads to a thyroid equivalent dose of less than 50 mSv for populations beyond a 1-km radius. Risk control measures were taken to limit overshooting the reference value for the equivalent thyroid dose. These included lowering the reactor coolant radioactivity limit and modifying the accident management procedure (see Section 6.3.1).

In addition, the long-term radiological consequences over a period of 50 years after the accident are assessed for adults 2 km from the point of release. The doses obtained for the most severe category-4 accident comply with the reference values: in the event of a category-4 SGTR, the total effective dose is estimated at less than 30 mSv for the whole body.

Conclusions for design-basis scenarios

For category-2 accidents, the radiological consequences are low for populations in the closest residential housing (with a short-term effective dose well below 1 mSv).

For category-2 accidents, the contamination of food intended for human consumption does not exceed the thresholds for marketed foods beyond a 1-km radius, and is below this threshold after one year.

The objectives for the radiological consequences of category 3 and 4 accidents are met. The outcomes of the category-4 SGTR have been improved by risk control measures, in response to the exceeded reference value observed for the equivalent thyroid dose within a 1-km radius of the reactors in this scenario. The risk control measures are presented in Section 6.3.1.

For category-3 and -4 conditions, only the category-4 SGTR scenario leads to food contamination exceeding the thresholds for marketed foods, beyond a 10-km radius, after 7 days. This situation would be limited in terms of duration: after two years, regardless of the accident considered, the Maximum Permissible Levels would no longer be exceeded.

- ***Transboundary effects of design-basis accidents***

Given the distances associated with the estimated effects detailed above, it is considered that a design-basis accident would have no particular impact on neighbouring countries, neither in the short term, nor in the long-term due to cumulative effects over time.

6.2.2. Radiological consequences of beyond-design-basis accidents

Beyond-design-basis accident studies were not provided for at the time of the initial design of the Saint-Laurent reactors. These studies analyse scenarios involving combinations of independent failures that are considered to be plausible, but very rare (with a return period of 1 in ~5,000,000 years of operation). The scenarios are categorised by frequency of occurrence, established using probabilistic safety assessments (PSA). In order to safeguard against these situations involving combined failures, beyond-design-basis provisions are defined, along with safety requirements, with a focus on guaranteeing functional operability and thus reducing the frequency of occurrence of this scenario. This approach has identified more than 30 improvement measures that were not included in the initial design.

The studies of the radiological consequences of beyond-design-basis accidents aim to demonstrate that the installation meets the highest levels of nuclear safety, and to verify that the radiological consequences of these accidents, taking into account their frequency of occurrence, comply with the reference values for category-4 design basis accidents.

The calculations of the radiological consequences of beyond-design-basis accidents focus on demonstrating that, taking into account the implementation of the beyond-design-basis provisions that were established, the release of radioactive material outside the power plant has limited consequences for the public and the environment.

The results of the studies of the radiological consequences of beyond-design-basis accidents are summarised below. The radiological consequences of accidents that are not listed are bounded by those that are presented.

The short-term radiological consequences of these accidents for the most radiation-sensitive populations at a distance of 650 m (the closest residential housing in the fleet of 900 MWe series plants) are as follows:

	Total effective dose (mSv)	Thyroid equivalent dose (mSv)
Reference values	50 mSv	50 mSv
Loss of RHR in reactor shutdown states	$2.3\ 10^{-1}$ mSv	3.8 mSv
Loss of spent fuel cooling	$8.5\ 10^{-3}$ mSv	$1.5\ 10^{-1}$ mSv
Total loss of off-site power (LOOP) or loss of emergency-supplied 6.6 kV AC distribution switchboards	$3.6\ 10^{-2}$ mSv	$2.2\ 10^{-1}$ mSv

In addition, the long-term radiological consequences over a period of 50 years after the accident are assessed for adults 2 km from the point of release. The doses obtained for the worst-case beyond-design-basis accident comply with the reference values: in the event of a loss of residual heat removal in reactor shutdown states, the total effective dose is estimated at less than 1.0 mSv to the whole body.

The doses obtained comply with the reference values for beyond-design-basis accidents, and no population protection measures are necessary.

For beyond-design-basis scenarios, the contamination of food intended for human consumption does not exceed the thresholds for marketed foods beyond a 5-km radius, after 7 days, and is limited to a 1-km radius after one year.

- ***Transboundary effects of beyond-design-basis accidents***

Given the distances associated with the estimated effects detailed above, it is considered that a beyond-design-basis accident would have no particular impact on neighbouring states, neither in the short term, nor in the long-term due to cumulative effects over time.

6.2.3. Radiological consequences of hypothetical core-melt accidents

The measures taken during the initial design of the reactor and those applied during plant operation, and in particular during periodic reviews (see Section 6.3.4), make the occurrence of a core-melt accident highly unlikely, given that it would require the failure of the preventive measures implemented. Nevertheless, the consequences of such a 'hypothetical core-melt accident' are analysed in relation to levels 4 and 5 of the concept of defence-in-depth (see Section 4.2.1). These studies postulate that an accident with core meltdown has occurred, i.e. that a sequence of events has led to at least partial core meltdown and that, beyond the loss of the first barrier (the fuel rods), it could lead to the loss of the second barrier (the primary circuit, including the reactor vessel).

Core-melt phenomena linked to the loss of the first two containment barriers

An extended loss of reactor core cooling can lead to core-melt accidents if there is no water in the reactor vessel. The fuel in the vessel could reach temperatures that would cause the metal it contains to melt (pellets and cladding), as well as surrounding metal (control rod assemblies or structures), until the bottom of the vessel is breached.

The liquid mixture of metals and materials formed during this process is called **corium.**

Core-melt accidents involve complex physical phenomena and may lead to the release of radioactive substances into the environment. Among other things, certain physical phenomena in these conditions could, in the absence of appropriate provisions, lead to the degradation of the integrity of the third barrier.

The releases that may result from these core-melt accidents will be determined by a large number of parameters, including the fission product inventory in the core, the release kinetics of radionuclides in the containment, their state (gaseous or aerosol form), their behaviour inside the containment (agglomeration, chemical reaction, deposition), and the leakage rates to the environment. The calculation of activity released during a core-melt accident is based on a set of parameters that determine the worst-case outcomes for discharges to the environment and total core meltdown. Margins are therefore applied, thereby ensuring that the calculations factor in the worst-case assumptions.

The **short-term** radiological consequences (after 7 days) of these accidents for the most radiation-sensitive populations are as follows:

Total effective dose, at a distance of 2 km (mSv)	Total effective dose, at a distance of 5 km (mSv)	Thyroid equivalent dose, at a distance of 10 km (mSv)
28.5 mSv	4.7 mSv	13.4 mSv

In view of the population protection thresholds (see Section 6.1.2), these results show that for such a core-melt accident, after 7 days, population protection measures are not necessary beyond a 2 km radius as regards evacuation, beyond a 5 km radius as regards shelter, and beyond a 10 km radius as regards stable iodine intake.

Furthermore, the **long-term** radiological consequences over a period of 50 years after the accident, assessed for adults 10 km from the point of release, are 18.7 mSv.

Finally, in the extreme event of a core-melt accident, calculations show that the design-basis measures taken to reduce environmental impacts (see Section 6.3.4) limit the degree of contamination of agricultural land, in terms of both scope and duration (to within a 20-km radius after 1 year).

Transboundary effects of core-melt accidents

The transboundary effects associated with the atmospheric dispersion of radioactive material must be assessed in terms of the country-specific radiological consequences, expressed as total effective dose (or whole-body dose), over the long term (50 years), for both children and adults. The table below illustrates these effects for countries up to 1,000 km from Saint-Laurent NPP, showing the worst-case results for each country.

These calculations of the long-range atmospheric dispersion of Saint-Laurent NPP emissions are based on air diffusion coefficients derived from meteorological observations over a period of 5 years. These coefficients factor in topography, meteorological conditions (mainly wind), and the depletion of concentrations through deposition processes as the distance from the source increases.

		Bounding long-term total effective dose (mSv)			
Country	Minimum distance from the source (km)	Very young child age bracket [1-2[	Young child age bracket [2-7[	Child age bracket [7-12[	Adult age bracket [17+[
Belgium	310	0.21	0.22	0,20	0.20
United Kingdom	345	0.10	0.10	0.09	0.08
Switzerland	365	0.16	0.16	0.14	0.14
Luxembourg	370	0.18	0.19	0.17	0.19
Germany	440	0.09	0.09	0.08	0.08
The Netherlands	450	0.13	0.13	0.12	0.12
Italy	450	0.04	0.04	0.04	0.03
Spain	545	0.04	0.04	0.04	0.04
Liechtenstein[20]	595	0.05	0.05	0.04	0.04
Austria	600	0.05	0.05	0.05	0.05
Ireland	750	0.05	0.05	0.04	0.04
Czech Republic	815	0.03	0.04	0.03	0.03
Slovenia	905	0.02	0.02	0.02	0.02
Portugal	915	0.01	0.01	0.01	0.01
Croatia	940	0.01	0.01	0.01	0.01
Denmark	950	0.04	0.04	0.04	0.04

By way of comparison, an individual's exposure to natural radioactivity in France averages 3.0 mSv per year. The European average is 3.2 mSv per year, varying between 1.5 and 6.2 mSv per year depending on the country.

The bounding dose value is obtained for Belgium and corresponds to around 0.22 mSv over 50 years for a very young child and a young child. In comparison, natural radioactivity in Belgium is 2.7 mSv per year.

As radiation doses decrease with distance, the radiological consequences would therefore be less significant for countries further away than those listed above.

Given the above results, in the event of a core-melt accident involving one of the two 900 MWe reactors at Saint-Laurent NPP, the transboundary effects associated with the atmospheric dispersion of radioactive material would be very limited, and even negligible, both in the short term, and in the long-term due to cumulative effects over time.

[20] The figures for Liechtenstein are interpolated from the results for Switzerland and Austria.

6.3. Radiological risk control measures

In accordance with the fundamental principle of nuclear safety set out in Section 4.2.1, the facility was designed with numerous provisions in place to reduce the risks associated with radiological impacts. These design provisions were supplemented by additional provisions aimed at reducing the risk of certain accidents linked to combined failures. The Saint-Laurent reactors have already undergone several periodic reviews, underpinned by operating experience feedback and continuous improvement measures, which have strengthened these provisions directed at maintaining the reactor in a safe condition.

The 4th periodic review specifies multiple provisions for radiological risk control, taking into consideration the ambitious objectives set by EDF and established by ASN in the course of drawing up these objectives (see Section 1.2 and Section 2.3.1).

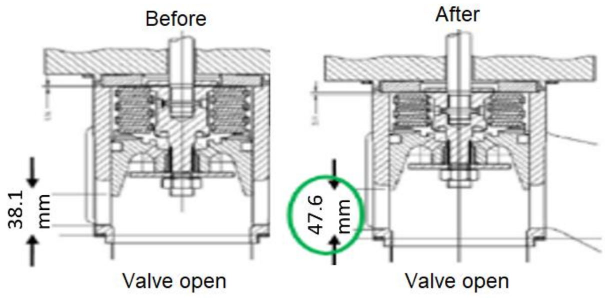
6.3.1. Main measures for non-core-melt accidents

The main operating and/or design provisions of the 4th periodic review of Saint-Laurent NPP, contributing to the objective of minimising the radiological consequences of non-core-meltdown accidents, are the following:

- Increased flow rate in atmopheric steam discharge valves.

Description of the provision

In accident conditions, in order to limit the duration of the accident and minimise potential associated radioactive releases, the discharge capacity of the turbine bypass system's atmospheric discharge valves (ASDV) is increased for faster reactor cooling. The internals of the ASDV have been modified.



Basic principle

The turbine bypass system [GCTa] discharges the steam produced by the steam generators directly to the atmosphere; it controls reactor cooling by the steam generators when there is not enough steam to drive the turbine or when the turbine is unavailable. It is therefore used at every shutdown and start-up. It is also used to cool the reactor in incident or accident conditions.

- Lower activity limit for primary circuit water.

Description of the provision

The technical specifications for operation of the Saint-Laurent reactors include a reduction from 150 to 80 GBq/t in the iodine-131-equivalent activity limit of primary circuit water during power transients in normal operation. The aim is to operate the reactors with improved contamination control of primary system water in order to reduce, in particular, the radiological consequences of a category-4 SGTR accident.

This provision reduces the activity levels of any radioactive releases and their radiological impacts (in terms of the effective dose and thyroid equivalent dose in the short term, and in terms of the effective dose in the medium-to-long term) for all accidents without fuel cladding failure, including the worst-case scenario of a steam generator tube rupture.

Basic principle

The water in the primary circuit has a low level of activity owing to the technological limitations of the fuel cladding design. The contamination control requirements governing the primary circuit also ensure that fuel assembly integrity is monitored.

- Modified procedure for a category-4 SGTR accident.

Description of the provision

EDF has amended the procedure for a category-4 SGTR transient, with a view to improving the conditions for shutting down the safety injection system. This modification, which also complies with an ASN requirement based on the conclusions of the generic phase of the 4th review, reduces the volume of liquid discharges by several dozen cubic metres in the Safety Report's study of a category-4 SGTR.

In addition, measures have already been implemented to limit the volume of liquid discharges:

- Automatic isolation of makeup from the auxiliary feedwater system (AFWS) [ASG] to the failed steam generator, thus preventing an increased risk of liquid discharges.
- Draining of the failed steam generator by the control room operator, using the steam generator blowdown system (SGBS) [APG].

Basic principle

The safety injection system is a primary circuit makeup water system, designed to compensate for water losses in the event of a steam generator tube rupture or loss of coolant accident. It generally starts up automatically. It is stopped by the control room operator, based on criteria indicating effective control of primary system inventory.

- Deployment of the HSC-CSS instead of the SIS/CSS.

Description of the provision

In the event of a failure of the safety injection system / containment spray system (SIS/CSS) [RIS/EAS] used for managing a loss of coolant accident (LOCA), the backup Hardened Safety Core containment spray system (HSC-CSS) [EAS-ND] maintains primary system inventory and thus avoids the discharges associated with a core-melt accident. The radiological consequences of a so-called 'H4' event (category-4 beyond-design-basis event: LOCA with failure of the SIS or CSS in recirculation mode) have been improved and brought more closely in line with those of a LOCA initiating event, as considered in the design-basis (see Section 6.2).

The operating requirements have been adapted to credit this additional provision.

Basic principle

The HSC-CSS [EAS-ND] is one of the new Hardened Safety Core systems installed for the management of extreme external hazard scenarios (see Section 6.3.2).

6.3.2. Main measures for hazards

The hazards that are considered are those specified in the regulations governing basic nuclear installations ("arrêté INB"):

- Internal hazards: fire, explosion, flooding, pressurised equipment failure, load collision or drop, electromagnetic interference, emissions of hazardous substances, malicious acts;
- External hazards (natural or man-made): earthquakes, extreme weather or climate conditions (flooding, snow, heatwaves, extreme cold, high winds, tornadoes), hazards arising from watercourses or the sea (frasil, ice encasement, clogging, oil slicks, siltation, low water levels, flooding), lightning. tornadoes), damage caused by rivers or the sea (frasil, barrier ice formation, clogging agents, oil slicks, silting, low water levels, flooding), lightning and electromagnetic interference, fire, industrial risks in the vicinity of the plant (explosion, hazardous substances), accidental aircraft crashes, malicious acts.

The operating and/or design provisions of the 4th periodic review of Saint-Laurent NPP, contributing to the objective of minimising the radiological consequences of hazard-related accidents, aim to ensure that the systems fulfilling the three safety functions (control of the nuclear chain reaction inside the reactor, cooling of fuel, and containment of radioactive substances) remain available to maintain the reactor in a safe state in the event of a hazard condition. These are primarily measures to protect or strengthen systems in relation to hazard conditions. These provisions therefore mainly contribute to reducing the risks associated with the consequences of core meltdown, the environmental impacts of which are specified in Section 6.2.3.

As an example, the provisions for fire, which is the main industrial hazard, are specified below.

Fire

The fire protection measures are designed to improve the fire resistance of elements of compartmentation:

Description of the provision

The proposed measures improve the fire resistance of certain components (fire doors, fire compartmentation elements, electrical cable fire protection, etc.) or reduce the size or intensity of a potential fire. These provisions include replacing fire compartmentation elements (e.g. fire doors) with elements that have a higher fire resistance rating. They also include protecting cables with firesleeving and reducing fire loads. All these fire safety measures help rule out a reactor core meltdown and the potential releases associated with certain fires.

Basic principle

Compartmentation consists in defining areas or sectors so that a fire in one compartment remains contained within that compartment, thus preventing a spead of fire that may compromise the principle of safety function redundancy.

Extreme external hazard conditions

Furthermore, as part of the periodic review of Saint-Laurent NPP, the deployment of the Hardened Safety Core measures ensures that the installation is able to withstand extreme external natural hazards which, for the purposes of the safety case, go beyond the requirements established up to now.

The Hardened Safety Core is a set of robust fixed equipment supplemented by mobile equipment, designed to prevent large radioactive releases and long-term environmental impacts in extreme conditions following an extreme external natural hazard event. Such events mainly include earthquakes, external flooding and associated phenomena (lightning, hail, high winds, heavy rains), and tornadoes.

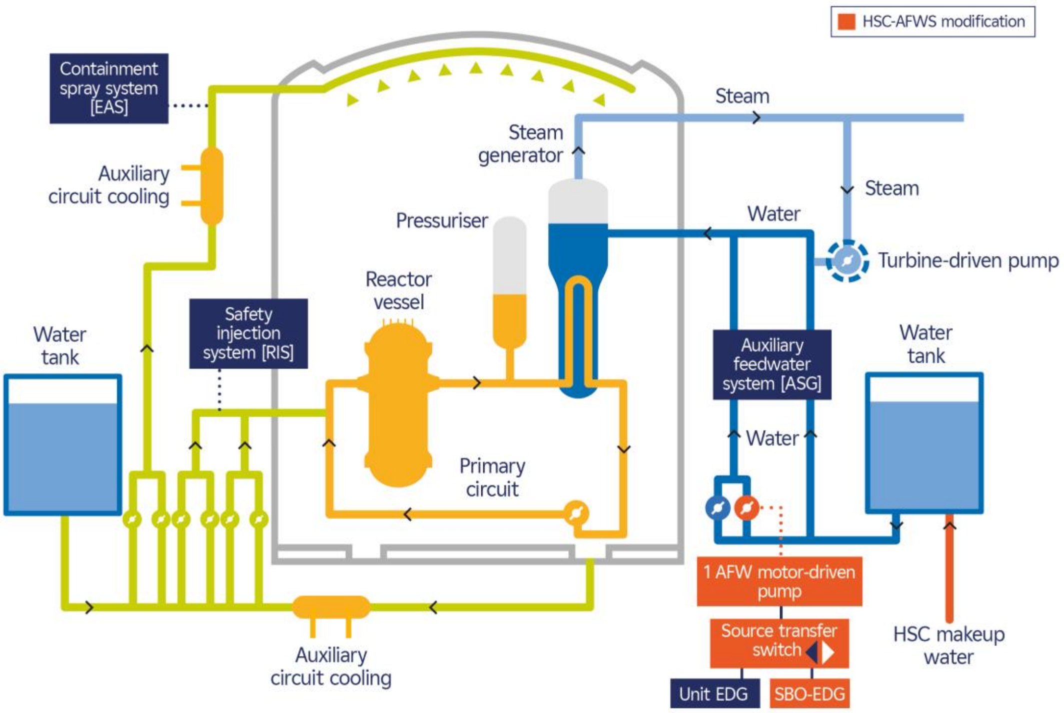
In order for the Saint-Laurent reactors to be able to withstand these extreme conditions, new water and power supplies have been installed, which are hazard-resistant, diversified and separate from existing systems:

- an additional power source: **the ultimate emergency diesel generator (SBO-EDG) [DUS]**,
- a diversified source of water [SEG].

3-MWe station blackout diesel generators [DUS]

Diversified source of water [SEG]

As regards the reactor, these extreme conditions can lead to loss of operability for certain equipment, such as the equipment linked to power sources and/or to cooling systems associated with the heat sink (the Loire River).
In such cases, the Hardened Safety Core equipment continues to fulfil the safety functions: part of the auxiliary feedwater system (backup water supply to the steam generators) is qualified for and resilient to the consequences of these extreme conditions, in order to fulfil the function of **Hardened Safety Core secondary cooling (HSC-AFWS) [ASG-ND]**. Power is supplied by the **ultimate emergency diesel generator (SBO-EDG) [DUS]**, via a dedicated power supply switchover panel installed as part of the provision, backed by the **diversified source of water [SEG]**, which then operates as a substitute heat sink.
All this equipment helps to prevent reactor core meltdown, and the potential releases associated with these extreme conditions.



Working principle of the HSC-AFWS

6.3.3. Main measures for fuel assembly storage

The main operating and/or design provisions of the 4th periodic review of Saint-Laurent NPP, contributing to the objective of minimising the radiological consequences of accidents related to the storage of fuel assemblies in the fuel building are as follows:

Fire

In the event of a fire, and in order to prevent the loss of the two cooling trains, EDF has made provision for the installation of flame-arrestors that will rule out the risk of a fire spreading from one cooling system pump to the other.

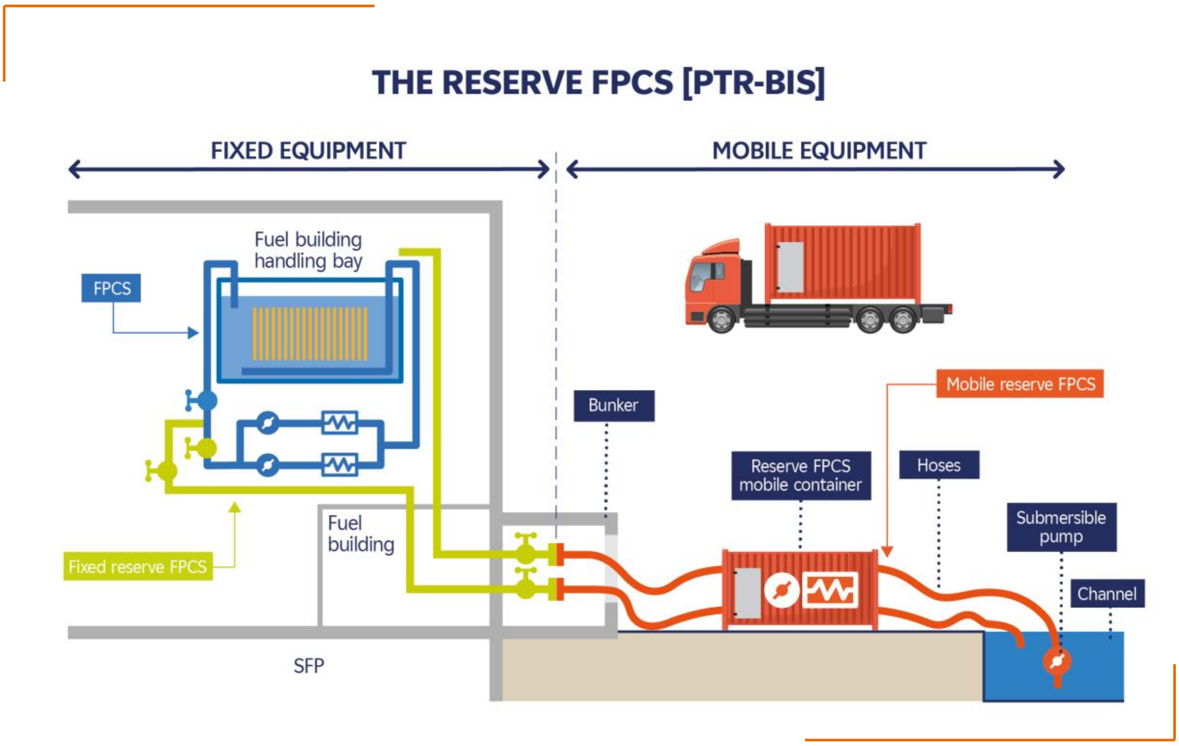
Review of 900 MWe series plants in consideration of FLA3 EPR accident conditions

The assessment of the behaviour of the spent fuel pools in 900 MWe power plants, including for the Saint-Laurent reactors, in relation to the accident scenarios selected for the Flamanville 3 EPR and not taken into account in the initial design, has demonstrated their current high level of robustness. In order to further enhance this robustness, a proposal has been made to install a second automatic isolation valve on the suction line of the spent fuel pool's normal cooling system.

Extreme external hazard conditions

As regards fuel storage, these extreme conditions can lead to loss of operability of certain equipment, potentially associated with a total loss of cooling. It is the Hardened Safety Core equipment, qualified for and resilient to the consequences of these extreme events, that then continues to fulfil the safety functions. In these extreme conditions:

- the **diversified source of water [SEG]** provides a backup for the reactor cavity and spent fuel pool makeup water systems. This makeup compensates for evaporation and ensures continued cooling of the fuel assemblies by keeping them submerged;
- in the longer term, the **reserve fuel pool cooling system (reserve FPCS) [PTR-bis]** restores spent fuel pool cooling and stops boiling.



6.3.4. Main measures for core-melt accidents

The main operating and/or design provisions of the 4th periodic review of Saint-Laurent NPP, contributing to the objective of minimising the radiological consequences of core-melt accidents, are based on a design approach focused on these accidents and drawing on the design of the EPR. In this scenario, the first two containment barriers are considered to be damaged, and the safety objective is therefore to maintain the integrity of the third barrier, the containment building, so as to prevent the release of radioactive material into the environment.

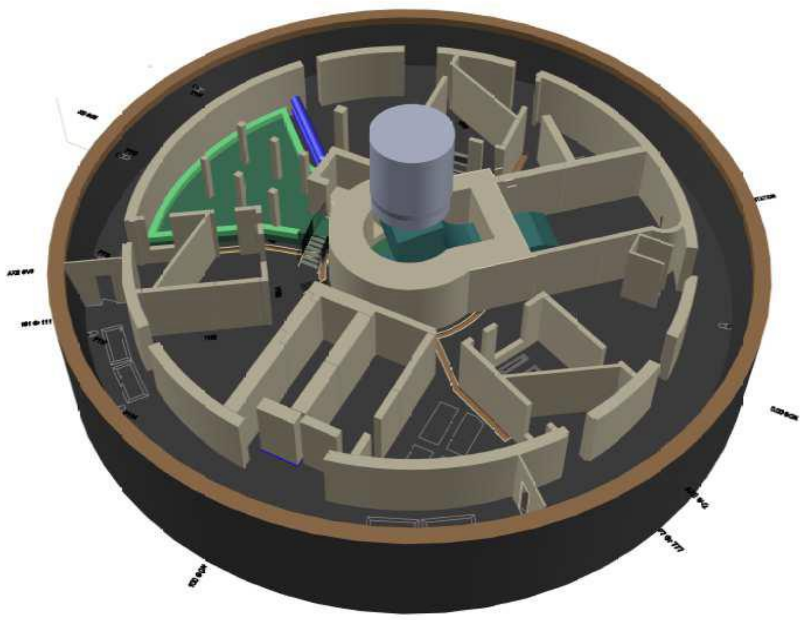
The management of core-melt accidents provides for the ‘dry-spreading’ of the corium, i.e. without water, at the bottom of the reactor building, the basemat. Spread out in this way, the layer of corium presents a large exchange surface and can be stabilised by the injection of borated water, which will cool it down and allow it to eventually solidify. This strategy makes it possible to:

- ensure that the reactor building's basemat is not breached by melt-through. If it is not stabilised, the corium can cause basemat erosion;
- limit slow pressurisation of the containment building, and thus prevent the opening of the filtered vent for depressurisation;
- control the physical effects of a core-melt accident (the risk of hydrogen combustion in particular).

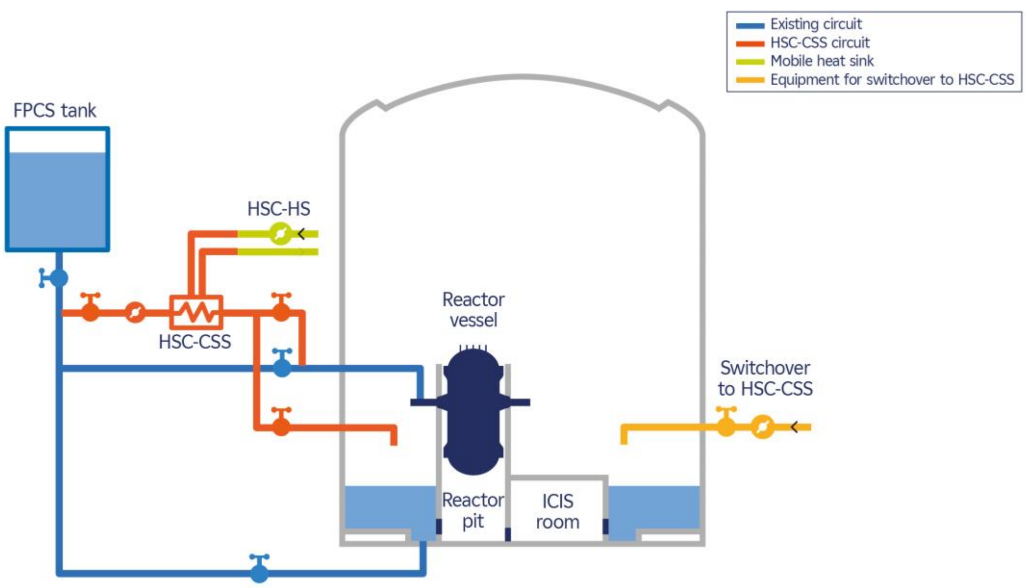
Thus, the measures implemented for the management of a core-melt accident in a Saint-Laurent reactor are the following:

- **The creation of a corium dry-spreading compartment** within a core catcher zone located underneath the reactor vessel: the ‘vessel pit’ area and the adjacent core instrumentation room.
- **The installation of a corium passive flooding system** consisting of a system of passive traps releasing the water previously injected into the reactor building sumps by the SIS, emergency-supplied by the two emergency diesel generators or, in extreme hazard events, by the new HSC-CSS emergency-supplied by the SBO-EDG.
- **The installation of a corium cooling system**, connected to the HSC-CSS, which provides residual heat removal from the corium without opening the containment building's depressurisation filter.
- HSC-CSS reinjection into the reactor building of water from potential leaks, collected in sumps.
- **Decontamination of the reactor building water** using a mobile contaminated water treatment unit.

Spaces used for the corium spreading strategy
(reactor pit and in-core instrumentation system room)



CORE-MELT ACCIDENT COOLING

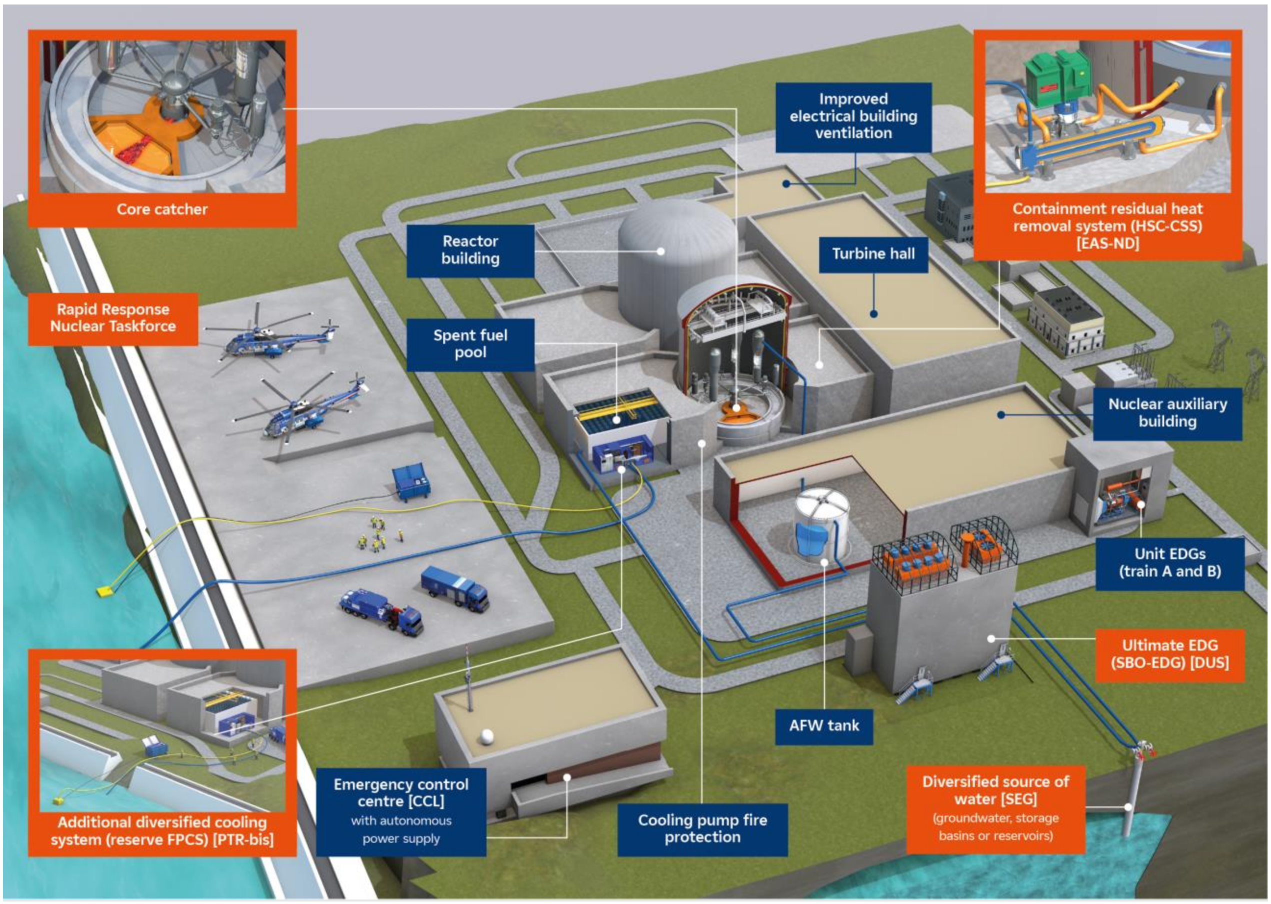


The HSC-CSS [EAS-ND] involves the deployment of:

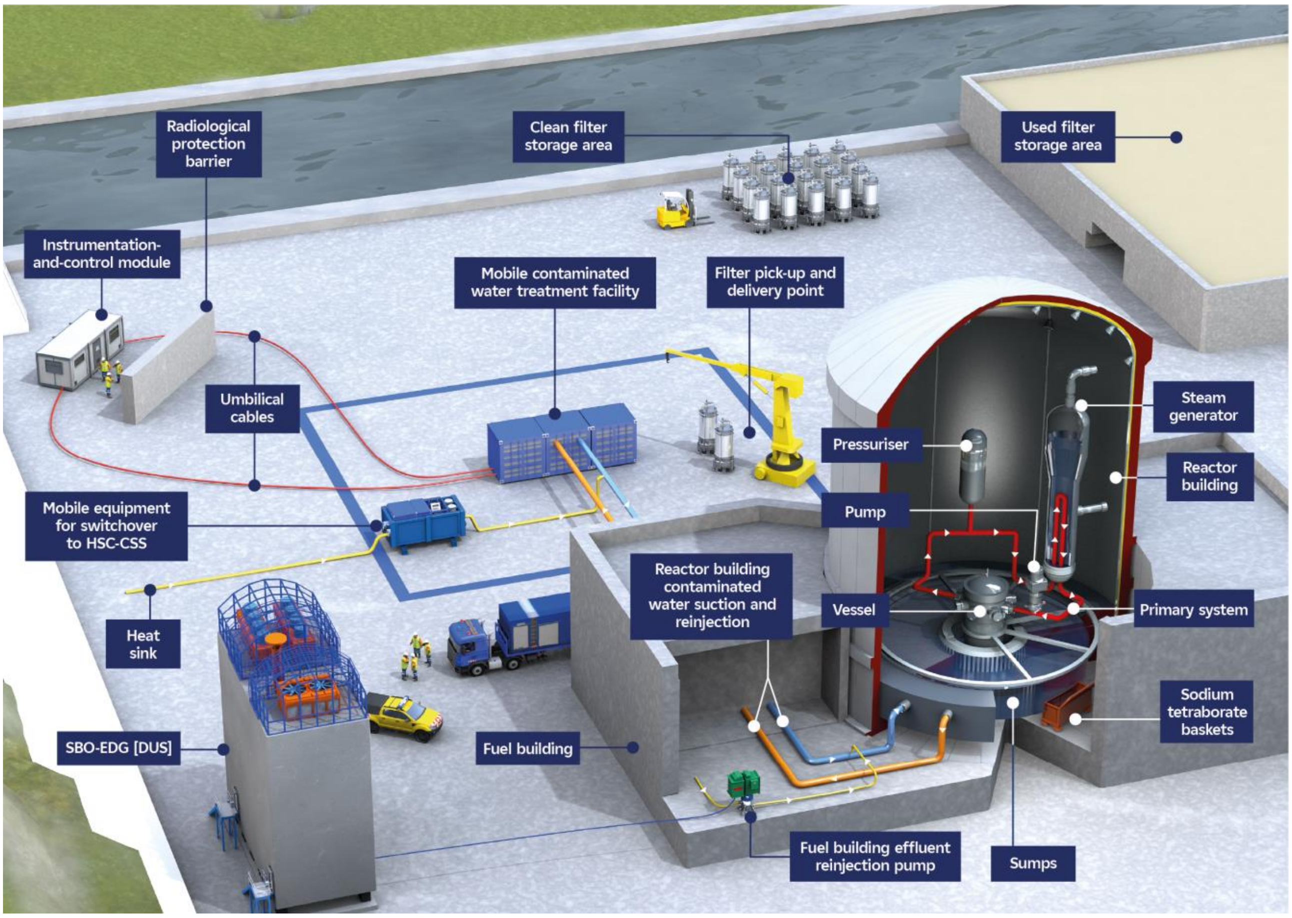
- a pump (powered by the SBO-EDG),
- an exchanger, to remove heat from the containment,
- a Hardened Safety Core heat sink (HSC-HS) [SF-ND], made up of mobile pumping equipment.

The mobile Hardened Safety Core equipment is operated by the **Rapid Response Nuclear Taskforce (FARN)**. Set up in response to the operating experience from the accident at the Fukushima Daiichi Nuclear Power Plant, the Taskforce is made up of 300 trained EDF personnel, ready for deployment to any French nuclear site requiring assistance, within 24 hours of the onset of an accident.

Main Hardened Safety Core measures



Post-core-melt-accident decontamination of reactor building water



7. ENVIRONMENTAL MONITORING

Saint-Laurent NPP, Loir-et-Cher Department
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7.1. Monitoring measures for normal operation

EDF has various environmental monitoring programmes in place. Since no significant changes are expected in the next ten years in relation to the impacts of Saint-Laurent NPP on the protected interests, environmental monitoring programmes will continue as they are today. The monitoring measures are described below.

Air and climate factors

The site's chemical effluent discharges to the atmosphere are estimated annually and included in its annual environmental report:

- emissions of sulphur oxides, calculated in particular on the basis of emergency diesel generator fuel-oil consumption, the type of fuel-oil used, the type of equipment, and operating conditions;
- emissions of formaldehyde and carbon monoxide, linked to insulation replacement operations, and determined from the volumes of new insulation installed during reactor outages;
- emissions of volatile substances related to secondary circuit conditioning operations (ethanolamine, ammonia);
- diffuse emissions of refrigerants and SF_6, quantified during maintenance operations in these installations.

Saint-Laurent NPP also has a weather monitoring programme, collecting observations from an automatic station (for temperature and rainfall metrics) as well as from 10-m-high and 100-m-high weather masts for wind direction and speed measurements.

Examples of rainfall, temperature and wind measurement equipment ©EDF

Surface water

Saint-Laurent NPP runs:

- a programme monitoring its surface water abstraction and consumption levels;
- a programme monitoring its liquid chemical discharges;
- a programme monitoring its thermal discharges;
- a hydrological monitoring programme;
- a programme for the continuous physico-chemical monitoring of surface water, using several autonomous multi-parameter measuring stations to track four physico-chemical parameters for water: temperature, pH, conductivity, and dissolved oxygen content;

© EDF – Liquid effluent analysis

- a programme for chemical, physico-chemical and biological monitoring of surface water, covering both chemical monitoring and hydroecological monitoring (analysing physico-chemical parameters and hydrobiological compartments):
  - for chemical monitoring, the objective is to determine the concentration in the water of chemical substances discharged by the power plant;
  - for hydroecological monitoring, the objective is to track the natural changes in the receiving environment in order to detect any abnormal changes that may be caused by plant operations. It covers physico-chemical parameters (temperature, pH, dissolved oxygen, conductivity, eutrophication and mineralisation parameters, etc.), as well as biological parameters (ichtjyofauna, phytoplankton, benthic diatoms, zooplancton, benthic macrophytes and macroinvertebrates);
- a programme for monitoring the aquatic environment, in relation to dredging operations.

Soil and surface water

Saint-Laurent NPP has implemented a programme for monitoring the chemical and radiological quality of groundwater, with the aim of detecting any potential water table contamination linked to plant operation.
The power plant makes use of a network of groundwater-monitoring piezometers sited both inside and outside the engineered confinement structures. Groundwater sampling and analysis is performed in accordance with certified standard NF EN ISO/IEC17025:2017.
A number of measures have also been put in place to calculate the volumes of abstracted groundwater and to ensure compliance with permissible regulatory limits.

Radioecology

Saint-Laurent NPP runs a programme for monitoring liquid effluent discharges and effluent discharges to atmosphere, thus ensuring alignment between planned discharges and tracked parameters.

The radioactive discharges to atmosphere from Saint-Laurent B are measured at the following points:

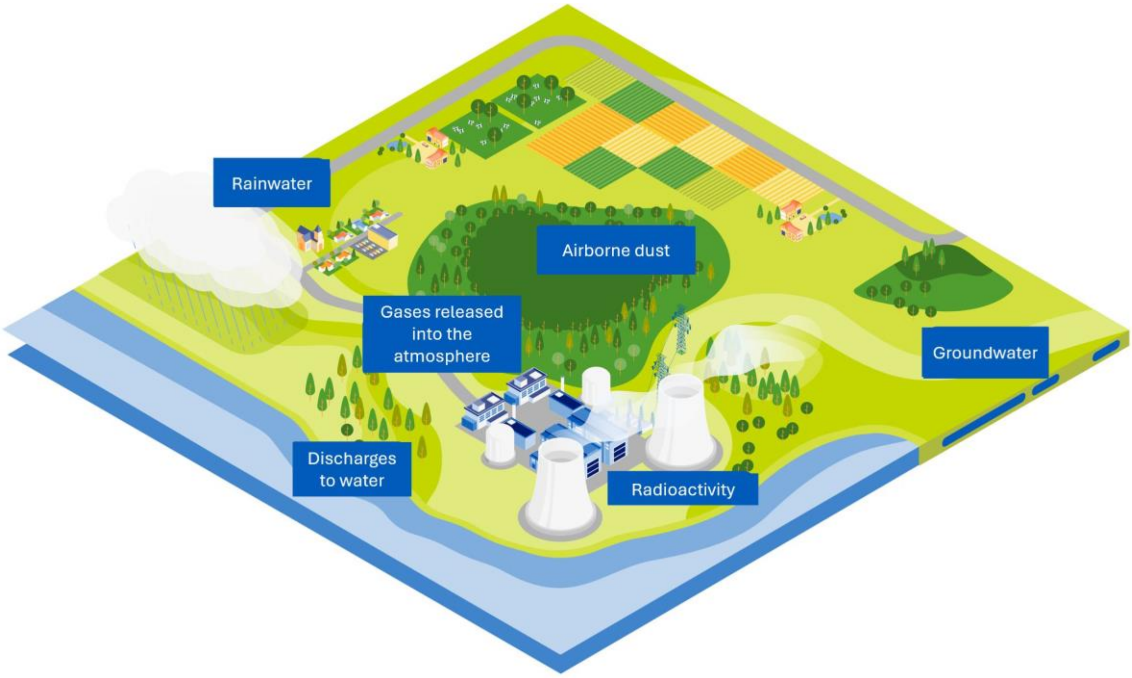
- the stacks for effluent discharge to atmosphere;
- storage tanks;
- the reactor buildings;
- the stacks on the waste conditoning building;
- the laundry facility;
- the hot workshop;
- the ‘effluent laboratory’;
- the ‘operations hot laboratory’;
- the secondary circuits of the reactors;
- interim storage tanks;
- the reactor cavity cooling water tanks for each reactor.

The radioactive discharges to atmosphere from Saint-Laurent A are monitored by way of sampling at the four stacks.

The liquid radioactive effluents from Saint-Laurent B are monitored at:

- the discharge storage and inspection tanks;
- tanks in the turbine hall;
- four rainwater, and sewage and rainwater, collection points.

The liquid radioactive effluents from Saint-Laurent A are monitored at Saint-Laurent B.



© EDF
Illustration of radiological monitoring of the environment

Radioactivity in the environment around Saint-Laurent des Eaux is monitored through:

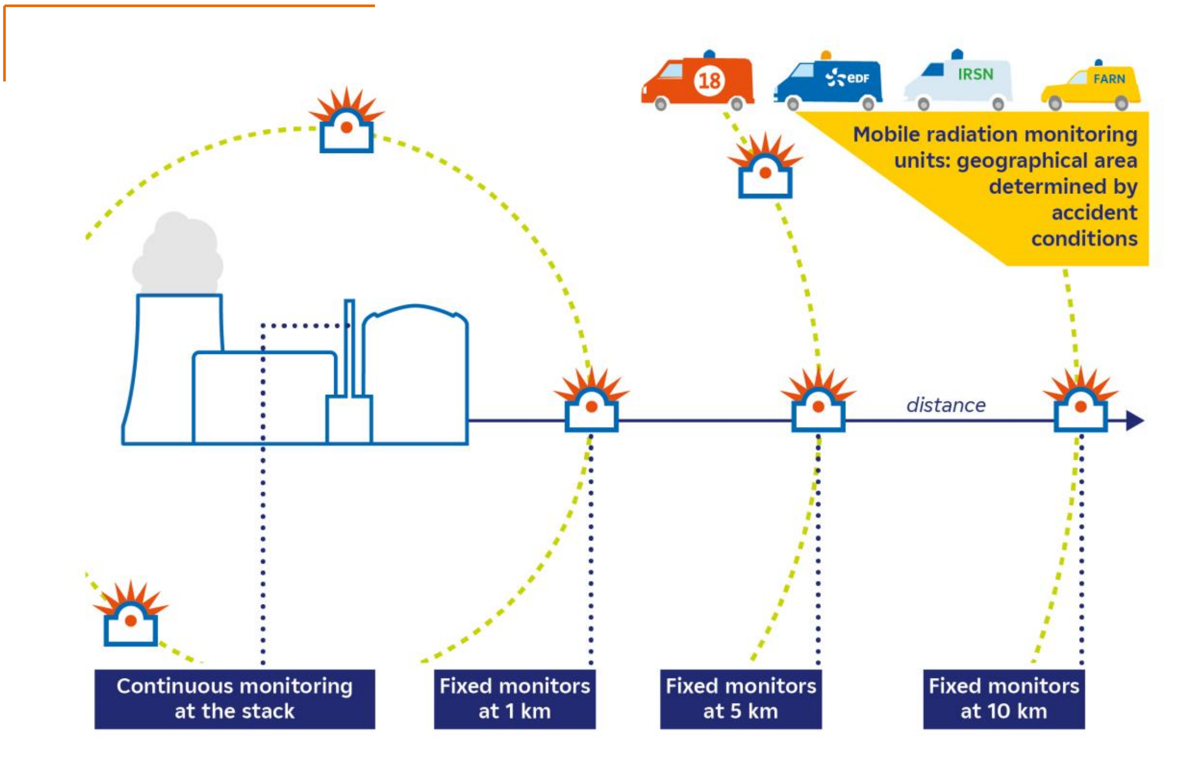
- a regulatory radiological monitoring programme implemented by the plant, focusing in particular on:
  - the atmosphere, with radiological monitoring of ambient gamma radiation, airborne dust, tritium in air, and rainwater;
  - groundwater;
  - the terrestrial environment, with measurements of radioactivity in milk and terrestrial plants, surface soil, and agricultural products;
  - the aquatic environment, with measurements of radioactivity in surface water, sediments, aquatic plants and aquatic fauna (fish).
- radioecological studies carried out on the initiative of the operator (annual monitoring, ten-year reviews, specific studies);
- a radiological monitoring programme consistenly implemented by ASNR, for its own account, which it assigns to its department of subject-matter specialists.

Population and human health

The impact of the Saint-Laurent des Eaux site on the health of neighbouring populations is monitored by keeping track of three environmental compartments, the atmosphere, surface water, and radioecology (as described above).
Noise emission is subject to periodic measurement campaigns to verify compliance with regulations.
Microbiological monitoring of the installations and the aquatic environment is also carried out (tracking of *Naegleria fowleri* amoebas and *Legionella pneumophila* bacteria) to prevent any risk of pathogenic microorganism dispersal into the environment via the cooling circuits.

7.2. Monitoring measures for radiological risks

In accident conditions, fixed and mobile equipment is used to check/monitor ambient radioactivity. Fixed monitoring systems, which are **operational at all times**, include radiation monitors at the stack discharge, and ambient-air radiation monitors at the site boundary, 1 km, 5 km and 10 km away.
In the event of an accident, these fixed systems are supplemented by the deployment of mobile radiation monitoring units. EDF vehicles, ASNR vehicles manned by subject-matter specialists, and fire service vehicles manned by firefighters, cover the area around the plant



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8. CONCLUSION

In France, the construction of a nuclear power plant is subject to Government authorisation, after consultation with the Authority for Nuclear Safety and Radiation Protection (ASNR). This authorisation does not stipulate any restrictions on the duration of operation. Nevertheless, the operator is required to carry out a thorough periodic review every 10 years to reassess the plant operating conditions for the following 10 years. The operator must ensure that the facility is operating in accordance with the applicable safety regulations, and must update the assessment of the risks and impacts that the facility may present in terms of public health and safety, and the protection of nature and the environment, collectively referred to as the protected interests.

The two 900 MWe reactors at Saint-Laurent Nuclear Power Plant, operated by Electricité de France (EDF), are undergoing their 4th periodic review.

At the end of each review, EDF draws up a report setting out its findings and planned provisions for enhanced safeguarding of the protected interests. Beyond 35 years of operation, this review report is subject to a public inquiry.

This document represents one of the supporting documents in the Public Inquiry File for the 4th periodic review of the Saint-Laurent reactors. It is a joint document for both reactors. It addresses the environmental impacts of operating these reactors for the ten years following their 4th periodic review, and covers both the radiological and non-radiological consequences of any incidents or accidents.

Impacts of normal operation

The interactions between the plant in normal operation and the environment, that is to say, water abstraction and discharges, waste production, noise emission and land use, will remain similar over the next ten years to those of the previous decade.

Analysis of the impacts of these interactions on various environmental compartments, namely, air and climate factors, surface water, soil and groundwater, radioecology, biodiversity, population and human health, and human activities, shows that plant operations have no significant impact at this point in time and in the ten years following the 4th periodic review.

No transboundary effects are therefore expected.

Impacts of accidents

For the 4th periodic review of its 900 MWe reactors, EDF has set itself the overall goal of bringing their safety features into line with those of 3rd generation reactors, which for EDF is its EPR reference design at Flamanville (FLA3 EPR).

Extensive provisions for enhancements to nuclear safety, summarised in this document, have therefore been implemented for the 4th periodic review, based upon four key focus areas:

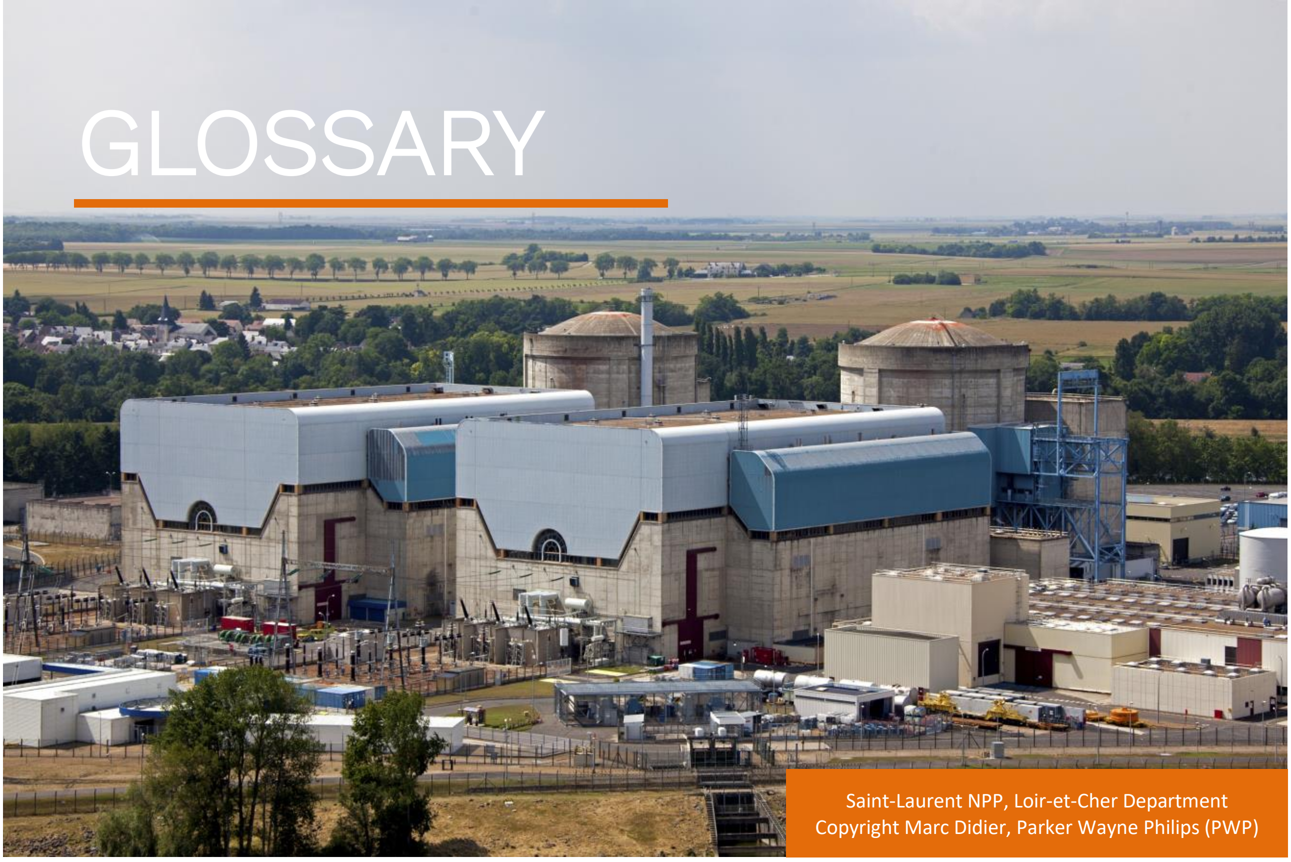
- **non-core-melt accidents:** measures to further reduce the radiological consequences of non-core-melt accidents, bringing them below the population protection thresholds;
- **hazards:** measures to take into account higher-level hazards, including in particular drought, heatwaves, flooding, earthquakes, and to deploy the Hardened Safety Core equipment designed to reinforce the robustness of the installations against extreme hazards such as earthquakes, tornadoes and flooding;
- **spent fuel pool:** measures to install an additional cooling system that is separate from existing systems;
- **core-melt accidents**: measures adding new provisions, including Hardened Safety Core equipment, in order to make early and significant releases extremely unlikely, and to avoid long-term effects on the environment.

The fundamental principle of nuclear safety applied to this 4th review, with significant changes to the design and operation of the Saint-Laurent reactors, significantly reduces the environmental impacts associated with the radiological risks.

As presented in the document, the radiological consequences of the most severe accidents, involving core meltdown, which are the most hypothetical scenarios, would be limited in terms of scope and duration, and aligned with public protection measures. The transboundary effects associated with the atmospheric dispersion of radioactive substances are negligible both in the short term, and in the long-term due to cumulative effects over time.

By conducting their 4th periodic reviews, EDF will continue to operate its Saint-Laurent reactors for up to fifty years, thereby contributing to ongoing low-carbon electricity generation, with less than 4 grammes of CO_2 per kWh produced over the entire life cycle of the power plant.

Over the next ten years, the normal operation of Saint-Laurent NPP is not expected to have a significant negative impact on the various surrounding environmental compartments. Decommissioning would therefore not bring any meaningful benefits to the environment. However, it would result in a sizeable loss of carbon-free electricity production, equivalent to the energy consumption of over 2.5 million households. Compensating for this lost electricity generation using the European energy mix would increase CO_2 emissions by more than 2 million tonnes a year.



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Acronym	Description
AP	Activation products
ARC	Avoid, Reduce, Compensate [ERC]
ASNR	Authority for Nuclear Safety and Radiation Protection [*Autorité de Sûreté Nucléaire et de Radioprotection*]
BNI	Basic Nuclear Installation [INB]
CENTRACO	Waste Treatment and Conditioning Centre [*Centre de Traitement et de Conditionnement*]
CIRES	Industrial Facility for Waste Collection, Sorting and Storage [*Centre Industriel de Regroupement d'Entreposage et de Stockage*] operated by the National Radioactive Waste Management Agency [ANDRA]
Conventional accident	The term 'conventional accident' is used to refer to an accident that may have non-radiological and/or low-level radiological consequences.
CSA	Aube Disposal Facility [*Centre de Stockage de l'Aube*]
CSS	Containment Spray System [EAS]
Dangerous accident phenomenon	A dangerous accident phenomenon involves the partial or total release of energy or substances that produces effects that may inflict damage to potential targets.
DER	Dose Equivalent Rate
DOCOB	Document of Objectives
DOR	Periodic Review Guidelines [*Dossier d'Orientations du Réexamen Périodique*]
DUS	Ultimate Emergency Diesel Generator (SBO-EDG) [*Diesel d'Ultime Secours*]
EDF	Electricité de France
EIP	Important Element for the Protection of Interests [*Elément Important pour la Protection des Intérêts*]
EPR	European Pressurised Reactor. A third-generation nuclear reactor.
EPRS	Prospective Evaluation of Health Risks [*Évaluation Prospective des Risques Sanitaires*]

EQS	Environmental Quality Standards [NQE]
FARN	Rapid Response Nuclear Taskforce [*Force d'Action Rapide du Nucléaire*]
FDW	Framework Directive on Water [DCE]
FLA3	Flamanville NPP production unit (EPR) No.3
FP	Fission products
GNU	Gas storage yard of the general store, used for storing unused cylinders
GP/GPE	Standing Panel of Experts [*Groupe Permanents d'Experts*]
Hazard	The concept of hazard defines a property that is intrinsic to a substance (butane, chlorine, etc.), a technical system (pressurisation of a gas, etc.), a method (lifting a load, etc.), a living organism (microbes), etc., that may cause harm to a 'vulnerable constituent of the environment'. Concepts of flammability or explosiveness, toxicity, infectiousness, available energy, etc., which characterise the hazard, are therefore tied to the concept.
Hazardous substance	A substance, preparation or mixture that meets the criteria relative to the physical hazards or health hazards or environmental hazards defined by the decree of 20 April 1994, amended.
HLW	High Level Waste [HA]
HSC	Hardened Safety Core [ND]
HSC-AFWS	Hardened Safety Core Auxiliary Feedwater System [ASG-ND]
HSC-CSS	Hardened Safety Core Containment Spray System [EAS-ND]
HSC-HS	Hardened Safety Core Heat Sink [SF-ND]
ICPE	Installation Classified for the Protection of the Environment [*Installation Classée pour la Protection de l'Environnement*]
IET	Irreversible Effects Threshold [SEI]
IL	Intermediate Level (radioactive waste) [MA]
INERIS	National Institute for the Environment and Industrial Risk [*Institut National de l'Environnement et des Risques*]
IRSN	Institute for Radiation Protection and Nuclear Safety [*Institut de Radioprotection et de Sûreté Nucléaire*]
LCA	Life cycle analysis [ACV]
LL	Long Lived [VL]
LLW	Low Level (radioactive waste) [FA]
LOCA	Loss of Coolant Accident [APRP]
MPL	Maximum Permissible Levels [NMA]
OISS	Inadvertent Opening of a secondary-side relief valve at 0%Pn [*Ouverture Intempestive d'une Soupape Secondaire à 0%Pn*]
OPEL	Loire Water Intake [*Ouvrage de Prise d'Eau en Loire*]
Potential source of hazard	A potential source of hazard is defined as a substance, technical process, method, organism, etc. that may cause damage to a vulnerable constituent of the environment.
Potential targets	These are members of the public beyond the boundaries of the site and the natural environment, corresponding to the protected interests defined in Article L593-1 of the Environment Code.
PR	Periodic review [RP]
4PR	4th periodic review [RP4]
4PR 900	4th periodic review of 900 MWe reactors [RP4 900]
PSA	Probabilistic Safety Assessment [EPS]
PWR	Pressurised water reactor [REP]
Reserve FPCS	Reserve Fuel Pool Cooling System [PTR-bis]
Risk	Risk, inherent in all human activities, is defined as the combination of the likelihood of a harmful event occurring and the severity of its consequences.

RCR	Periodic Review Findings Report [*Rapport de Conclusion du Réexamen Périodique*]
SAC	Special Area of Conservation [ZSC]
SEG	Diversified source of water
SG	Steam Generator [GV]
SGTR	Steam Generator Tube Rupture [RTGV]
SIS	Safety Injection System (primary system safeguard and protection system) [RIS]
SL	Short Lived [VC]
SLB	Steam Line Break [RTV]
SLB + nSGTR	Steam line break combined with multiple steam generator tube ruptures [RTV + nRTGV]
SM	Suspended matter [MES]
SPA	Special Protection Area [ZPS]
SPA	Site Pollution Assessment [IEM]
THM	Trihalomethanes
VHE	Very High Efficiency [THE]
VLLW	Very Low Level Waste
VSL	Very Short Lived [VTC]
WENRA	Western European Nuclear Regulators Association
ZER	Regulated Noise Aggravation Zones [*Zone à Émergence Règlementée*]
ZNIEFF	Natural Areas of Interest for Ecology, Fauna and Flora [*Zones Naturelles d'Intérêt Écologique, Faunistique et Floristique*]