



DOCUMENT

3bis

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

Public inquiry into the 4th periodic review

Gravelines Nuclear Power Plant
Reactor No. 2

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INTRODUCTION



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'.

Gravelines Nuclear Power Plant's six 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 to 4 at Gravelines Nuclear Power Plant were submitted to the Government and to the Authority for Nuclear Safety and Radiation Protection (ASNR, www.asnr.fr) on 10 September 2022, 16 March 2024, 18 April 2023 and 14 December 2024, respectively. At the time of drafting this document, the reports for reactors Nos. 5 and 6 remain to be released.

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 Gravelines reactors. It is a joint document for all six reactors at the Gravelines 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 it may specify regarding the reactors at the Gravelines site.

1. THE OPERATOR OF GRAVELINES NPP AND THE BACKGROUND TO THE PERIODIC REVIEW

1.1. The operator of Gravelines Power Plant

EDF is the operator of Gravelines 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 gCO₂/kWh - compared to a European average of 230 gCO₂/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 reactors across 18 sites in France.

In 2024, the Gravelines Nuclear Power Plant (NPP) generated nearly 32.7 billion kilowatt-hours of low-carbon electricity, representing the electricity consumption of nearly 6.5 million French households, in other words, 9% of France's nuclear-generated electricity. Gravelines NPP supports the climate goals set by France and the European Union, as well as the objective of security of supply.

Gravelines NPP is a major economic player in the Hauts-de-France region. It is one of the leading industrial employers in the region, with 3,800 people, on average, on site at any given time. It is strongly committed to training young people, taking on more than 90 apprentices and 190 interns in 2024. It is fully invested in local life, and supports numerous initiatives and associations that promote 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

Gravelines NPP is made up of six pressurised water reactors (PWR), each with an electrical output of 900 MWe, cooled by an 'open' circuit cooling system. These reactors were commissioned between 1980 and 1985. They have been reliably contributing to carbon-free electricity generation for over forty years. EDF is carrying out the 4th periodic review of each of the six reactors currently in operation at the Gravelines 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. ASNR 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 ASNR's examination of this 'guidelines' component of the review concluded in April 2016 with a position statement, and requests made to the operator EDF².

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 2 categories of risk:
 1. **radiological risks** associated with the presence of radioactive substances,
 2. **conventional risks**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

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 ASNR – Generic guidelines for the fourth periodic reviews of 900 MWe reactors – CODEP - DCN-2016-007286 dated 20 April 2016.

³ See glossary.

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**.

The 4th periodic review of the Gravelines 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 Gravelines reactors belong to the fleet’s 900 MWe reactor series. This generic phase concluded with the publication on 23 February 2021 of ASNR Decision No. 2021-DC-0706⁴ 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 Gravelines reactor.

Following the review⁵, EDF submitted the Review Findings Report [RCR] for each of the 6 Gravelines 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 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 **Erreur ! Source du renvoi introuvable.**).

In regard to this 4th periodic review of the Gravelines 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 the new requirements governing the continued operation of the Gravelines reactors.

After the review, the continued operation of Gravelines NPP 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 2 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 its 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 [DEM]. 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 [PDEM]

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 ASNRR 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 ASNRR. 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 ASNRR. 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 ASNRR for approval.

2. THE CONTINUED OPERATION OF THE GRAVELINES REACTORS

Aerial view of Gravelines NPP, Nord
Copyright Burnod Jean-Louis, Happy Day

2.1. Gravelines Nuclear Power Plant

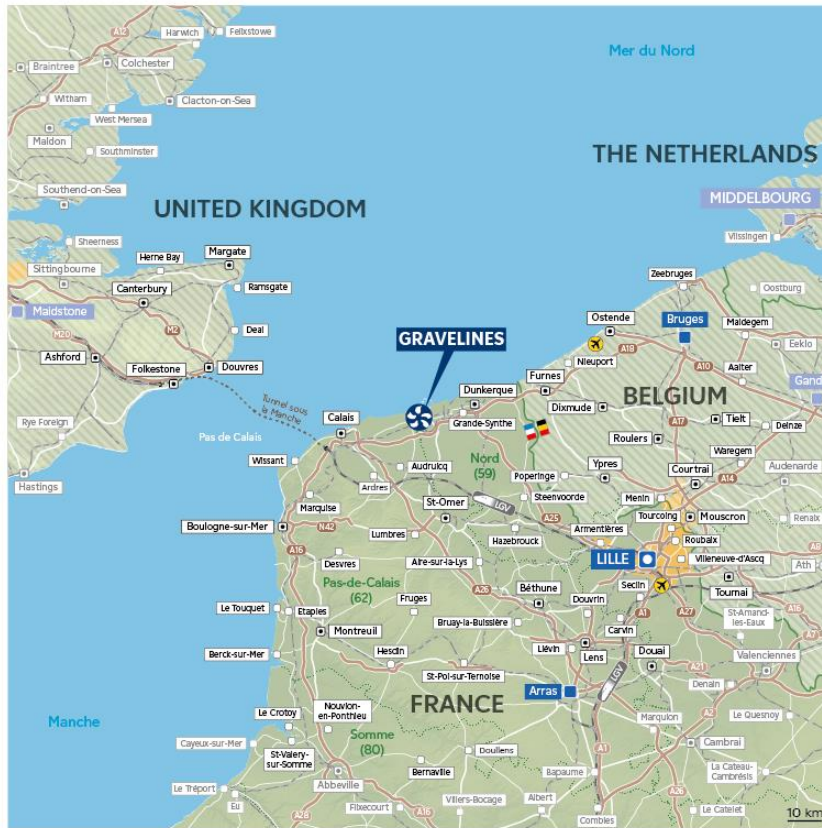
This EDF nuclear power plant is located in the Commune of Gravelines, in the Nord Department, bordering on the Department of Pas-de-Calais, in the region of Hauts-de-France. It is sited on the North Sea, midway between Dunkirk and Calais, at the centre of a regional industrial powerhouse.

The largest towns near the power plant are Dunkirk (17 km), Calais (21 km) and Boulogne-sur-Mer (47 km).

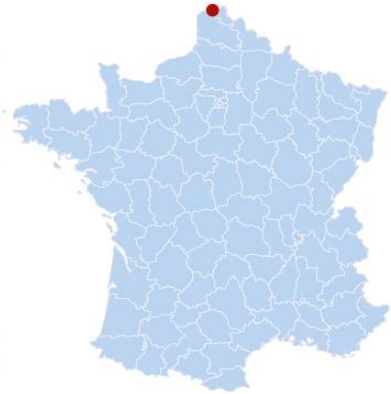
The plant is close to a Regional Nature Park, two nature reserves, Natura 2000 protected sites, and areas owned by the Coastline Conservation Trust (Conservatoire du Littoral).

Gravelines NPP comprises six pressurised water reactors (PWR), which were commissioned between 1980 and 1985, and are all undergoing their 4th periodic reviews.

GRAVELINES NUCLEAR POWER PLANT (NORD)



Main towns and communication routes



- ▣ Regional prefecture
(administrative centre of the region)
- Departmental prefecture
(administrative centre of the department)
(Belgium: capital of province /
The Netherlands: capital of province /
United Kingdom: county town)
- ◻ Subprefecture
(administrative centre of the district)
(Belgium: administrative arrondissement /
United Kingdom: district of the
administrative county)
- Other town

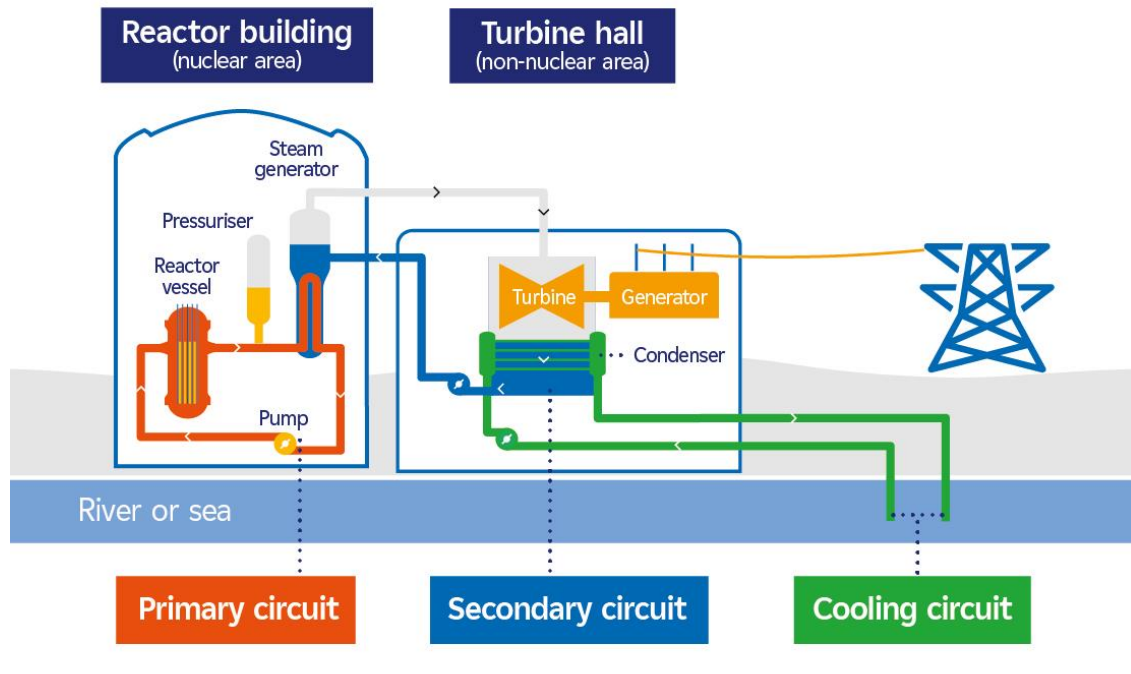
2.2. Overview of the power plant

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.

Gravelines NPP has six pressurised water reactors, each with a rated electrical output of 900 MWe, cooled by an open circuit cooling system. The working principle of a pressurised water reactor is based on three separate and sealed circuits (see illustration below).

THE NUCLEAR POWER PLANT

Operating principle, without a cooling tower



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 lines.
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 river. This third circuit is the cooling system. At Gravelines NPP, the water from this third circuit is drawn from the North Sea.

In 2024, Gravelines NPP generated nearly 32.7 billion kilowatt-hours of low-carbon electricity, representing the electricity consumption of around 6.5 million households, in other words, 9% 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.

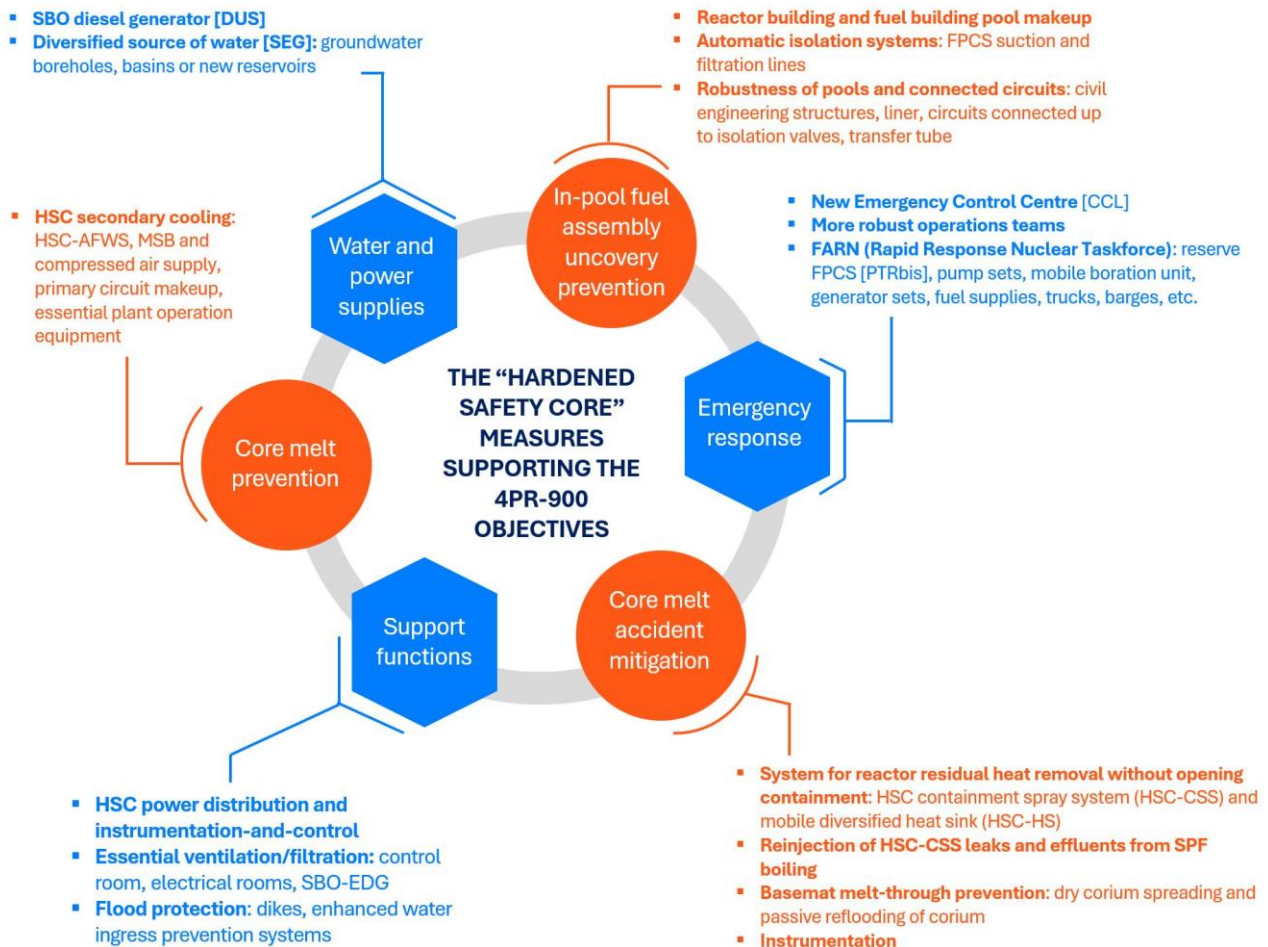
2.3.1. The measures put forward

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 ASN, which will be setting out the conditions for continued operation.

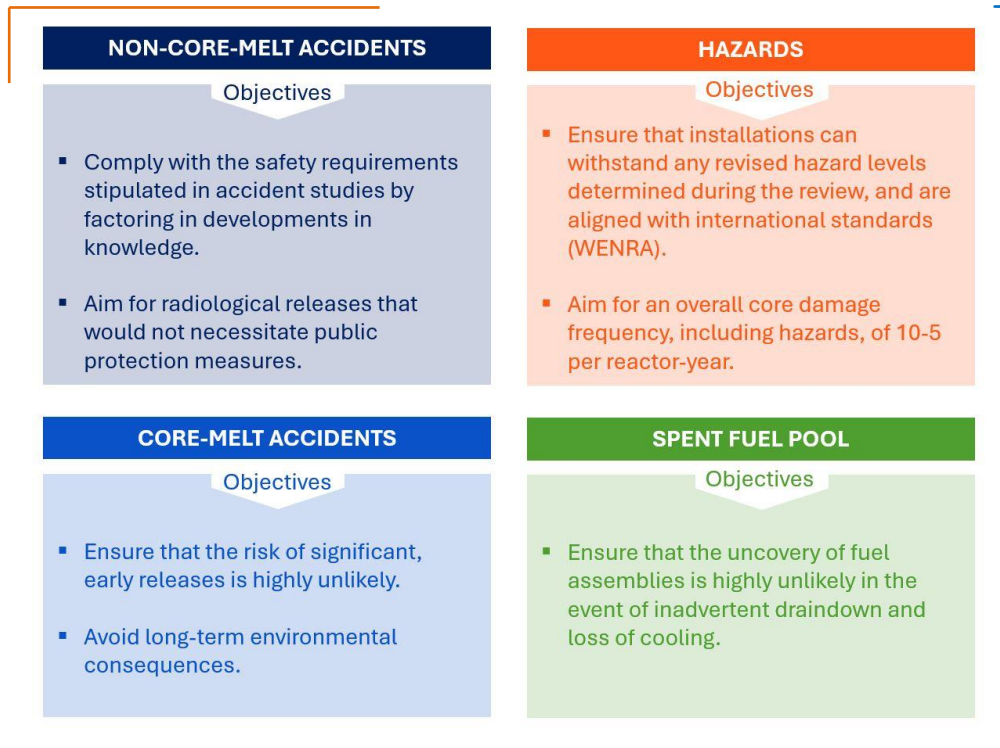
Firstly, the improvement measures consist in ensuring that the safety case for the reactors takes into account the equipment and organisational provisions made in response to the operating experience from the accident in the Fukushima Daiichi Nuclear Power Plant in March 2011. These provisions were strengthened after the review and were 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 equipments, 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), and tornadoes.

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



Secondly, the other improvement measures under the 4th periodic review of Gravelines 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 sites⁶:

- 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 Gravelines 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.

3. THE PROCEDURE FOR THE PUBLIC INQUIRY INTO THE PERIODIC REVIEW

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.

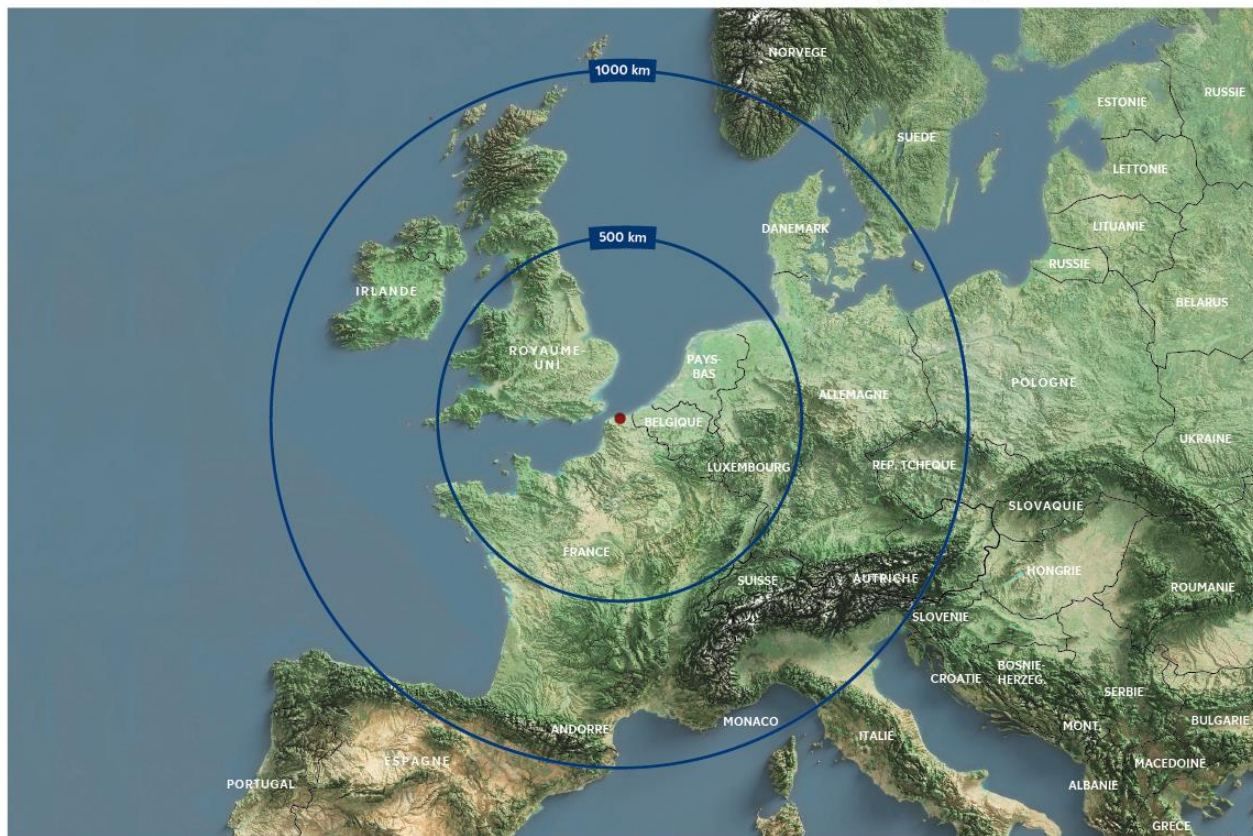
3.2. Cross-border consultation

For the purposes of this public inquiry on 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 Gravelines NPP in relation to neighbouring states, up to a distance of 1,000 kilometres.

GRAVELINES NUCLEAR POWER PLANT (NORD)

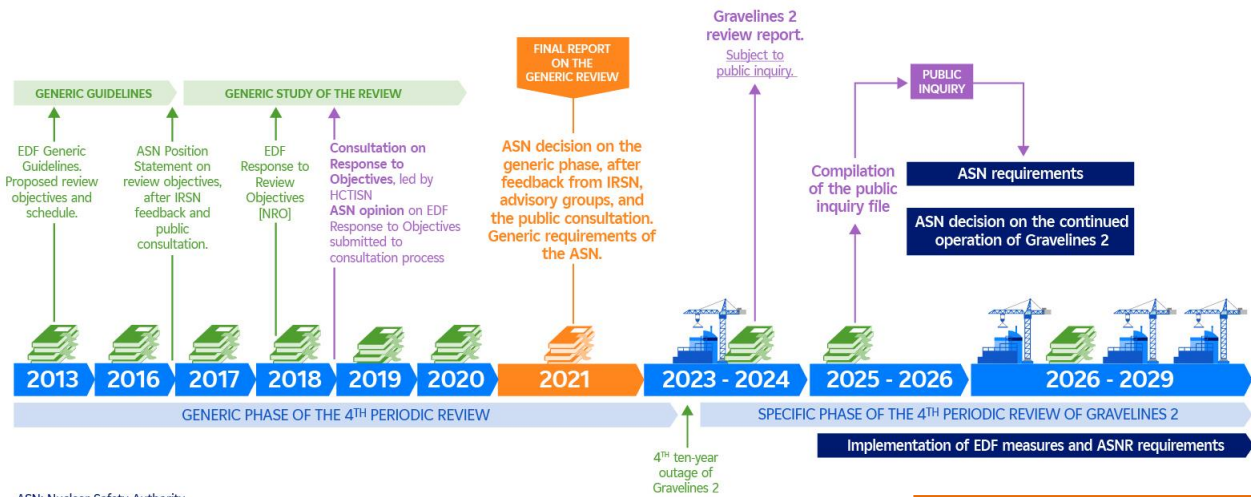


The Gravelines site relative to neighbouring foreign states

3.3. Timeline of the regulatory procedure

The Prefect of the Nord 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 Gravelines reactor No. 2 is summarised below.



As matters stand, the public inquiries into Gravelines reactors Nos. 2 and 4 could be held between end 2025 and mid-2026, while the public inquiries into reactors Nos. 5 and 6 will take place from 2030 to 2031.

4. NUCLEAR POWER PLANT SAFETY

Gravelines Nuclear Power Plant, Nord
Copyright EDF

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 ALARA⁷ 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 aims 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:

4. **radiological risks** linked to the presence of radioactive material,
5. **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.

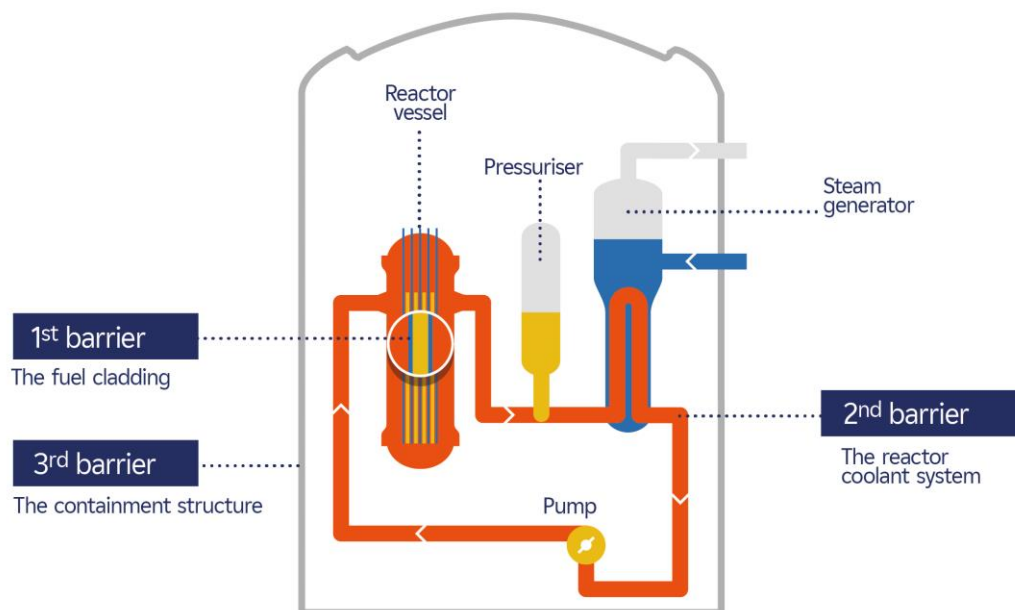
4.2.1. Radiological risk management

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 THREE CONTAINMENT BARRIERS



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.

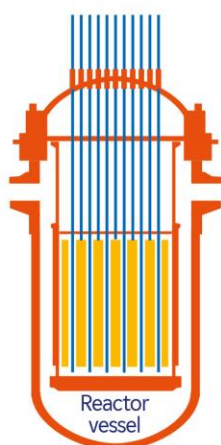
In order to maintain the effectiveness of the containment barriers over time, and in all situations, equipment and systems are designed to continuously fulfil three 'safety functions'.

THE THREE SAFETY FUNCTIONS

1

Control the fission chain reaction

- Position of control rods
- Boron concentration of water

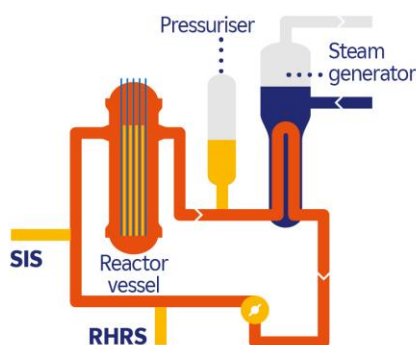


2

Cool the fuel

Remove heat:

- via the steam generators, in normal operation
- via the residual heat removal system [RHRS] [RRA]
- Via the safety injection systems [SIS] [RIS]

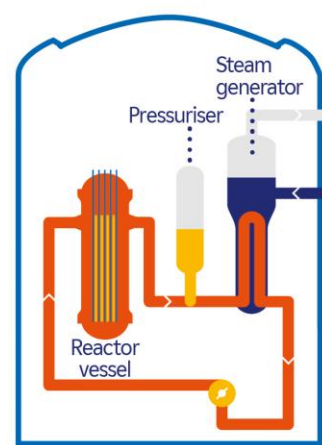


3

Contain radioactive material

By means of the three barriers:

- Fuel cladding
- Primary coolant system
- Containment structure



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 decree of 7 February 2012, laying down the general rules for basic nuclear installations, and known as the '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:

6. **prevention (level 1):** prevent the occurrence of failures;
7. **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 Gravelines reactors, as described in their 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 Gravelines reactors will incorporate robust design features for withstanding core-melt accidents. The scenarios studied have led to the implementation of provisions⁸ 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.

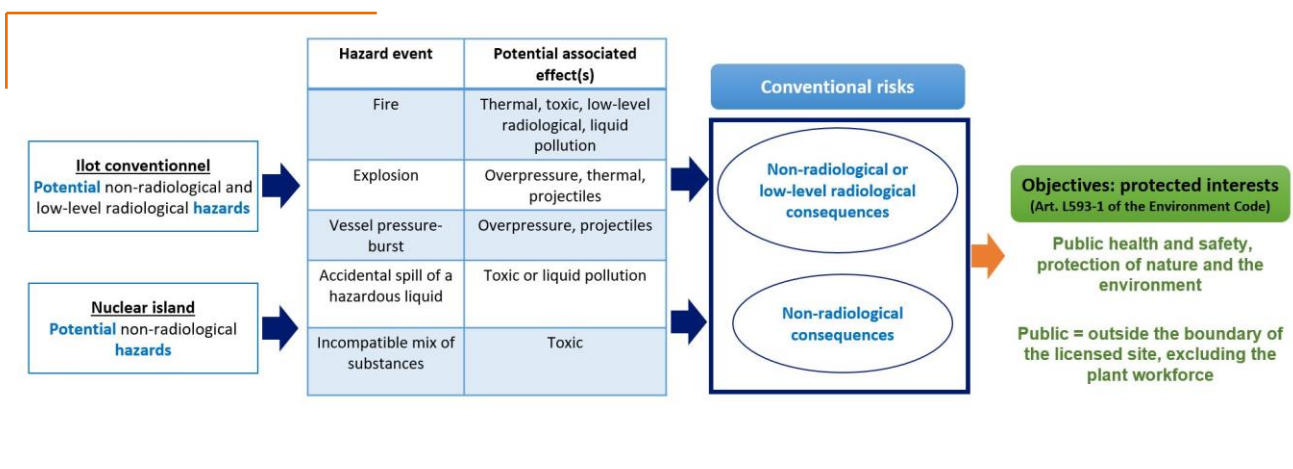
4.2.2. Conventional risk management

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 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 risk management measures (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 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 ([EIP] [AIP]), 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 Gravelines

■ 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 Gravelines NPP identified five conventional accident scenarios that may impact the interests to be protected:

- In the VLLW storage area, a generalised fire scenario, bringing into play all the potential sources of hazard in the facility, could produce thermal effects;
- In the 'GNU' (unused gases) storage yard, the rupture of a pressurised nitrogen cylinder following a leak could generate overpressure effects;
- In the electrochlorination plant, loss of confinement of a hydrochloric acid container in the unloading area could lead to a toxic dispersion of hydrochloric acid;
- In the unloading area⁹ of the carbonate-removal plant, where several products can be unloaded from tanker trucks, a scenario may occur during an unloading operation, with the dispersion of a toxic chlorine cloud

⁹ Unloading is the action of transferring liquids or gases from a tanker truck to a storage tank.

resulting from the mixing of incompatible substances in the facility;

- A mix-up between different unloading areas, where a tanker truck delivering its contents may mix up the carbonate-removal plant, the anti-scaling treatment facilities and the demineralisation station, could also lead to the mixing of incompatible hazardous substances across several installations, leading to the dispersion of a toxic chlorine cloud.

The numerous preventive measures that have been implemented defend against such accidents occurring: training of personnel, implementation of detailed procedures, use of visual signage and fool-proofing mechanisms to minimise the risk of hose-connection errors, use of human error-reduction techniques during task execution, etc.

The scenario of a generalised fire in the very-low-level waste storage area presents a tolerable level of risk. It has a frequency of occurrence categorising it as a highly unlikely event (less than 1 in 10,000 years).

The scenario of a failed pressurised nitrogen cylinder in the the 'GNU' gas storage yard presents a tolerable level of risk. It has a frequency of occurrence categorising it as an unlikely event (less than 1 in 1,000 years).

With regard to the scenario involving a toxic dispersion of hydrochloric acid, targeted preventive measures have been implemented to reduce its likelihood of occurrence. 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 unloading:

- the presence of an EDF employee, who authorises the unloading operation and, in particular, ensures that there are no leaks and checks the hose connection, before giving the go-ahead for unloading;
- the presence of an emergency shutoff on the tanker truck or at the pumping system, for activation by the tanker truck driver.

Given the provisions in place, the scenario of a toxic dispersion of hydrochloric acid has a frequency of occurrence categorising it as a highly unlikely event (less than 1 in 10,000 years).

Lastly, in regard to the scenario of involving the mixing of incompatible substances, targeted preventive measures have been implemented to reduce its 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 unloading:

- a systematic escort for trucks, from the site entrance to their designated unloading area, so as to minimise the likelihood of a mix-up of unloading areas;
- an inspection by the delivery coordinator of the hose/loading-arm attachment to the connector, and a check to ensure that the tank being unloaded is fully immobilised (the vehicle engine is turned off and the parking brake is engaged, the hose is in good condition, there are no leaks, the snap-in/screw-in connection is secure);
- a sample test of the product being delivered, to physically check that the delivered product meets specifications;
- an independent check by a third party, tasked with authorising unloading by way of a physical manoeuvre (such as removing the lockout-tagout on a valve).

Given the provisions in place, the scenarios involving a mixing of incompatible substances have a frequency of occurrence categorising them as extremely unlikely events (less than 1 in 100,000 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 Gravelines 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 Gravelines,
 - 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 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 Gravelines 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 Gravelines 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 installation'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

Aerial view of Gravelines NPP, Nord
Copyright Burnod Jean-Louis, Happy Day

5.1. Approach

Section 5 presents the assessment of the environmental impact of Gravelines 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).

Subsection 5.6 presents the interactions between Gravelines NPP operation and the environment, both currently and over the next ten years.

Subsection 5.7 sets out the impacts of Gravelines NPP operation on the environment, currently and for the next ten years. The impacts of plant decommissioning are presented in Subsection 5.7.10.

5.2. Impact assessment methods

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

■ *Air and climate factors*

The analysis of the impacts of Gravelines NPP operation on the climate is based on the life cycle assessment (LCA) [ACV] 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 analysis of the impact on air quality is based on a comparison between the concentrations of released substances and the air quality standards defined in the Environment Code (R. 221-1).

■ *Surface water*

The impact assessment of liquid chemical effluent discharges on surface water quality is based 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 site;
- a quantitative substance-by-substance evaluation of the impacts of liquid chemical discharges, based on a comparison between the calculated concentrations in the environment and reference values (thresholds, guidance values, ecotoxicological data, etc.).

■ *Soil and groundwater*

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

- a survey of the soil and groundwater at the plant, based on an analysis of historical data and a review of piezometer monitoring carried out on site, supplemented by measurement campaigns;
- comparisons with reference data for soils: data on the quality of surrounding soils (excluding areas potentially affected by the facility), 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 is based on:

- a retrospective analysis of the impact of past discharges, drawing on the results of the initial baseline assessment, the ten-year reports and the annual follow-ups;
- a prospective 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 the Gravelines site, 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 Gravelines NPP operation on biodiversity is based on:

- the study of the natural areas, habitats, fauna, flora and ecological functions present within the study area (bibliographic studies and field investigations);
- the analysis of the effects of each interaction between Gravelines NPP and natural areas, fauna, flora and ecological functions.

■ **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.

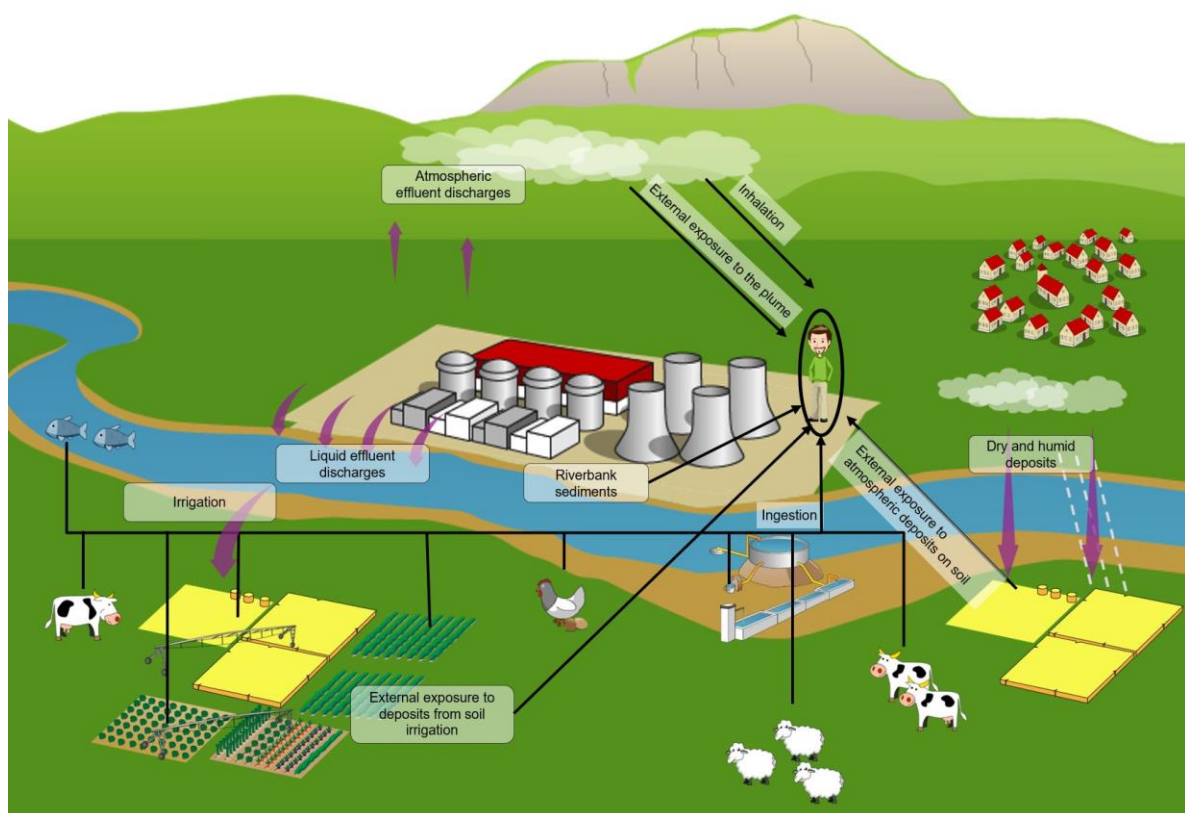
The following exposure pathways are considered (see figure below):

- 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, soil);
- 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 specific measurements;
- A Prospective Health Risk Assessment [EPRS], drawn up by modelling the discharges attributable to the Gravelines site. This assessment is broken down into five steps:
 - an inventory of the substances discharged,
 - an assessment of issues and of exposure pathways,
 - identification of hazards, assessment of dose-response relationships, and identification of pollutant tracers that could pose a risk to health,
 - 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 Gravelines NPP operation is based 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 concerns:

- 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 impacts of the waste that is produced is mainly assessed through an analysis of the measures implemented for waste zoning, characterisation, sorting, treatment, packaging and inspection.

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 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 as well as 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 representative 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 Gravelines 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 Gravelines NPP. This data is presented in Section 5.5 and covers:
 - air quality;
 - meteorology;
 - surface water quality;
 - the state of soils and groundwater;
 - the radiological state of the environment;
 - biodiversity;
 - population and human activities.

Gravelines 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 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

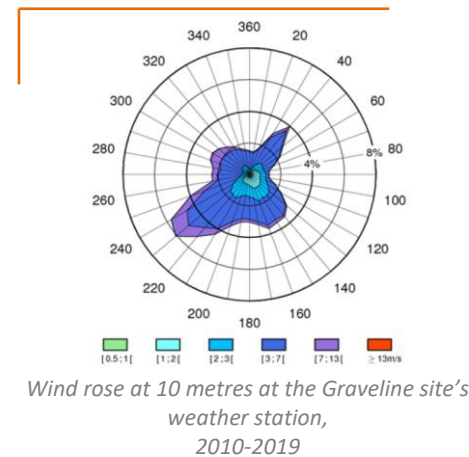
■ Climate

The region in which Gravelines NPP is sited has a distinct Oceanic climate. Heatwaves and cold spells are rare, while frosts are regular during the winter. The area is very windy all year round, making the weather very changeable

Between 2010 and 2019, the average monthly temperatures in Gravelines ranged from 4.9°C (in February) to 18°C (in July and August); it rains on average 190.5 days a year; and the prevailing winds are from the south-west.

■ Air quality

The air quality around the Gravelines site is generally good, despite some periods of higher ozone levels.



5.5.2. Surface water

■ Hydrology

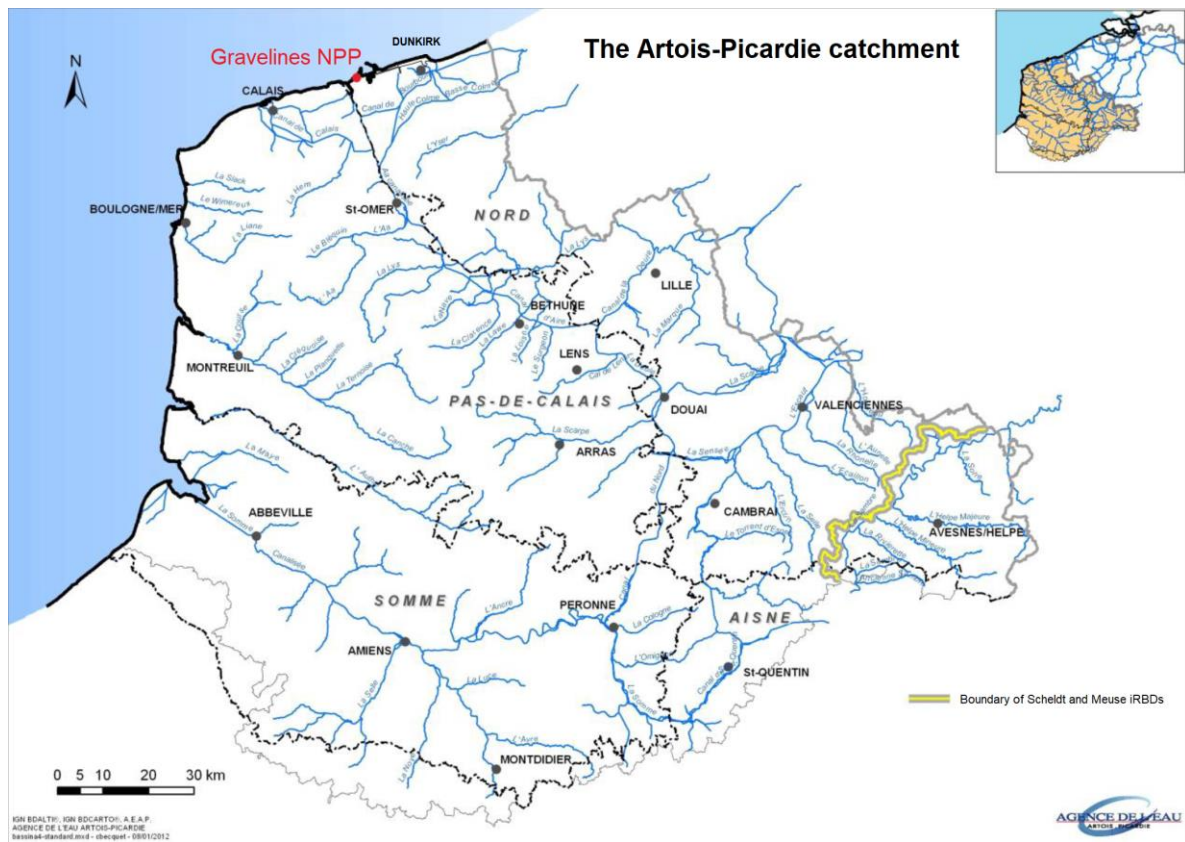
Gravelines power station is located to the west of the North Sea, near the Strait of Dover. This location, combined with the shallow waters, results in a tide-dominated hydrodynamic regime, with semidiurnal tides. The tidal currents are alternating and flow parallel to the coast.

The closest continental input to the power station is the Aa, a small coastal river draining the inland area and maritime plain. Due to the very low altitude of this plain, the flow to the sea is controlled by locks. The same applies to the two other outlets in the region: at Dunkerque (the Canal Exutoire) and at Calais (the Marck, River Neuve and Saint-Omer canals). The Bourbourg Diversion Canal is used during periods of high waters to discharge large volumes of water through the Eastern Port of Dunkirk.

The estimated average flowrates of these freshwater inflows are as follows:

- Dunkirk Canal: 4.6 m³/s;
- The Aa River: 6.1 m³/s ;
- Canals at Calais: 3.0 m³/s.

Due to their low flow rates, these watercourses do not have a significant impact on the quality of the seawater passing through the power plant.



The Artois-Picardie Catchment (© Agence de l'Eau Artois-Picardie)

■ Thermal regime

The thermal regime of the North Sea around Gravelines NPP changes over time, in response to natural conditions:

- Intraday temperature variations at the water intake are limited and remain below 1°C on average.
- Seawater temperatures vary across the seasons, with an average monthly temperature of 19.7°C in August (the warmest month) and 7.0°C in February (the coldest month), and a range of temperatures bounded by recorded upper and lower readings from 0.1°C to 22.0°C.
- The average annual temperature is 13.0°C for the period 1997-2020. There is a slight upward trend in the average annual temperature over this period. However, the temperature records for this period (24 years) do not point to a statistically significant trend of climate change.

■ **Physico-chemical and biological quality**

The bodies of water affected by Gravelines power plant's water abstraction and liquid chemical discharges are the two water bodies FRAT04 (harbour water body 'Port de Dunkerque') and FRAC02 (coastal water body 'De Malo à Griz Nez'). The ecological and chemical status of these water bodies was assessed in 2019 by the Artois-Picardy Water Agency. Water body FRAC02 has an average ecological status and a good chemical status. Water body FRAT04 is considered to have achieved good ecological potential and good chemical status in 2019.

The results of hydroecological and chemical monitoring over the period 2011-2020 indicate that the quality of the aquatic environment is satisfactory, both in terms of physico-chemical parameters and biological indicators.

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, hydromorphological 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 (eau, biota and/or sediments), compared with the Environmental Quality Standards (EQS).

5.5.3. Soil and groundwater

■ **Geology**

Gravelines NPP is built on recent Quaternary formations, which can be divided into:

- Quaternary sand and silt, approximately 30 metres deep;
- Flanders tertiary clay, over 100 metres deep.

The earthworks for the power plant led to the creation of a general platform supported by hydraulic backfill of sand extracted from the outer harbour of Dunkirk. At the level of the nuclear islands and turbine halls, sand was almost entirely replaced by a concrete load-distribution slab to limit settlement of foundation soils.

The plant's main facilities are enclosed in engineered confinement structures (one confinement structure per pair of reactors), which act as a barrier and prevent transfers to groundwater.

■ **Hydrogeology**

At the Gravelines power plant, the main aquifer is made up of stratified sand and silt deposits from the Quaternary period. These strata subdivide the aquifer into several distinct units, consisting of three layers of sand interspersed with low-permeability silt lenses. Flows are directed towards the outer harbour of Dunkirk, first in a south-west/north-east direction along the south-east flank of the installations, then in a south/north direction as they approach the outer harbour.

The behaviour of the water table outside the engineered confinement structures differs from that inside the structures. The engineered confinement structures, which are embedded in Flanders clay and isolate the nuclear island structures and the last 700 metres of the intake/discharge channels, form a barrier to any direct flow to the sea. Inside the structures, makeup (from the offsite groundwater table) and drainage flows (via the intake channel) are limited.

Under the 2022-2027 Water Development and Management Plan for Artois-Picardy [SDAGE Artois-Picardie], the objective for the underground body of water next to the site (FREAG314 'Sables du Landénien des Flandres') is to maintain the good chemical status and good qualitative status standards achieved in 2015.

■ **Soil status**

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

5.5.4. Radioecology

The environment surrounding the site has been subject to radiological 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 site'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 the radioecological monitoring carried out by the operator in the vicinity of the Gravelines power plant highlights the predominantly natural sources of radioactivity.

Artificial radioactivity mainly originates from the residual effects of atmospheric depositions from atmospheric nuclear tests, the Chernobyl accident and, to a lesser extent, the Fukushima accident, as well as effluent discharges from the Gravelines site, and from other facilities on the coast (the La Hague reprocessing plant and other nuclear power plants).

5.5.5. Biodiversity

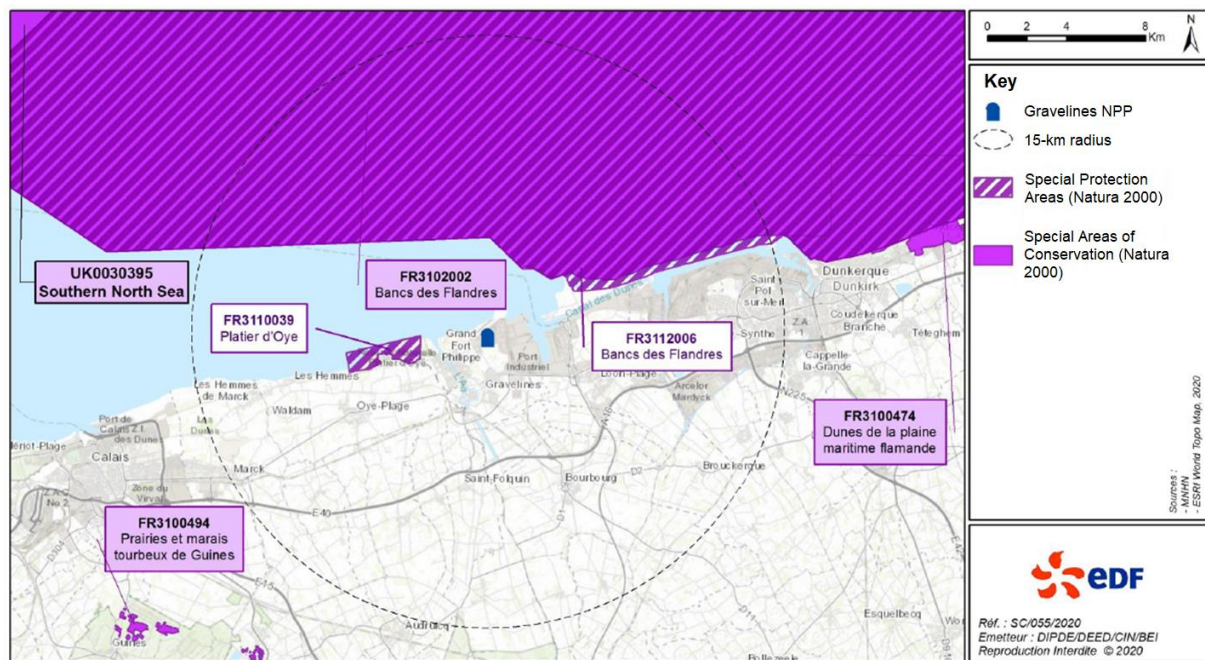
A review of the ecological priorities for the area around Gravelines NPP was carried out:

- firstly, by detailing the areas of special interest and the ecological functions within a 15-km radius of the site;
- secondly, by conducting an impact assessment in relation to the study area defined as the overlap between the power plant's area of influence on the terrestrial environment (a circle of radius 6 km) and its area of influence on the marine environment (a bounding area encompassing a 1°C temperature increase and a circle of radius 6 km).

■ *Natural areas of special interest*

The following natural areas of special interest have been identified within a 15-km radius of Gravelines power plant:

- Three sites in the Natura 2000 protected areas network: 2 Special Protection Areas (SPA FR3110039 'Platier d'Oye' and SPA FR3112006 'Bancs des Flandres') and 1 Special Area of Conservation (SAC FR3102002 'Bancs de Flandres'); it should be noted that the Natura 2000 SPA and SAC sites 'Bancs des Flandres' are also designated Marine Protected Areas under the OSPAR Convention;



Natura 2000 sites within a 15-km radius of Gravelines NPP

- 1 National Nature Reserve and 1 Regional Nature Reserve;
- 1 Regional Nature Park;
- 3 areas owned by the Coastline Conservation Trust (Conservatoire du Littoral);
- 1 area under a Biotope Protection Order (BPO) [APB];
- 8 sites classified as vulnerable natural areas [ENS];
- Ten type-1 Natural Areas of Interest for Ecology, Fauna and Flora [ZNIEFF] and one type-2 ZNIEFF.

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 categories: coastal and marine habitats, which are home to a series of environments reflecting changes in humidity and salinity, and terrestrial habitats consisting of agricultural lowlands criss-crossed by a network of canals, watercourses, watergangs, etc. The most important habitats of special interest are mostly concentrated in the northern half of the study area, in the coastal environments. There are also habitats of special interest inland, particularly in wetlands such as marshes, peat bogs, reedbeds, etc.

■ Vegetation

Over 1,000 plant species have been identified in the study area, including 250 plant species of special interest and around 50 invasive alien species. The marine phytoplankton populations surveyed are typical of those generally observed in the Channel and North Sea.



Sea Kale (a protected species nationwide) – © Biotope – 2016

■ Fauna

Bibliographic data supplemented by field investigations highlighted the potential presence in the area of around 350 species of special interest, classified as such due to their protected and/or heritage status. A few invasive species were also identified.

Worth noting also is the presence of a conservation-priority nesting colony of Common Terns, north of the Gravelines power station.



© Harbour Seal – Biotope - 2016



© Common Tern – Biotope - 2016

Species of special interest

■ Ecological functionalities

Gravelines power plant is located on the coast, in a man-made, fenced-off area. However, it is close to areas identified in the Hauts-de-France Regional Blueprint for Planning, Sustainable Development, and Regional Balance and Equality [SRADDET] as biodiversity reservoirs, ecological corridors or areas for rewilding.

Given the importance of ecological continuity, the canalised River Aa is registered in List 1 and List 2 for ecological continuity prioritisation, while the Oye River is registered in List 1 (in accordance with Article L. 214-17 of the Environment Code).

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.

5.5.6. Population and human health

■ Population

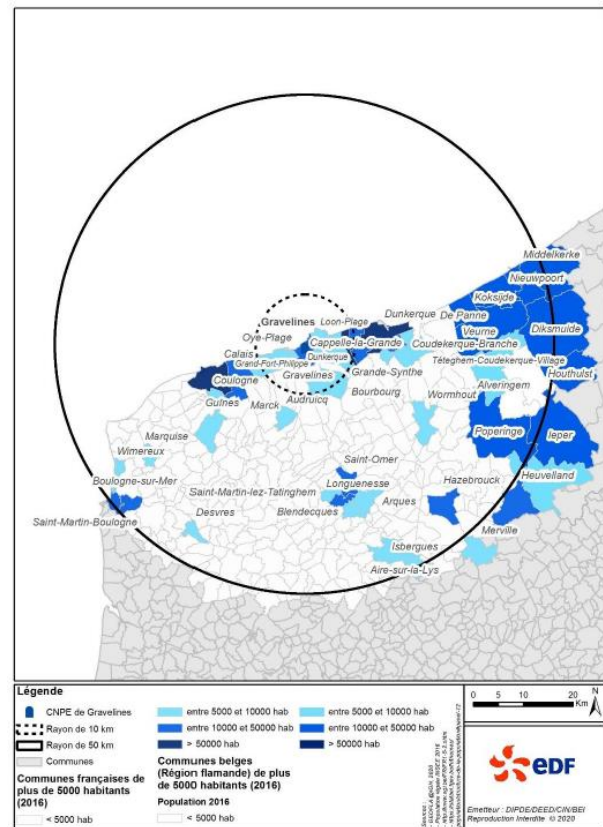
The extended 50-km-radius study area shows the distribution of the population around the Gravelines site, while the local 10-km-radius study area focuses on identifying populations of interest.

Within the 50-km radius, the average population density is around 210 inhabitants/km², while it is approximately 520 inhabitants/km² within the 10-km radius. For both the first and second radius, this average density is significantly higher than the average for mainland France, which is of the order of 120 inhabitants/km² (2016 census).

Within a radius of 50 km, the largest communes are Dunkirk (88,108), Calais (74,978) and Boulogne-sur-Mer (41,669).

The nearest vulnerable populations (in schools, childcare facilities, healthcare facilities, social services facilities, and nursing homes) are located approximately 1.2 kilometres south-west of the site boundary.

The closest residential housing is located less than 1 kilometre south-west, in the Commune of Gravelines.



Communes of over 5,000 inhabitants within a 50-km radius of Gravelines NPP (2016)

■ Noise and light pollution

A noise measurement campaign was carried out in 2015 at Gravelines NPP.

Light emissions in the vicinity of the power plant mainly originate from public lighting in the Commune of Gravelines.

5.5.7. Human activities

■ Land use

Within a 10-kilometre radius of Gravelines power plant, land use is primarily defined as agricultural use (approximately 63% of the study area), followed by developed land use (22% of the territory). The rest of the study area is mainly covered by wetlands (approximately 9%) and forests (approximately 5%).

■ Landscape and cultural heritage

The area around the Gravelines power plant features three major landscape units:

- the industrial port, which spans 15 kilometres, from Dunkirk to Gravelines NPP;
- Blotland, a triangular maritime plain with its base in the Commune of Watten and its western tip in the Commune of Sangatte, while its eastern tip sits in Belgium;
- the dune systems of the North Sea coastline, consisting of sand, dune areas with abundant vegetation but few trees, isolated farms, and harbours.

Two monuments of artistic, historical, scientific, folkloric and aesthetic importance fall within a 10-km radius of the power station: the Moulin des Huttes (or Moulin Lebriez), a windmill in the municipality of Gravelines, listed as a Historic Monument in 1986, and the Beffroi de Gravelines, a belfry also in the municipality of Gravelines, listed as a Historic Monument in 1948, and a UNESCO World Heritage Site since 2005.

■ **Water use**

Within a 10-km radius of Gravelines NPP, there is no freshwater abstraction for drinking water or for agricultural purposes (irrigation). Water for industrial uses is abstracted either by companies or by intermediaries supplying industrial water to nearby companies (as in the case of the Gravelines power plant), with water extracted from the Bourbourg Canal.

■ **Infrastructure and transport links**

Access to the Gravelines power station is via the Route des Enrochements. The main roads serving the surrounding area include the A16, the D601 from Ghyvelde to Gravelines, the D940 from Calais to Gravelines, the D11 linking Cassel and Gravelines, the N316 passing 5 kilometres south-east of the plant, and the RD119 passing approximately 3 kilometres south-west of the site.

The main railway line is the Calais-Dunkirk line, with seven trains running every day. Two freight railways managed by the Grand Port Maritime de Dunkerque generate a volume of traffic of around five trains per day. There is a rail link to the power plant for spent fuel removal.

In addition to the heavy maritime traffic in the North Sea, there are two navigable waterways within a 10-km radius of the Gravelines power plant: the Mardyck Diversion Canal and the Bourbourg Canal.

■ **Industrial environment**

This is a highly industrial area: within a 10-km radius of the site, there are around 50 facilities classified for environmental protection [ICPE], nearly a quarter of which are classified **SEVESO** sites. These companies are operating primarily in the food, chemical, petrochemical, construction, and metals industries. The power plant supplies warm water to the fish farm sited between its facilities and the North Sea (see following section), and to the LNG terminal on the other side of the western outer harbour of Dunkirk.

Since 2015, Directive 2012/18/UE of 4 July 2012, known as the 'Seveso III directive', has required European Union Member 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 areas and leisure activities**

Recreational hunting and fishing take place in the area around the Gravelines power station. The main hunted species are small and large game. As for freshwater fishing, the main species caught are pike, zander, brown trout, rainbow trout and black bass. There is also recreational sea and shore fishing along the coast.

The area around Gravelines NPP offers cultural and tourism activities (museums, nature parks, etc.), as well as sports and leisure activities such as hiking, aquatic walking, swimming, tree climbing, horse riding and golf. There are several designated swimming areas within a 10-kilometre radius of the power plant (beaches, Parc des Rives de l'Aa, Parc Galamé).

■ **Other uses**

There are two aquaculture companies - Aquanord Ichthus, and Ecloserie Marine de Gravelines Ichthus (hatchery) - within a 10-kilometre radius of the power plant. Under an agreement between Gravelines NPP and Aquanord Ichthus, warm water from the plant's cooling circuits is supplied to the aquafarm.

Professional fishing is a key activity for the region. Around 160 fishing boats are registered in the maritime districts of Boulogne-sur-Mer and Dunkirk, though this number varies from year to year.

■ **Energy consumption**

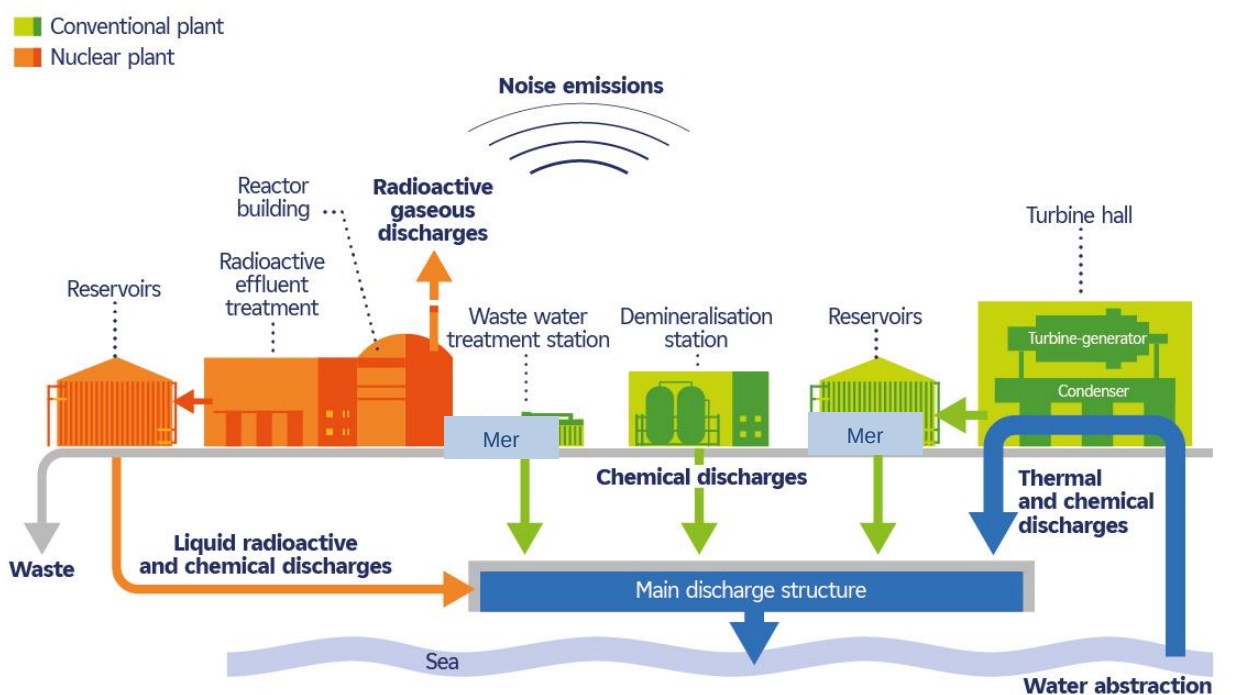
In 2024, Gravelines nuclear power plant produced 32.7 billion kilowatt-hours of low-carbon electricity. The plant's annual output meets its own electricity consumption requirements and covers 60% to 70% of the electricity needs of the Hauts-de-France region.

5.6. Gravelines NPP interactions with the environment

This subsection sets out the interactions between Gravelines 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 Subsections 5.6.1 to 5.6.8. Subsection 5.6.9 presents the changes in these interactions over the next ten years.

OVERVIEW OF THE ENVIRONMENTAL IMPACT OF DIFFERENT PARTS OF THE INSTALLATION

“Open” circuit heat sink



5.6.1. Water abstraction and consumption

Gravelines NPP's various requirements for water supplies are met by seawater and groundwater abstraction, and by the Dunkirk Public Water Authority's distribution networks (Syndicat des Eaux du Dunkerquois).

Water abstracted from the North Sea is used for cooling the turbine generator condensers and the auxiliary systems. These systems operate in an 'open' circuit, and all this water is returned to source.

Groundwater is primarily pumped to:

- feed the ultimate emergency makeup water system during tests or periodic maintenance operations;
- drain an area for civil engineering works or for road-and-utilities works below the water table and, if necessary, clean up the water table.

The water supplied by the Dunkirk Public Water Authority covers all the plant's requirements in terms of drinking water and in terms of industrial water for demineralised water production and firefighting systems.

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. They are determined with the objective of ensuring normal plant operation, taking into account some operating contingencies, and protecting the environment. Note: it is only groundwater abstraction that is subject to a regulatory limit.

Actual volumes of abstraction therefore remain below the regulatory limits (Decision No. 2018-DC-0647¹⁰). The table below shows the annual water abstraction limits, and average annual volumes of water abstraction 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 is expected.

Source of abstraction	Use	Maximum volume	
		Regulatory limit (annual volume)	Average annual volumes 2013-2022
Sea	Cooling water	/	6,388 million m ³
Bourbourg Canal (Dunkirk Public Water Authority)	Industrial water (demineralised water, firefighting water)	/	842,000 m ³
Aquifer	Ultimate emergency makeup	8,100 m ³ (can be increased to 35,000 m ³ for tests, or for work in the ultimate makeup pumping station)	2,895 m ³ (*)

(*): average taken for 2022-2023 (tests)

Table 1: Regulatory limits and water abstraction volumes for the Gravelines site.

5.6.2. Liquid and gaseous 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 for release into the sea via the discharge channel, as regards liquid effluents, or into the atmosphere via the stacks on top of the nuclear auxiliary buildings, as regards gaseous effluents.



© EDF

A stack on top of a nuclear auxiliary building in the power plant

¹⁰ The Authority for Nuclear Safety and Radiation Protection's Decision No. 2018-DC-0647 dated 16 October 2018, setting out the requirements for water abstraction and consumption, effluent discharges, and environmental monitoring, directed at basic nuclear installations Nos. 96, 97 and 122 operated by Électricité de France (EDF) in the Commune of Gravelines.

The plant discharges 5 categories of radionuclides:

- Carbon-14 is mainly produced by neutron activation of oxygen-17 and nitrogen-14 present in the primary circuit 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.
- Tritium is produced by the fission of uranium in fuel rods and by the activation of conditioning products (boron and lithium). Almost all the tritium produced in the fuel rods remains contained in the rods. It is the tritium produced by activation that is found in the majority of liquid and gaseous effluents. At present, due to its low activity concentration, there are no technically and economically feasible industrial means of removing the tritium from these effluents. Consequently,, given its low radiological impact, tritium is released into the environment as and when it is produced.
- Iodine is a by-product of uranium fission and remains mostly contained within the fuel rods. However, a small quantity of iodine may migrate into the primary circuit water in the event of fuel cladding failure. Iodine present in liquid radioactive effluents is trapped by the treatment systems, and a short half-life means that it disappears quickly.
- Other fission or activation products ('other FP/APs') are formed by the fission reaction, such as caesium-134 and 137, which remain contained in the fuel rods but may migrate, for the reasons mentioned above, or by activation, as in the case of cobalt-58 and 60, manganese-54 and antimony-124. The 'other FP/APs' present in the form of aerosol particles in the 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 FP/APs' are largely contained by the filter- or resin-based treatment systems of the reactor coolant continuous cleanup system and the effluent treatment system.
- Rare gases are produced by fission and remain mostly contained within the fuel rods. However, a small quantity of rare gases may migrate into the primary circuit water for the reasons mentioned above, and end up in the radioactive gaseous effluents. These effluents are discharged to atmosphere after sufficient radioactive decay in storage tanks.

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.

The limit values for radioactive effluent discharges from Gravelines NPP are defined in regulations set out by the Authority for Nuclear Safety and Radiation Protection (Decision No. 2018-DC-0646¹¹).

¹¹ The Authority for Nuclear Safety and Radiation Protection's Decision No. 2018-DC-0646 dated 16 October 2018, setting out the requirements for water abstraction and consumption, effluent discharges, and environmental monitoring, directed at basic nuclear installations Nos. 96, 97 and 122 operated by Électricité de France (EDF) in the Commune of Gravelines.

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 the regulatory limits, is therefore a bounding assessment of the site's actual discharges.

The projected discharges related to the operation of Gravelines 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 Gravelines NPP's radioactive discharges over a 10-year period (average discharges between 2013 and 2022).

Overview of liquid radioactive discharges between 2013 and 2022

	Annual limits (GBq/yr)	Annual average activity released GBq/yr
Tritium	120,000	62,300
Carbon-14	900	48.9
Iodine	0.9	0.038
Other fission and activation products	90	3.19

Overview of gaseous radioactive discharges between 2013 and 2022

	Annual limits (GBq/yr)	Annual average activity released GBq/yr
Tritium	12,000	2,337
Carbon-14	3,300	1,014
Rare gases	108,000	3,563
Iodine	2.4	0.094
Other fission and activation products	2.4	0.0132

5.6.3. Liquid and gaseous chemical effluent discharges

Operating a nuclear power plant requires the use of chemical substances and leads to discharges of liquid chemical effluents (from substances used for circuit conditioning, and for operations in the demineralisation station and the purification plant) and, to a lesser extent, to discharges to atmosphere (from circuit and equipment operation).

In so-called 'open' cooling circuits, such as the one in Gravelines NPP, water treatment is required in order to:

- control the risk of dispersion of pathogenic microorganisms, through preventive maintenance of the circuits, and **biocidal treatments** that inject sodium hypochlorite derived from seawater electrochlorination.

■ **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 respectively to condition the primary circuit in order to control the nuclear reaction and minimise corrosion of materials;
- hydrazine hydrate, injected during the start-up phase to remove oxygen from primary circuit water, and also used in the secondary circuit to maintain a reducing environment and to limit corrosion;
- ethanolamine, used to condition the secondary circuit in order to minimise corrosion;
- sodium, chlorides, ammonium, nitrates, nitrites, adsorbable organic halogens on activated carbon, total residual chlorine, and sulphates from biocide and anti-scaling treatments of cooling circuits.
- metals derived from the presence of impurities in commercial chemicals and from circuit corrosion (aluminium, chromium, copper, iron, manganese, nickel, lead, zinc);
- trisodium phosphate, used for conditioning intermediate cooling circuits;
- commercial detergents, used for routine operations such as cleaning floors and washing the workwear used in nuclear areas;
- iron, sulphates, oxidisable substances (measured by COD – chemical oxygen demand) and suspended matter (SM) from the demineralisation plant
- active chlorine, bromoform and residual oxidants derived from seawater electrochlorination.

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 the plant's operation. The assessment of the impact of the discharges, carried out on the basis of these maximum values, therefore covers the site's actual discharges.

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 to sea (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 derived from plant operations, over a 10-year period.

Substances	Annual flow (kg)	
	Maximum discharge values	Actual discharges (2013-2022 average)
Boric acid	43,500	21,920
Phosphates	1,404	308
Hydrazine	198	5.6
Ethanolamine	1,920	70(*)
Ammonia	23,210	4,619
Bromoforms	230,000	53,148
Residual oxidants	1,370,000	208,640

(*) Ethanolamine has been in use since 2016 (6-year average)

■ 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;
- ethanolamine and ammonia from the conditioning of the secondary circuit during reactor shutdown phases, when secondary-circuit steam is discharged to atmosphere, bypassing the turbine.
- ammonia from the extraction system for non-condensable gases from the secondary circuit, when the condenser is kept under vacuum;
- diffuse emissions of refrigerants and SF₆ used respectively in chiller units (for the production of chilled water and for cooling technical and administrative facilities) and in the site's power transmission switchyards. These emissions are quantified during maintenance operations in these installations.

5.6.4. Thermal discharges

The Gravelines NPP condensers are cooled by way of an 'open' circuit: cooling water is drawn from the sea via the intake channel, before being released back to sea via the discharge channel.

The temperature-increase between the water intake and discharge, generated by the power plant, was on average 9.7°C between 1 November and 31 May, and 8.7°C between 1 June and 31 October, during the period 2011-2020, with a maximum recorded value of 12°C.

The temperature at the far end of the discharge channel averaged 21.1°C between 1 November and 31 May, and 28°C between 1 June and 31 October, with a maximum recorded value of 34.6°C.

The temperature measured by thermograph 7 was on average 11.5°C between 1 November and 31 May, and 18.8°C between 1 June and 31 October, with a maximum recorded value of 28.3°C.

Thermal discharges are governed by regulations that limit increases in the temperature of the water between the intake and discharge structures.

Thermal discharge limits for Gravelines NPP		
Temperature difference between intake and discharge (thermograph 11 at the far end of the channel)	≤ 12°C	
Temperature at the far end of the discharge channel	30°C from 01/11 to 31/05	35°C from 01/06 to 31/10
Temperature at sea (thermograph 7 installed around 700 m from the shore)	< 30°C	

5.6.5. Waste production

The operation of Gravelines 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.), and from fuel handling operations (clusters, fuel rod capsule-canisters, skeleton assemblies, etc.).

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 (paint, oil waste, asbestos, 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	 VSL Management by decay	 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		 LILW-SL Surface disposal (Centre de l'Aube and Centre de la Manche disposal facilities)	 LLW-LL Near-surface disposal under examination
Intermediate Level Waste (ILW) a million Bq/g to a billion Bq/g			 ILW-LL Deep geological repository under development (Cigéo project)
High Level Waste (HLW) several billion Bq/g	Not applicable	 HLW Deep geological repository under development (Cigéo project)	

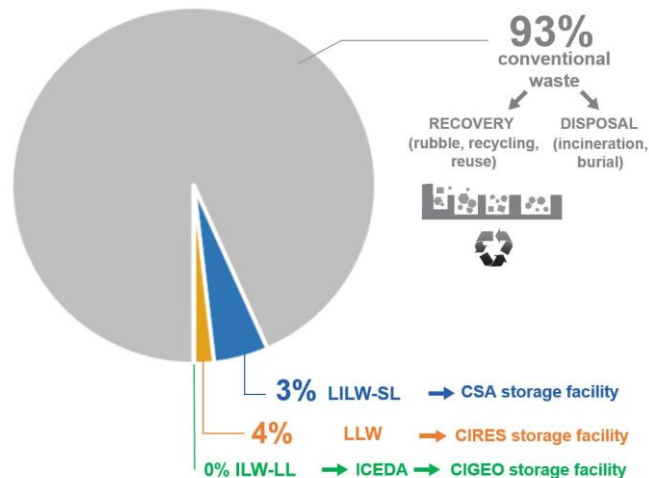
* The half-life of the radioactive material (radionuclides) in the waste to decay.
** The level of radioactivity of the radioactive waste.

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 Gravelines NPP generate conventional waste (93% of total waste produced) and radioactive waste (7% of total waste produced).



Breakdown of waste categories and waste disposal routes for waste generated by Gravelines NPP operation

The following table presents an overview of the radioactive waste produced by Gravelines 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 Gravelines NPP over the next ten years is of the same order of magnitude as that produced over the reference period.

Radioactive waste	Average annual waste-package volume (m ³) (average for 2013-2022)	Projected average annual waste-package volume (m ³) (average for 2025-2028)
Solid VLLW for storage at CIRES*	496	560
Solid SL-ILW for storage at CSA (Aube Disposal Facility**)	525	494
Solid SL-LLW for direct storage at CSA	225	302
Solid SL-LLW for processing (melting)	44	38
Solid SL-LLW waste for processing (incineration)	680	740
Liquid SL-LLW for processing (incineration)	7	6.5

5.6.6. Noise and vibration emissions

Gravelines NPP conducts a noise emission measurement campaign every ten years. The noise emission measurement campaign carried out in 2015 concluded that noise levels comply with the targets set by regulations. The Gravelines site 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 outside.

5.6.7. Land use

There are no plans for any changes in the land area required for operating Gravelines NPP's 6 reactors over the next ten years.

5.6.8. Other interactions

Other interactions between Gravelines 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.

5.6.9. Ten-year projection of interactions between Gravelines NPP and the environment

The past and current interactions between Gravelines NPP operation and the environment were presented in Subsections 5.6.1 to 5.6.8 above.

As shown in the table below, the interactions between 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	Gravelines NPP's requirements are covered by seawater and groundwater abstraction, and by the Dunkirk Public Water Authority's distribution networks. Regulated (groundwater) abstraction has always remained below stipulated limits (Decision No. 2018-DC-0647) ¹¹	There are no plans to change the sources of water supplies. Over the next ten years, the projected volumes abstracted for purposes of Gravelines plant operation will remain of the same order of magnitude as during the previous decade, and within regulatory limits.
Liquid radioactive effluent discharges	The radioactive effluent discharge point is at sea, via the discharge channel. The discharges are regulated by Decision No. 2018-DC-646 ¹² .	There are no plans to change the discharge point at sea. Over the next ten years, the projected volumes discharged for purposes of Gravelines 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. The discharges are regulated by Decisions Nos 2018-DC-0646 ¹² and 2018-DC-0647 ¹¹ .	There are no plans to change the sites of discharges to atmosphere. Over the next ten years, the projected discharges for purposes of Gravelines plant operation will remain of the same order of magnitude as during the previous decade, and within regulatory limits.
Chemical effluent discharges	Liquid chemical effluent discharges are regulated by Decisions Nos. 2018-DC-0646 ¹² and 2018-DC-0647 ¹¹ .	Over the next ten years, the projected liquid chemical effluent discharges for purposes of Gravelines 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 seawater between the intake and discharge structures, the temperature of seawater at the far end of the discharge channel, and the temperature of seawater at the discharge point.	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: 496 Low level waste: 956 Intermediate level waste: 525	The projected volumes of radioactive will remain of the same order of magnitude as the volumes of waste generated during the previous decade.

Interaction with the environment	Past operation	Ten-year projection
Noise emission	Gravelines 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, but temporary noise and vibrations may be caused by possible modification and construction work.
Land use	The Gravelines site covers an area of 152 hectares.	There are no plans for any changes to the land surface required for operating Gravelines NPP's six 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 Gravelines 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 (dispersion of pathogenic microorganisms, 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 Gravelines NPP and the environment will remain similar in the next ten years to those of the previous decade.

The environmental effects of Gravelines NPP operation are presented by area (Subsections 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 (see Section 1.2) is provided in Section 5.7.10.

5.7.1. Air and climate factors

■ *Impact on climate*

Nuclear power generation produces very little carbon dioxide (CO₂), 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 CO₂**. 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 Gravelines 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 clusters of traffic and various human activities (heating, industrial emissions).

Among the chemical discharges to atmosphere from the Gravelines site, 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 impact on air quality.

With regard to those substances that are not regulated by an air quality standard (such as formaldehyde, ammonia, ethanolamine, refrigerants and SF₆), their concentrations in the environment attributable to Gravelines NPP are not likely to degrade air quality.

Gravelines NPP operation is aligned with the measures of the interdepartmental Air Protection Plan (APP) [PPA] for Nord-Pas-de-Calais, and with those of the Hauts-de-France Regional Blueprint for Planning, Sustainable Development, and Regional Balance and Equality [SRADDET].

AIR PROTECTION PLANS [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].

The interdepartmental APP for Nord-Pas-de-Calais was approved by prefectural decree on 1 July 2014. The Gravelines power plant is covered by this APP, which specifies an action plan comprising 14 regulatory measures, 8 voluntary supporting measures, and 4 studies.

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].

The process of developing SRADDET began in late 2016 and culminated in an order regulating the project scope, which was issued by the Regional Council in January 2019, and approved by prefectural decree on 4 August 2020 after a public inquiry.

SRADDET Hauts-de-France comprises three commitments broken down into 13 strategic guidelines that set out the objectives and rules of SRADDET.

■ ***Climate change sensitivity***

Local projections by Météo-France of the main climate factors show an upward trend in future average annual air temperatures, with temperature increases that may exceed +3°C by 2071-2100, compared with the historical period of 1986-2016.

Apart from a slightly greater need for cooling in tertiary and industrial premises, the climate changes presented above do not alter the outcome of the analysis of the impact on air quality and climate of Gravelines NPP's discharges to atmosphere.

5.7.2. Surface water

■ ***Impact on hydrology***

Gravelines NPP is sited on the coast, and the water used for its operation flows through two channels: the intake channel and the discharge channel. This operating mode has no significant impact on the hydrology of the transitional water body 'Port de Dunkerque' (FRAT04).

With regard to the coastal water body 'De Malo à Gris Nez' (FRAC02), the power plant discharges part of its black and grey water, after treatment, into the Hemmes-Saint-Pol watergang, which in turn discharges into the canalised section of the Aa River, near its mouth at the North Sea. The influence of plant operation on the hydrology of the canalised section of the Aa is minimal compared to natural variations due to tidal ranges.

■ **Impact on surface water temperature**

The variations in surface water temperature caused by discharges from Gravelines power plant were analysed using data from infrared thermography inspections and digital modelling.

The impact of thermal discharges on surface waters is limited given the size of the receiving environment and the tidal effects. Owing to the changing location of the thermal plume, the areas subject to thermal discharges are not permanently exposed. Increased temperatures generated by the power plant are mainly observable in surface waters, with deeper areas remaining unaffected.

■ **Impact on morphology-sedimentology**

Liquid effluents are discharged after transiting through the discharge channel. The impact of plant operation on the morphology and sedimentology of the coastal area is minimal given the natural changes in sea currents caused by tides. Furthermore, the power plant does not carry out any dredging in either the intake or discharge channel, and therefore does not conduct any sediment release/disposal into the natural environment that could affect underwater depth and/or the quality of benthic habitats. In view of these factors, Gravelines power plant has no observable impact on the morphology and sedimentology of the coastline.

■ **Impact on surface water quality**

Retrospective analysis of all the results of environmental monitoring around Gravelines NPP, in terms of chemical and physical-chemical readings, and measurements in the different biological compartments, does not reveal any plant impact on the marine ecosystem.

Monitoring of chemical compounds in the environment around Gravelines power plant focuses on substances produced by electrochlorination: residual chlorine, haloforms (bromoform, dichlorobromomethane, monochlorodibromomethane) and bromophenols. Analysis of all these parameters leads to the conclusion that there is no significant spatial or temporal occurrence resulting from plant operation.

Physical-chemical monitoring focuses on salinity and nutrient salts (ammonium, nitrates, nitrites, phosphates, silicates). Retrospective analysis of physical-chemical parameters does not reveal any impact on the marine ecosystem.

Biological monitoring of plankton (phytoplankton, zooplankton, halophilic vibrios), intertidal benthos and fish stocks (sprats, sole, brown shrimp) does not indicate any plant impact on the environment or shows that the impact of the plant's discharge plume remains geographically limited.

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

5.7.3. Soil and groundwater

■ **Impact on soil**

The development of the site has altered its topography and geology, and has anthropised the entire surface area. In 2016, a study was conducted of historical and environmental data for Gravelines NPP.

It was based on documentary research, staff testimonials, and plant walkdowns. This made it possible to draw up an inventory of past and current activities, to locate these activities, and to assess their level of risk in relation to soil and groundwater.

In 2016, soil investigations were also carried out around the water tank for reactor pool 5 where, in 1986, 600 m³ of water spilled onto the ground through a breach in the tank lining. These surveys revealed residual traces of cobalt-60 and caesium-137 in the soil.

Following on from the analysis of historical data, soil investigations (geological drilling for chemical and radiological analysis) were carried out in 2019, in the areas identified as being at risk.

The radiological analyses did not find evidence of contamination in the surveyed areas. The chemical analyses showed that the samples taken were consistent with the anthropogenic background levels adopted for the target parameters. However, higher concentrations of trace metals (heavy metals) were measured at a few sampling points. Soil samples from underlying horizons revealed no anomalies at depth. These higher concentrations are therefore localised,

isolated and infrequent. These findings led to the implementation of enhanced monitoring programmes, and action plans to restore the soil and to realign groundwater and soil concentrations with the NPP's background levels. Some piezometers are still operating under the enhanced groundwater monitoring programmes.

■ *Impact on groundwater*

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

Since it began operating, Gravelines NPP has been monitoring the quality and quantity of the target groundwater 'Quaternary sand aquifer'. Radiological monitoring of groundwater between 2015 and 2020 showed that surveillance thresholds had been exceeded within the engineered confinement structures. Additional groundwater surveys were initiated to determine or confirm the origin of the various radiological markers that had been identified. Apart from the engineered confinement structures, no threshold values had been exceeded elsewhere. The necessary measures have been implemented to limit the environmental impact of these threshold-value overruns at the Gravelines power plant and at the hydrogeological downstream of the site.

The results of the chemical analyses showed that the samples taken were in compliance with the anthropogenic background levels adopted for the target parameters.

Groundwater is pumped for testing and periodic maintenance of ultimate emergency system pump flow. However, given the productivity of the aquifer and the one-off nature of these pumping operations, there is no significant impact on water resources.

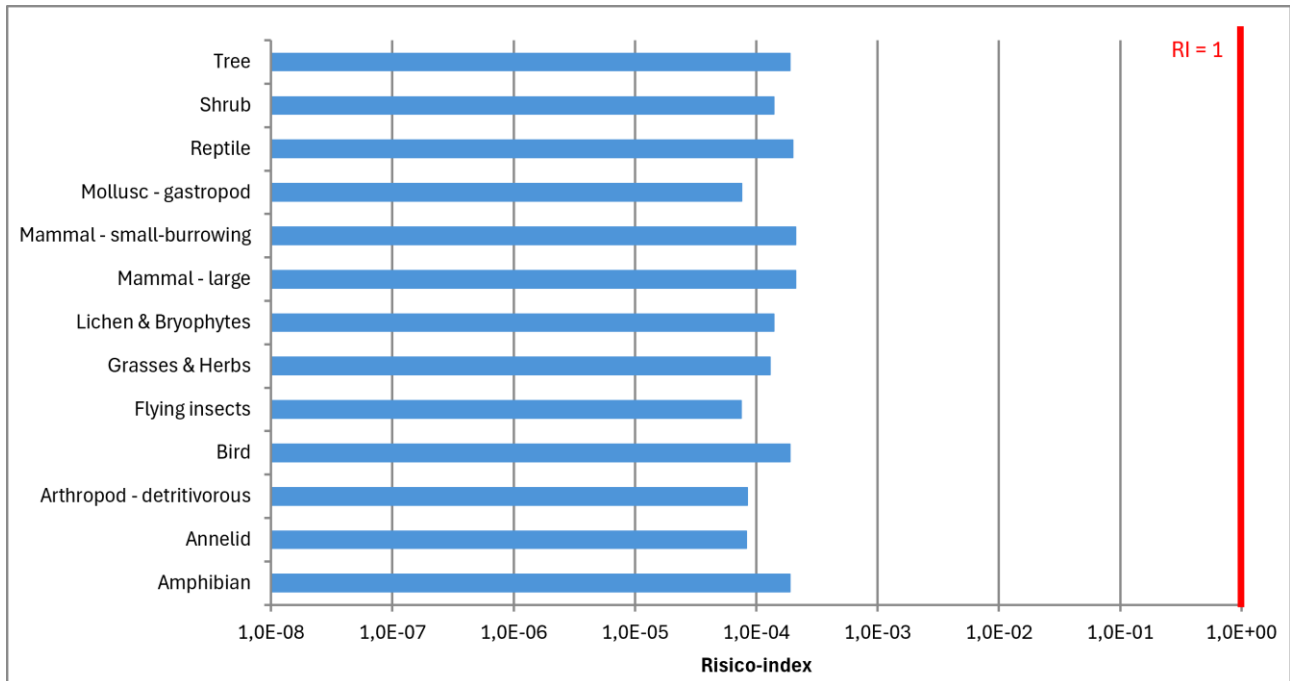
During civil engineering works, it may be necessary to pump water from the bottom of an excavation. Groundwater may also be extracted for possible groundwater remediation purposes. Given the occasional nature of these pumping operations, they have no significant impact on water resources.

In light of the groundwater flow towards the sea, and the protection provided by the engineered confinement structures, the operation of the NPP has no impact on groundwater outside the plant's footprint. What is more, there is no groundwater abstraction - for drinking water, agricultural or industrial purposes - at the hydrogeological downstream of Gravelines power plant.

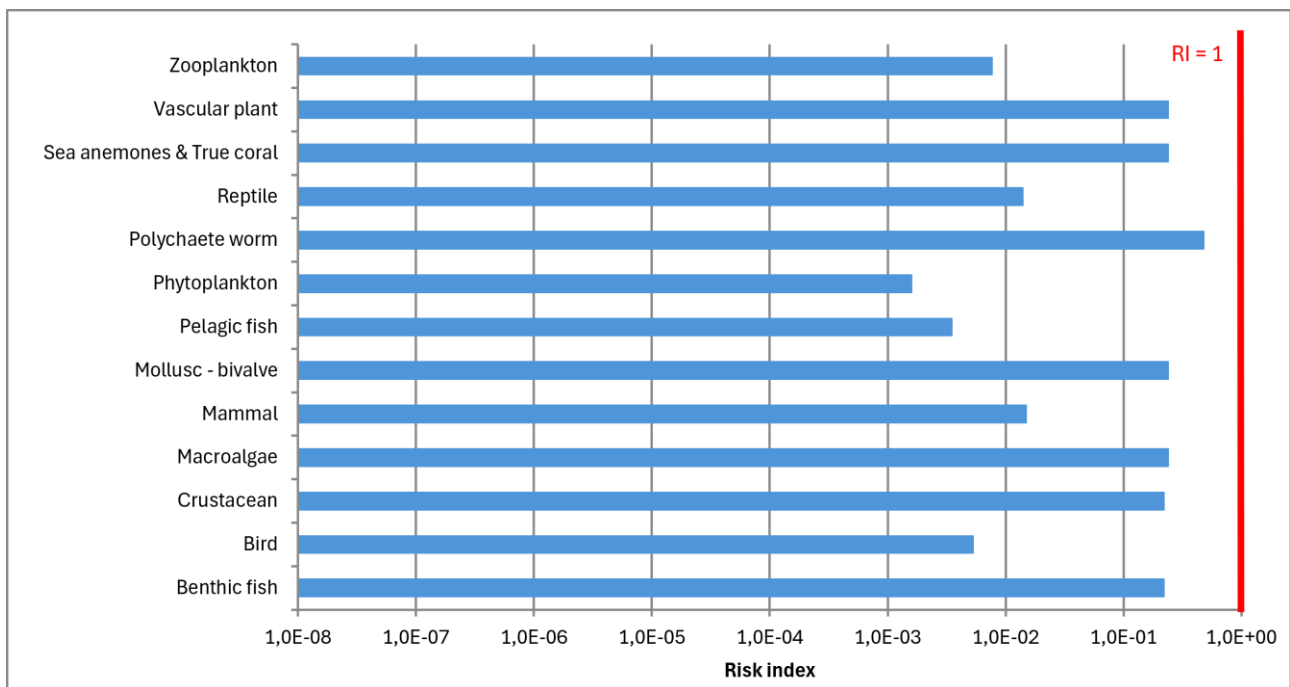
5.7.4. Radioecology

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 the Gravelines site is negligible, both now and for the next ten years.

5.7.5. Biodiversity

The analysis of the impacts of Gravelines NPP operation on air, climate factors, the radiological status of the environment, topsoil and subsoil, and the aquatic environment of the North Sea, as presented in the preceding

sections, does not indicate any significant plant impact on the ecological characteristics required to foster biodiversity in the study area.

By reason of these factors, and in view of the avoidance, reduction and compensation measures implemented for the nesting colony of Common Terns under the order of 28 October 2019, the analysis does not show any significant plant impacts on natural areas of special interest, fauna, flora or ecological functions. Furthermore, based on current knowledge, the operation of the power plant does not hamper the ability of the marine invertebrate and fish species identified in the study area to successfully complete their biological cycles.

What is more, Gravelines power plant does not undermine in any way the objectives defined in the management plans of the Natura 2000 sites (the Documents of Objectives, DOCOB).

5.7.6. Population and human health

■ *Evaluation of the dose impact on man*

The overall impact of radioactive effluent discharges from Gravelines 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 the most exposed.

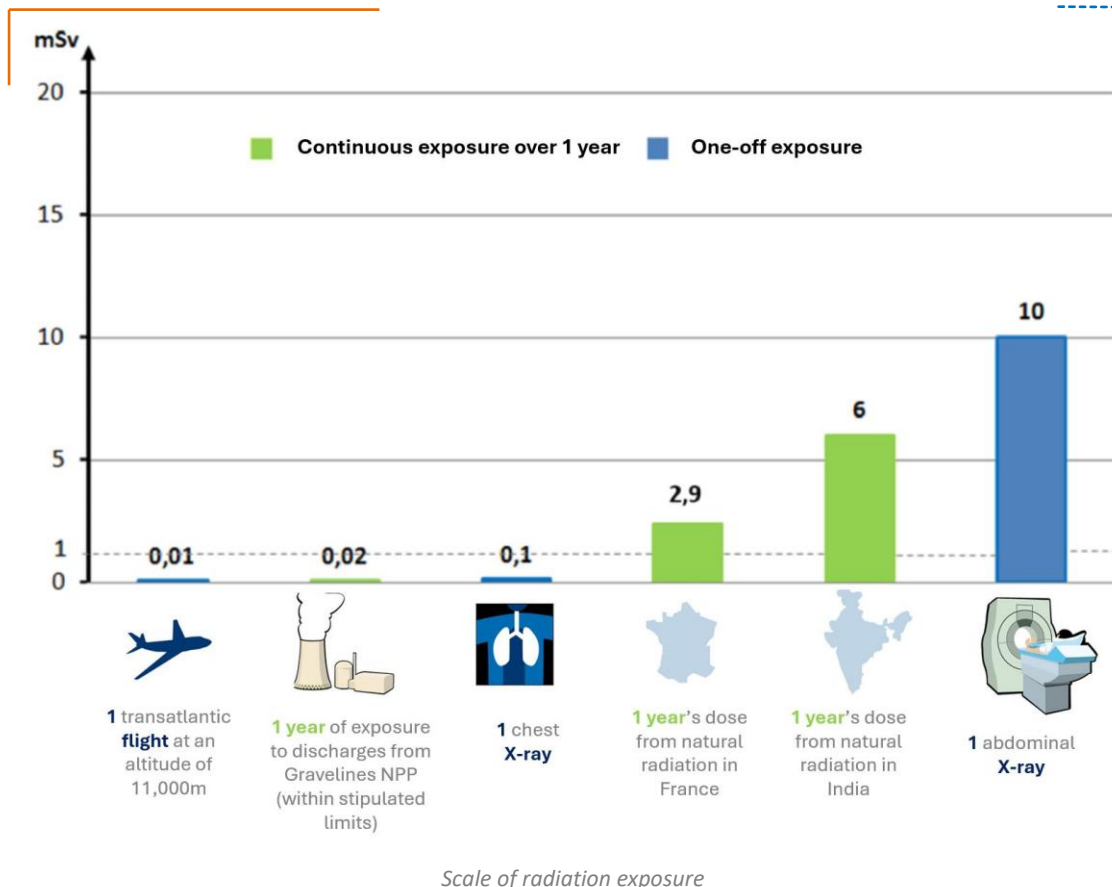
The **effective dose** measures the biological effect of radioactivity. It is expressed in sieverts (Sv), or more commonly in millisieverts (mSv) or microsieverts (μSv).

The 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 0.019 mSv/year;
- For a 10-year old child, at 0.01 mSv/year;
- For a 1-year old child, at 0.001 mSv/year.

Each of these doses represents less than 2% 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.



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

It was found that the current discharges from the Gravelines site have no impact on the chemical status of the North Sea.

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 Gravelines power plant, for neighbouring populations potentially exposed to substances through consumption of seafood or inadvertent ingestion of seawater when swimming, nor any health risk due to chemical discharges to atmosphere for neighbouring populations potentially exposed to substances through inhalation.

■ **Evaluation of the impact of noise and vibration**

In 2015, a noise emission measurement campaign was conducted in the area surrounding the power plant; it concluded that noise levels conform to the limits set by the regulations. In addition, plant operation causes 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. Civil engineering works, and road and utility works, which are sources of vibration, are carried out inside the site, for a limited period of time, and take place during daytime working hours on working days, which restricts any potential disturbance.

The existing facilities therefore do not cause any disturbance for neighbouring populations.

■ **Evaluation of the impact of light emissions**

Light emissions from the site are mainly related to site security lighting (intruder protection system, aviation obstruction lighting, etc.). They are therefore essential; their visual impact outside the site is minimised by the angle of the lighting. The impact of these light emissions is negligible.

5.7.7. Human activities

■ *Evaluation of impacts on land uses*

The assessment of the health impact of radioactive and chemical discharges from the Gravelines site does not reveal any health risk, attributable to the operation of the power plant, for potentially exposed neighbouring populations. This leads to the conclusion that there is no significant impact on land use, and on agricultural land and assets in particular (residential areas, industrial areas, etc.).

■ *Evaluation of impacts on landscape and cultural heritage*

Gravelines power plant has been in situ for over 40 years and is now part of the landscape. The operation of the Gravelines site 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*

Gravelines NPP operation gives rise to various requirements for water supplies, the most important of which is for condenser cooling. However, water abstracted from the sea for cooling purposes is returned to the environment. The health impact assessment of liquid radioactive and chemical discharges (including in relation to swimming and seafood ingestion) does not reveal any health risk, attributable to the operation of the Gravelines site, for potentially exposed neighbouring populations. Gravelines NPP operation therefore 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*

The volume of traffic generated by the power plant accounts for 61% and 6% (light vehicles and heavy goods vehicles) of the total volume of traffic on the N316 and A16 roads, respectively. Light vehicle traffic generated by the Gravelines power plant therefore represents a significant proportion of the traffic flows on nearby road infrastructure. However, the roads used are designed to accommodate these volumes of traffic. In addition, Gravelines power plant generates around 20 rail freight transport operations per year (fuel removal), representing around 1% of the total traffic on the rail network for the Grand Port Maritime de Dunkerque (GPMD). Finally, Gravelines NPP has never carried out any dredging operations and therefore has no impact on maritime traffic.

■ *Evaluation of impacts on the industrial environment*

For over 40 years, Gravelines power plant has been sited in a designated area for economic and industrial development. The plant has contributed to the area's development by supplying warm water to nearby companies:

- Dunkerque LNG, which operates the Dunkirk LNG terminal;
- Aquanord Ichthus, owner of an aquaculture farm located along the discharge channel and a sea-bass hatchery 0.6 km south-west of the plant.

■ *Evaluation of impacts on recreation areas and leisure activities*

The health impact assessment:

- of radioactive liquid and atmospheric discharges (including food ingestion, fishing, external and internal exposure related to swimming, etc.),
- and liquid chemical discharges and chemical discharges to atmosphere (related to fishing and swimming),

does not reveal any health risk, attributable to Gravelines NPP, for potentially exposed neighbouring populations.

Gravelines NPP operation therefore has no impact on recreation areas and leisure activities.

■ *Evaluation of impacts on energy consumption*

Gravelines power plant generates over 30 billion KWh of electricity every year, in other words, 60% to 70% of the electricity needs of the Hauts-de-France region, or the electricity consumption of over 6 million households. For its own electricity requirements, the site uses less than 5% of its output, equivalent to around 0.3% of regional consumption. The power plant's 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, facility maintenance, waste storage and logistics activities, Gravelines NPP generates two categories of waste: radioactive waste and conventional waste.

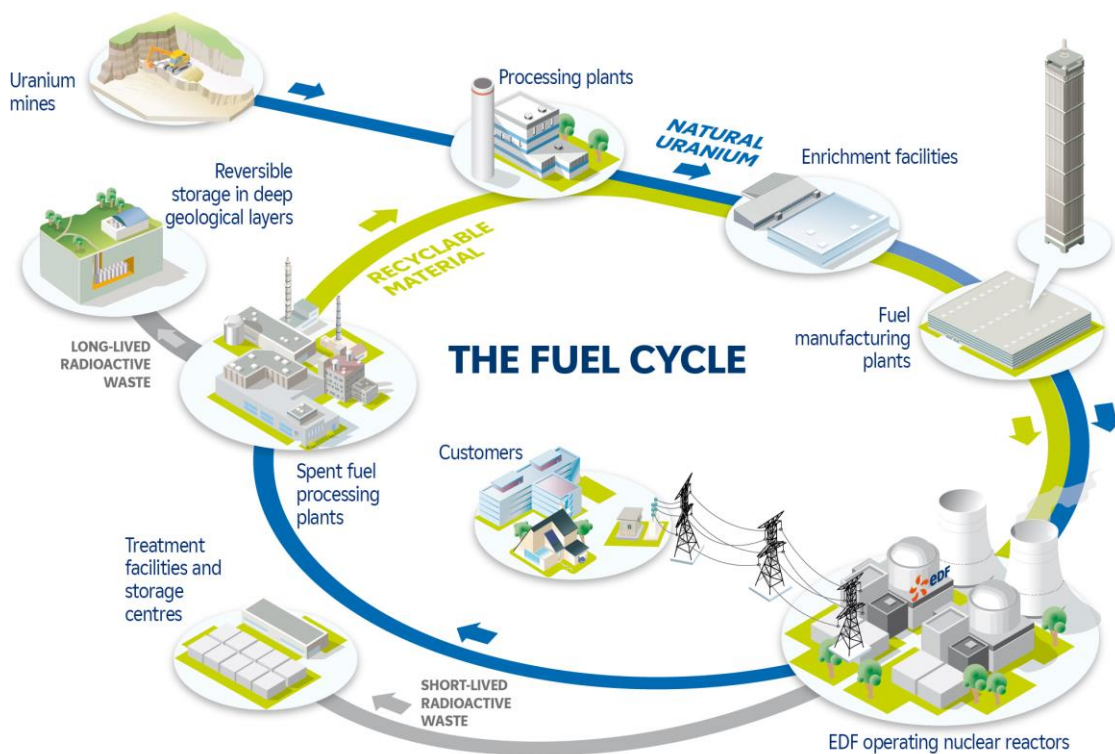
- Radioactive waste is classified by its level of activity and by the lifespan of the radionuclides it contains. It may be derived from:
 - the treatment of radioactive effluents: filters, activated carbon, evaporation concentrates, water filters, ion exchange resins sludge, etc.;
 - fuel handling operations: 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. These 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 site's conventional waste transit area, and then removed after being checked at the C3 portal monitors (radiological monitoring equipment at site exit points, used to check for contamination).

Gravelines NPP uses two types of waste streams for conventional waste: disposal and recovery.

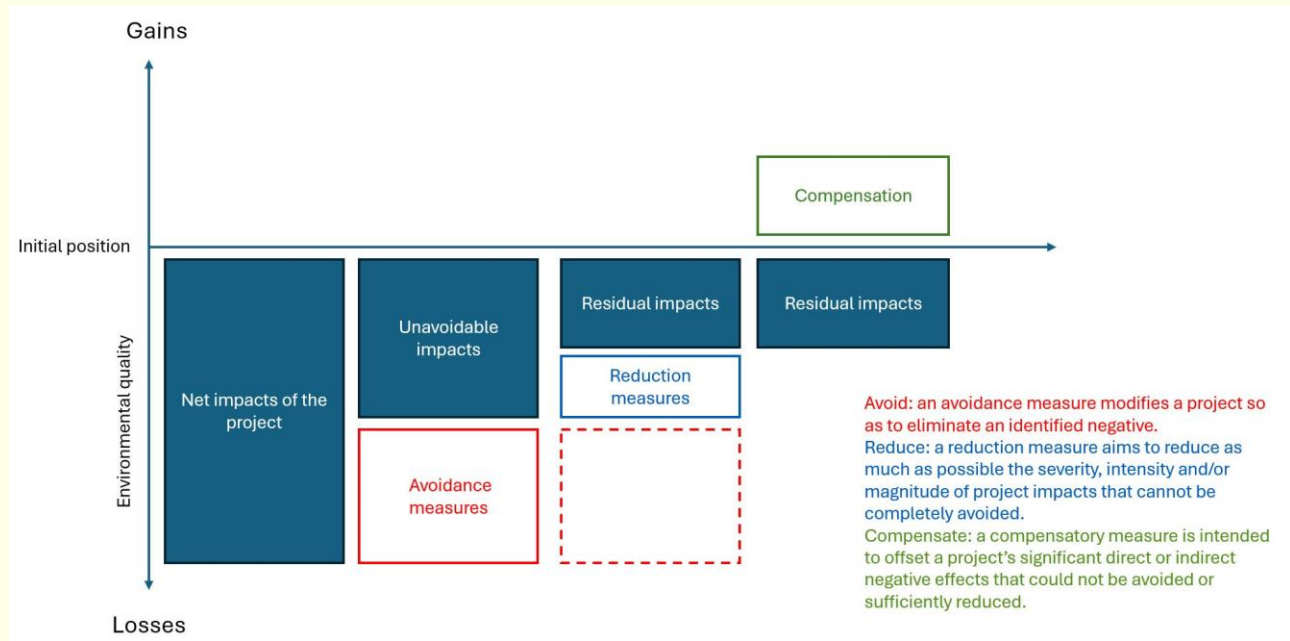
The choice of stream takes into account the following three principles:

- 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

Measures have been taken on site to limit gas emissions:

- With regard to diesel engine operation: implementation of an optimised maintenance programme, use of very low sulphur fuel oil and of water- and glycol-based antifreeze, and running engines only when necessary.
- With regard to limiting greenhouse gases:
 - in relation to plant operation: implementation of a corporate leak management plan for SF₆, a gas used as an electrical insulator in electrical equipment,
 - in relation to staff transport: introduction of bus routes to transport staff from their homes to the power plant, provision of a fleet of electric vehicles for work-related movement around the site, incentives for service providers to adopt electric vehicles to travel to the plant, and restrictions on vehicle traffic on site.

Surface water

For several years now, Gravelines NPP has been taking measures to reduce industrial water consumption by optimising the use of demineralised water in various circuits in the facility, particularly during reactor shutdown and startup phases, which require large volumes of water.

The plant is also taking steps to optimise its effluent management processes by reducing production at source, by collecting and separating effluents, by treating effluents in high-performance facilities, and by optimising circuit conditioning with a view to keeping the use and subsequent discharge of chemical substances to the absolute minimum, ensuring compliance with regulatory provisions, and fostering the involvement of all stakeholders.

In addition, so as to reduce the impact of thermal discharges, adjustments are made to reactor operation, in full compliance with regulatory requirements, particularly in response to weather events such as heatwaves. If necessary,

the plant downpowers in order to ensure that the water temperature at the discharge point, the temperature of the seawater, and increases in North Sea water temperature, all remain below regulatory limits.

■ **Soil and groundwater**

Gravelines power plant is committed to minimising the risk of chemical and hydrocarbon spills into soil and groundwater.

The storage and use of hazardous products is strictly regulated, and all necessary precautions are taken during storage to prevent any accidental releases into the environment (retention tanks, transfer to sealed areas). Environmental spill kits are on standby at strategic locations for deployment in the event of a spill.

■ **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 (e.g. ion exchange resins);
- 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**

As set out above, the analysis of the consequences of Gravelines NPP operation does not reveal any impacts on fauna, flora or habitats, beside specific provisions for the Common Tern.

With regard to the Common Tern, the power plant implements targeted impact avoidance, reduction and compensation measures, as stipulated by the prefectural order of 28 October 2019: environmental support during the construction phase of the flood protection project (MS1), environmental support for plant monitoring and maintenance activities (MS2), ecological monitoring of Common Tern nesting activities (MS3), and participation in the Common Tern Nesting Monitoring Committee (MS4).

■ **Population and human health**

The impact avoidance and reduction measures for discharges to atmosphere and to 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 levels are measured during the surveillance testing of certain equipment contributing to nuclear safety. 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 light pollution: projectors are angled if possible towards the site and towards the ground, and within and outside working hours, lighting is limited to the strict minimum needed for site perimeter security.

■ **Human activities**

Gravelines NPP is designed to minimise its impact on human activities in the surrounding area.

■ Waste management

Gravelines NPP is structured to ensure optimised waste management based on:

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

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 CO₂ 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 CO₂ for the European electricity mix (<https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/chiffres-cles-du-climat-2024/fr/livre>).

Gravelines power plant produces on average around 30 TWh/year of electricity, emitting less than 120,000 tonnes of CO₂.

Should Gravelines NPP be decommissioned, producing the same amount of electricity using the European energy mix would increase CO₂ emissions by more than 8 million tonnes¹².

¹² Based on the CO₂-absorption capacity of a deciduous forest of around 4 tonnes of CO₂/ha/yr. A forest area of more than 2 million hectares (200 km by 100 km) would need to be planted to offset this additional CO₂ in the atmosphere.



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. 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 has been studied, adopting 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.

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 900 metres from the Gravelines 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 taking into account 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 factors in all the 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.

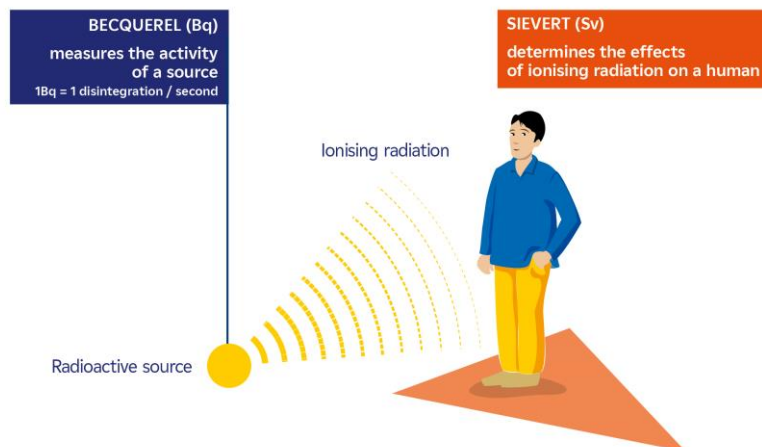
All these dose assessments take into account uncertainties in knowledge. No gaps in knowledge have emerged that would prevent a relevant determination of these doses, the main results of which are presented below.

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.

RADIOACTIVITY MEASUREMENT UNITS



Only the two most commonly used
units are shown here:

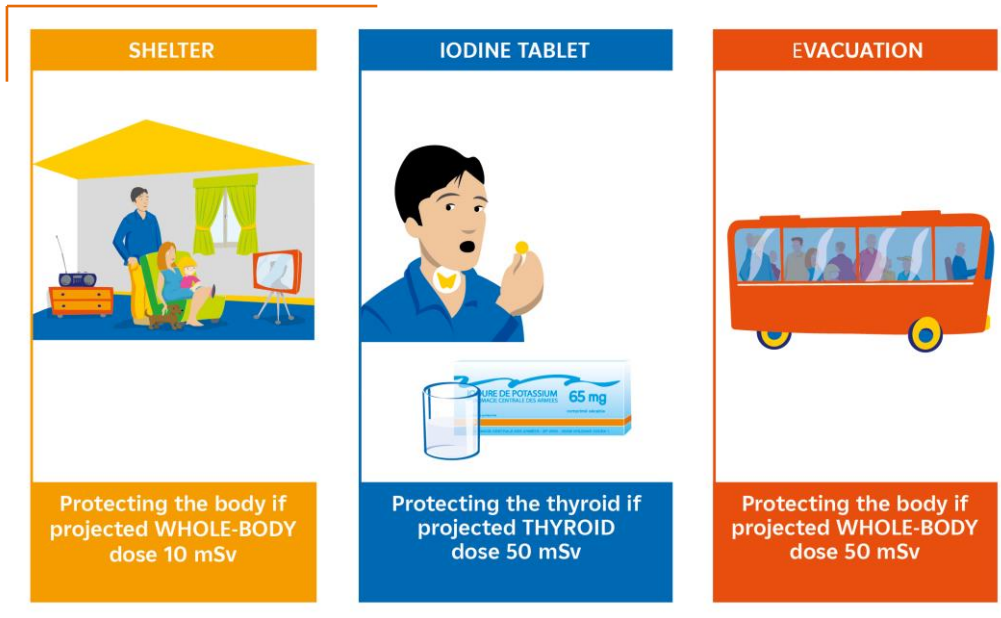
- **The Becquerel (Bq)** measures the activity of a radioactive source, in other words, the number of disintegrations per second. It is an extremely small unit: granite, for example, has an activity per unit mass of 1,000 Bq/kg.

- **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:

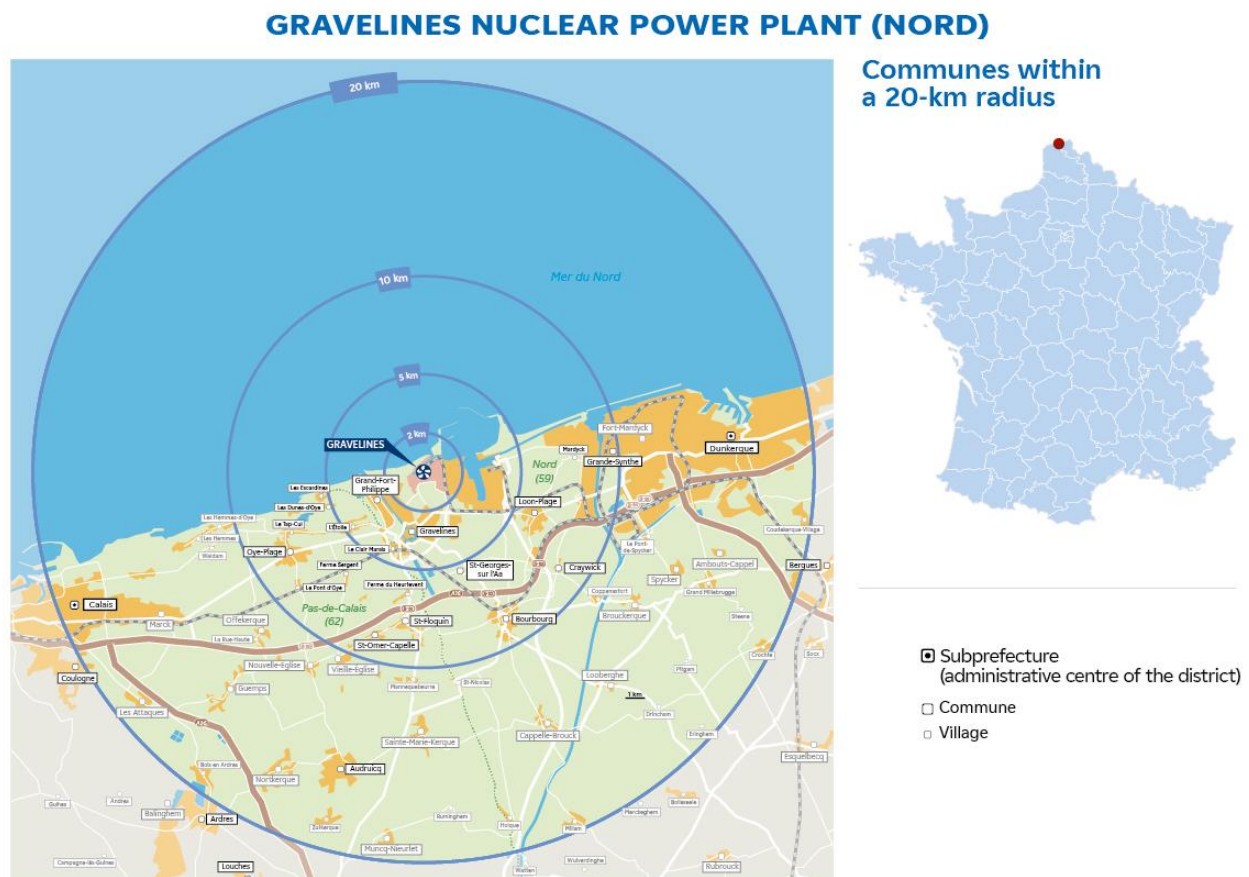
- an effective dose of 10 mSv for sheltering;
- an effective dose of 50 mSv for evacuation;
- a thyroid equivalent dose of 50 mSv for the administration of stable iodine.



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.



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 (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	$5.0 \cdot 10^{-4}$ mSv
Inadvertent opening of a secondary-side relief valve or steam line break	$1.5 \cdot 10^{-3}$ 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)	$5.7 \cdot 10^{-3}$ mSv	$1.0 \cdot 10^{-1}$ mSv
Withdrawal of only one power control rod	$9.1 \cdot 10^{-1}$ mSv	6.9 mSv
Failure of the chemical and volume control system tank	$3.1 \cdot 10^{-2}$ mSv	$3.0 \cdot 10^{-4}$ mSv
Failure of the gaseous effluent storage tank	$1.9 \cdot 10^{-1}$ mSv	$2.0 \cdot 10^{-2}$ mSv
Steam generator tube rupture (SGTR)	$8.9 \cdot 10^{-1}$ 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.

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	$2.0 \cdot 10^{-2}$ mSv	$1.4 \cdot 10^{-1}$ mSv
Blocked rotor on a reactor coolant pump	$4.0 \cdot 10^{-1}$ 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 in order 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 Gravelines 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	$2.3 \cdot 10^{-1}$ mSv	3.8 mSv
Loss of spent fuel cooling	$8.5 \cdot 10^{-3}$ mSv	$1.5 \cdot 10^{-1}$ mSv
Total loss of off-site power (LOOP) or loss of emergency-supplied 6.6 kV AC distribution switchboards	$3.6 \cdot 10^{-2}$ mSv	$2.2 \cdot 10^{-1}$ 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 Gravelines NPP, showing the worst-case results for each country.

These calculations of the long-range atmospheric dispersion of Gravelines 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.

Country	Minimum distance from the source (km)	Bounding long-term total effective dose (mSv)			
		Very young child age bracket [1-2[	Young child age bracket [2-7[	Child age bracket [7-12[	Adult age bracket [17+[
Belgium	30	2.03	2.01	1.86	1.71
United Kingdom	55	0.61	0.59	0.56	0.48
The Netherlands	90	0.82	0.83	0.76	0.73
Germany	260	0.18	0.18	0.17	0.16
Luxembourg	280	0.16	0.16	0.15	0.15
Switzerland	525	0.04	0.04	0.04	0.04
Ireland	595	0.05	0.05	0.05	0.04
Denmark	615	0.10	0.10	0.09	0.09
Austria	665	0.03	0.04	0.03	0.03
Italy	670	0.02	0.02	0.01	0.01
Liechtenstein ¹³	680	0.03	0.03	0.03	0.03
Czech Republic	705	0.05	0.05	0.05	0.04
Poland	830	0.06	0.07	0.06	0.06
Sweden	830	0.09	0.10	0.09	0.09
Norway	850	0.09	0.09	0.08	0.09
Spain	915	0.02	0.02	0.02	0.02
Slovenia	975	0.01	0.01	0.01	0.01
Croatia	1,045	0.01	0.01	0.01	0.01

By way of comparison, an individual's exposure to natural radioactivity in France averages 3 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 approximately 2.0 mSv over 50 years for very young and young children. 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 six 900 MWe reactors at the Gravelines site, 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.

¹³ 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 Gravelines 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 Subsection 2.3.1).

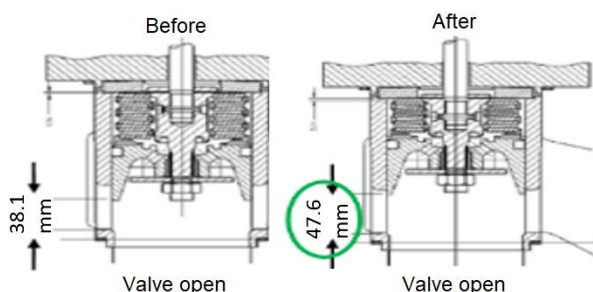
6.3.1. Main measures for non-core-melt accidents

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

- Increased flow rate in atmospheric 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 Gravelines 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 ASNR 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].

- 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 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.

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 Gravelines 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 spread of fire that may compromise the principle of safety function redundancy.

Extreme external hazard conditions

Furthermore, as part of the periodic review of Gravelines 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 Gravelines 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].



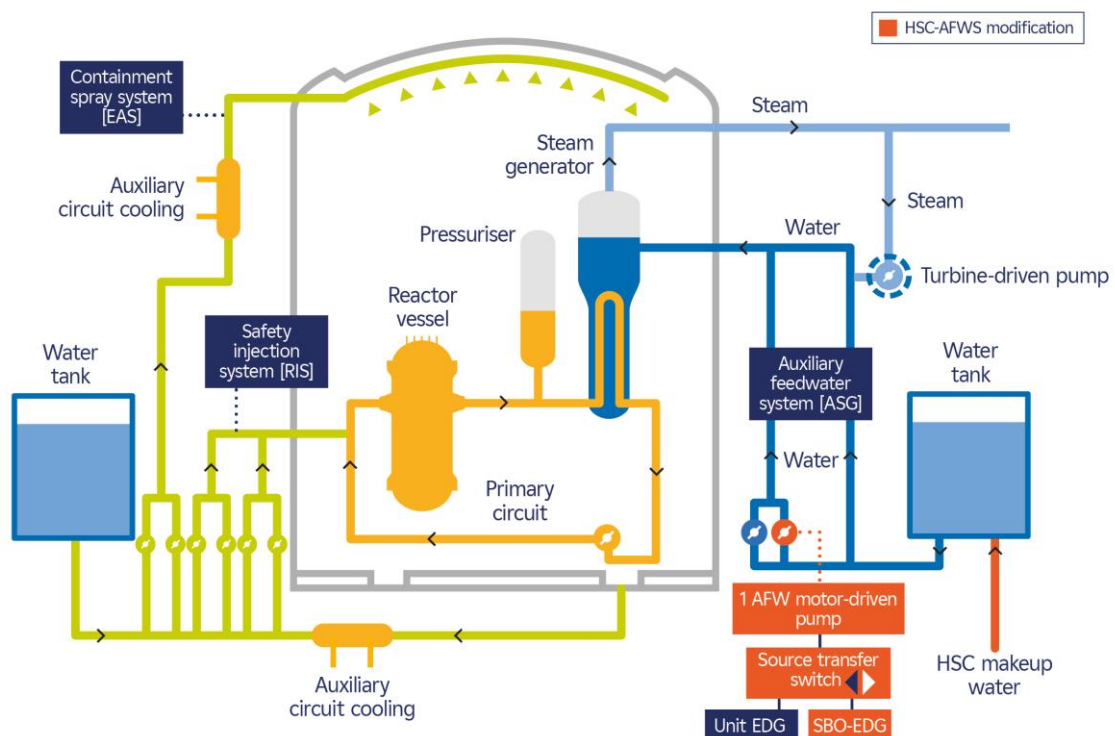
3-MWe station blackout diesel generators [DUS]



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 North Sea). 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 Gravelines 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.

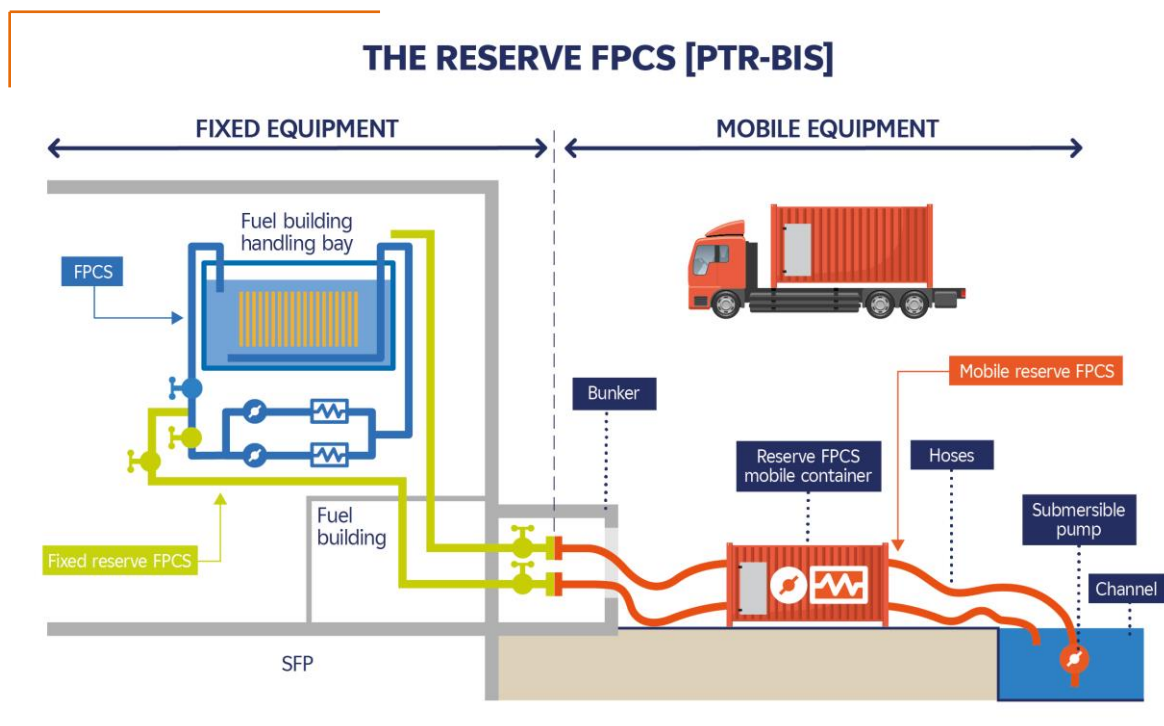
Review of 900 MWe series plants in consideration of FLA3 EPR accident conditions

The assessment of the behaviour of the spent fuel pools in 900 MWe power plants, including for the Gravelines 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 Gravelines 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.

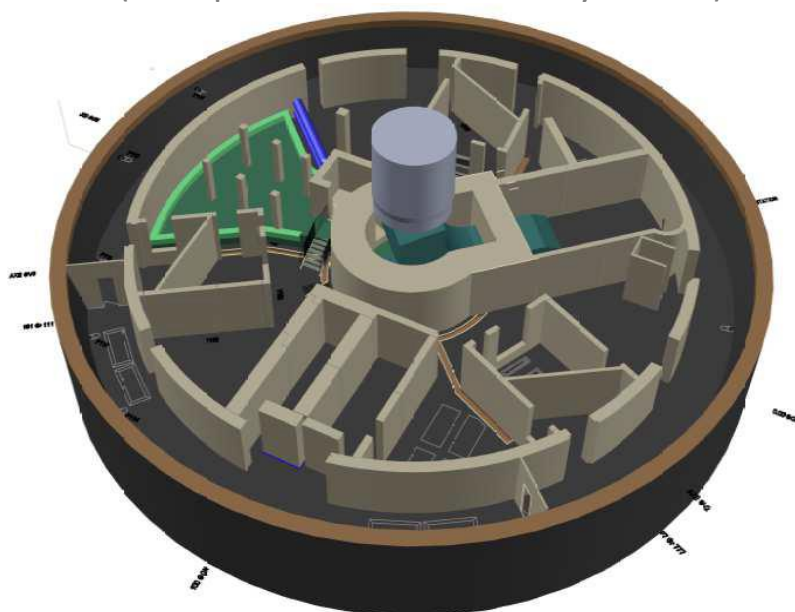
The management of core-melt accidents provides for the 'dry-spreading' of the corium, i.e. without water, at the bottom of the reactor building, the basemat. Spread out in this way, the layer of corium presents a large exchange surface and can be stabilised by the injection of borated water, which will 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).

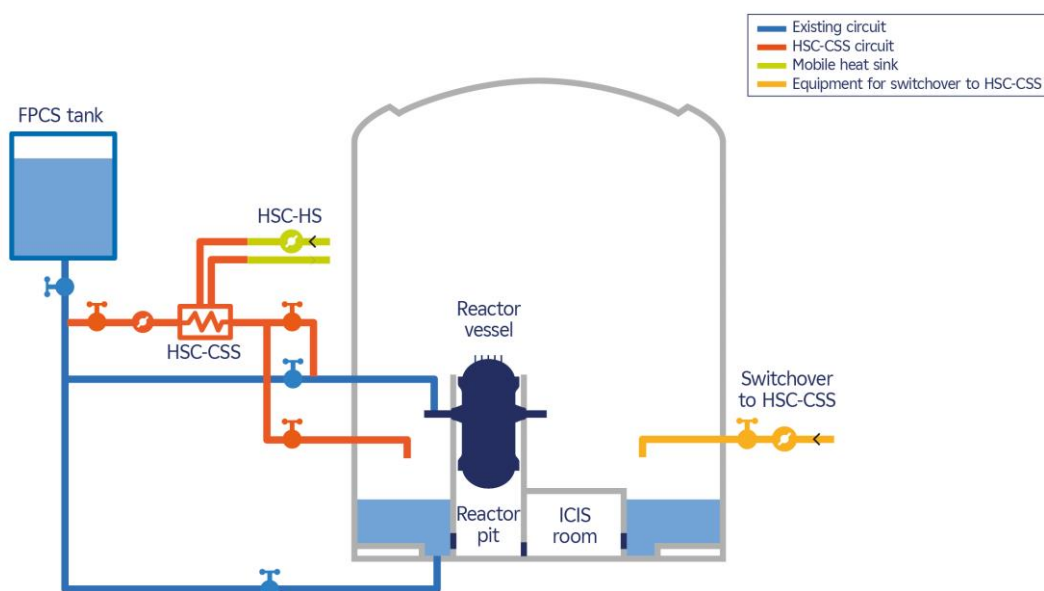
Thus, the measures implemented for the management of a core-melt accident in a Gravelines reactor are the following:

- 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

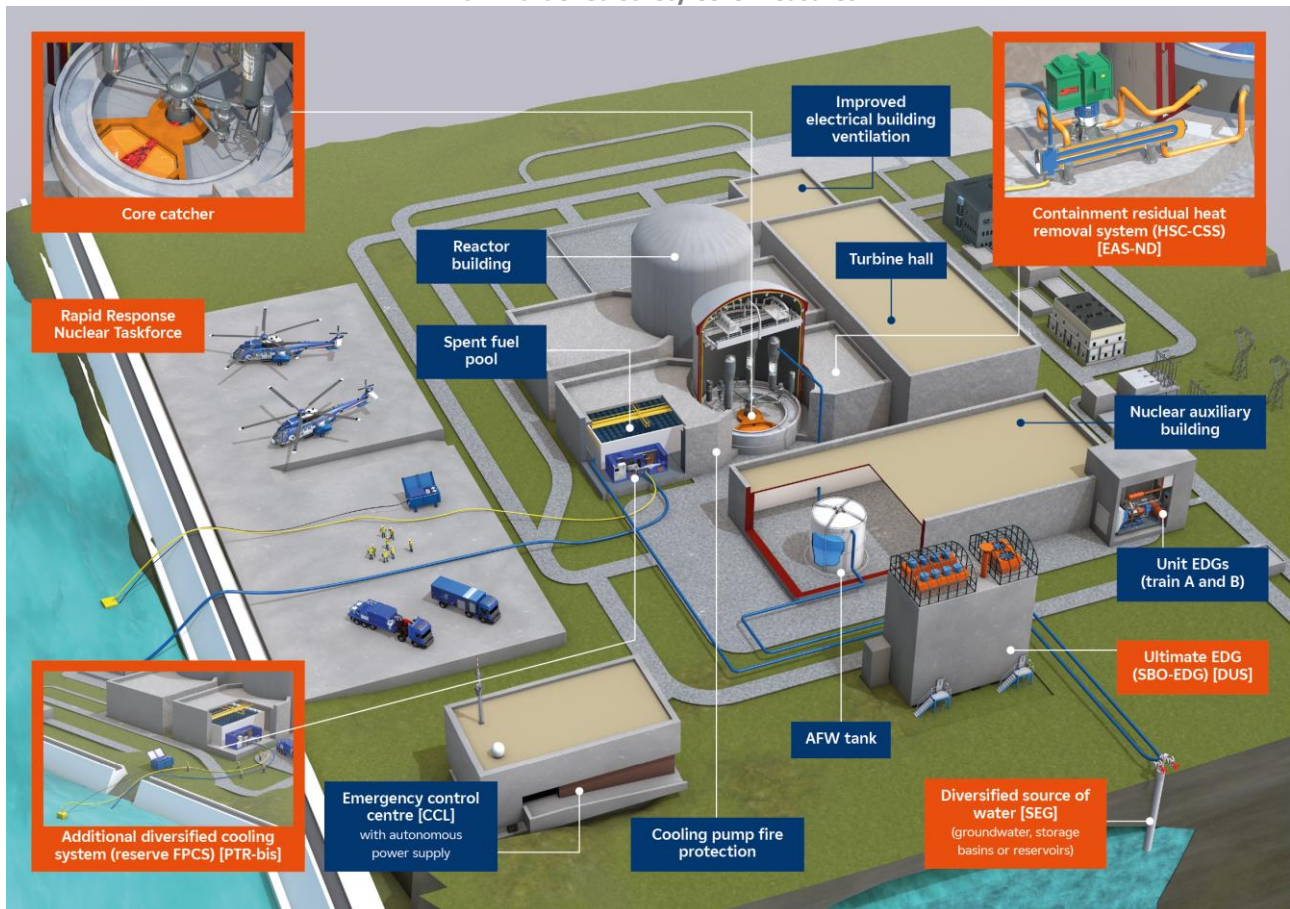


The 'HSC-CSS' [EAS-ND] involves the deployment of:

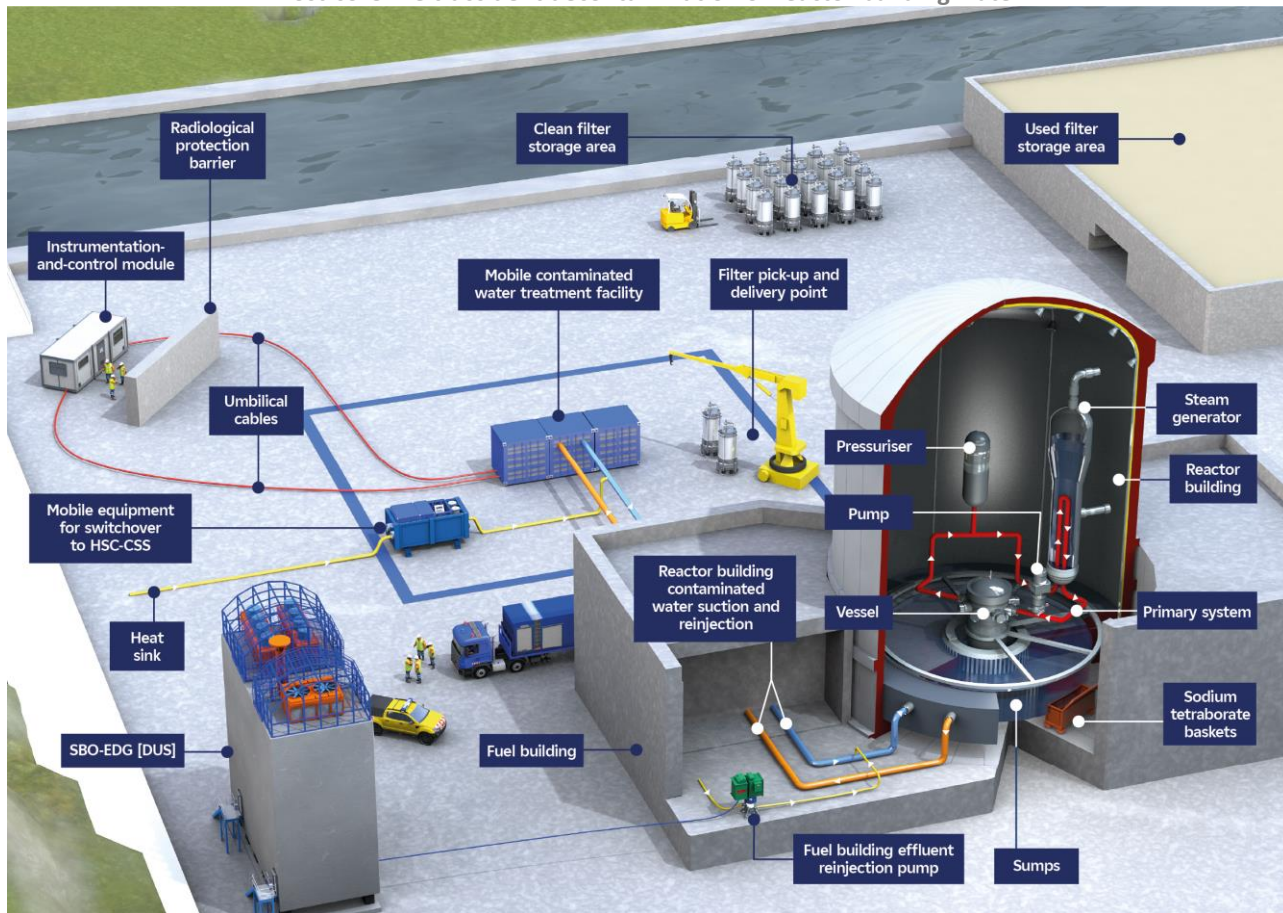
- a pump (powered by the SBO-EDG),
- an exchanger, which removes containment heat,
- a Hardened Safety Core heat sink (HSC-HS) [SF-ND], made up of mobile pumping equipment.

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





7.1. 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 Gravelines 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:

- discharges of sulphur oxides, calculated in particular on the basis of emergency diesel generator fuel consumption, the type of fuel used, the type of equipment, and operating conditions;
- discharges of formaldehyde and carbon monoxide, linked to lagging replacement operations;
- emissions of volatile substances linked to secondary circuit conditioning operations (ethanolamine, ammonia);
- emissions of greenhouse gas and refrigerant.

Gravelines NPP also has a weather monitoring programme, with an automatic weather station (measuring temperature and rainfall) and an acoustic wind sensor (measuring wind direction and speed, and turbulence at altitude).



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Examples of rainfall, temperature and wind measurement equipment ©EDF

■ **Surface water**

Gravelines NPP monitors its chemical discharges primarily through sampling and analysis, with samples taken from storage tanks, prior to discharge, from discharge outlets into the environment, and from the demineralisation station and purification plants.

- The Gravelines power plant performs chemical, physico-chemical and ecological monitoring of the aquatic environment so as to determine the concentrations in the water of chemical substances discharged by the site, to track the natural changes in the receiving environment, and to detect any abnormal changes.
- Thermal discharges are measured and monitored by way of thermographs, positioned in the intake and discharge channels and out at sea, which continuously record temperatures at various depths.
- Bathymetric surveys are carried out regularly along the Gravelines beach, to assess any potential impacts on the shoreline of plant discharges of cooling water.



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Liquid effluent analysis

■ **Soil and groundwater**

Gravelines NPP runs a programme monitoring groundwater quality in terms of chemical and radiological parameters, with the aim of detecting any contamination linked to plant operation.

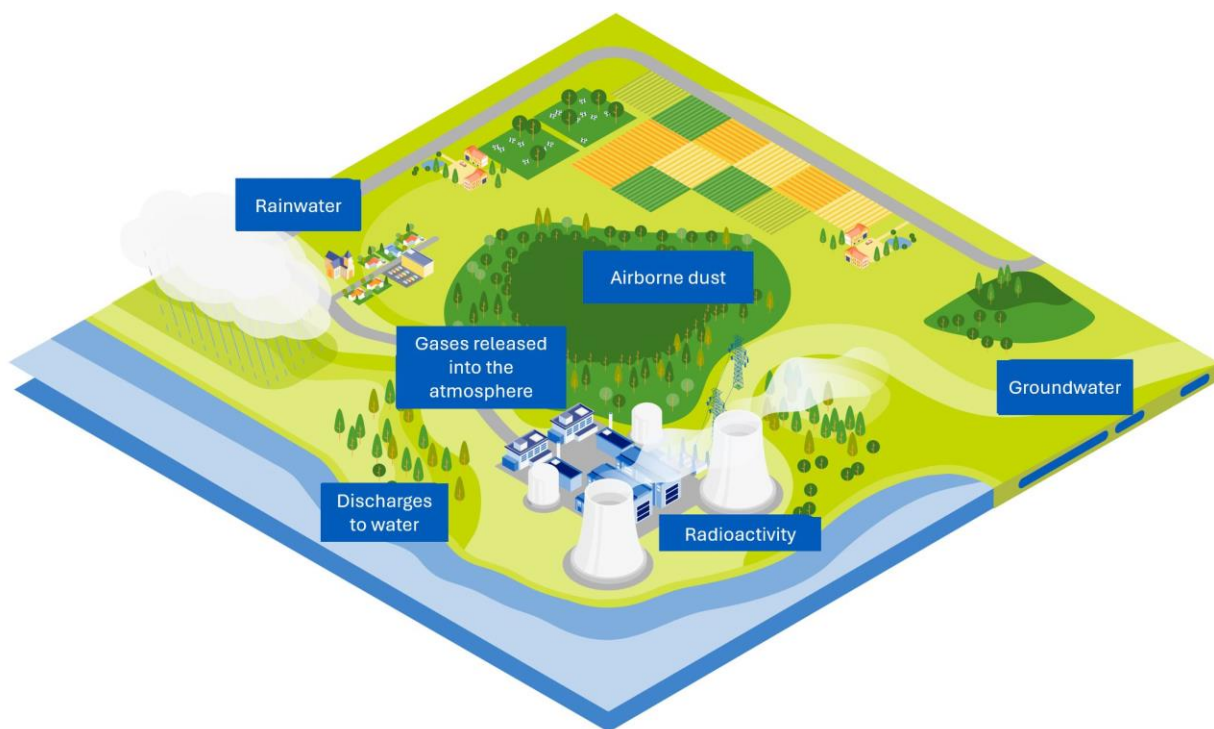
The power plant runs a groundwater monitoring programme using a network of piezometers sited inside and outside the engineered confinement structures. Groundwater samples are taken and analysed in accordance with standard NF EN IS/EC17025.

- Several systems are also installed to monitor the volumes of water abstracted from the aquifer, and to ensure compliance with regulatory limits.

■ **Radioecology**

Gravelines power plant runs a programme for monitoring radioactive effluents at several key locations:

- in the stacks used for effluent discharges to atmosphere;
- in the storage tanks used prior to the discharge of gaseous effluents to atmosphere;
- in the extraction circuits of ventilation systems in premises that may be contaminated, to ensure that there is no artificial radioactivity;
- at the discharge structures for radioactive liquid effluents;
- in rainwater, to ensure that there is no artificial radioactivity.



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Illustration of radiological monitoring of the environment

Radioactivity in the environment around the Gravelines site is monitored by way of:

- a regulatory radiological monitoring programme implemented by the power plant, focusing in particular on:
 - the atmosphere, with radiological monitoring of ambient gamma radiation, airborne dust, and tritium in the air and in 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;
- radioecological studies carried out on the initiative of the operator (annual monitoring, ten-year reviews, specific studies);
- a radiological monitoring programme consistently implemented by ASN, for its own account, which it assigns to its department of subject-matter specialists.

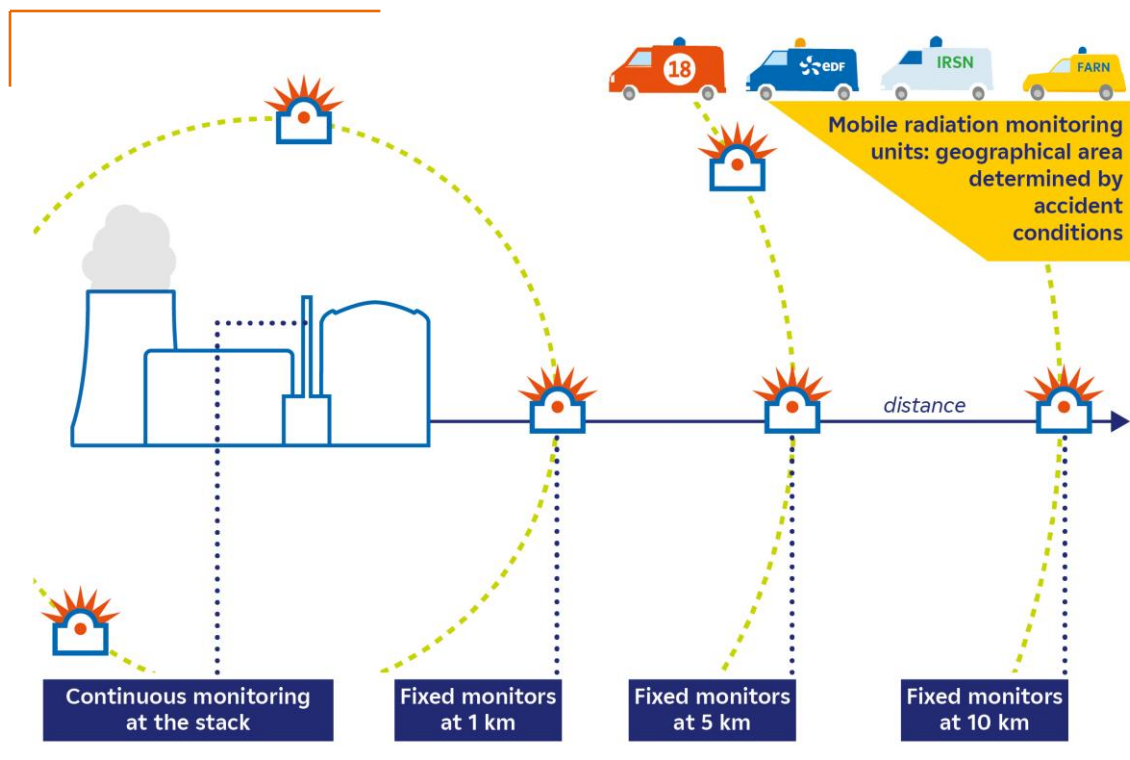
■ Population and human health

The impact of the Gravelines site on the health of neighbouring populations is monitored by keeping track of the atmospheric compartment, surface water compartment, and radioecological compartment (see above). Noise emission is subject to periodic measurement campaigns to verify compliance with regulations.

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, ASN vehicles manned by subject-matter specialists, and fire service vehicles manned by firefighters, cover the area around the plant.



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 six 900 MWe reactors at Gravelines 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 Gravelines reactors. It is a joint document for all six reactors at the Gravelines site. 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 Gravelines 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 Gravelines reactors for up to fifty years, thereby contributing to ongoing low-carbon electricity generation, with less than 4 grammes of CO₂ per kWh produced over the entire life cycle of the power plant.

Over the next ten years, the normal operation of Gravelines 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 6 million households. Compensating for this lost electricity generation using the European energy mix would increase CO₂ emissions by more than 8 million tonnes a year.

GLOSSARY



Gravelines Nuclear Power Plant, Nord
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Acronym	Description
AP	Activation products
ARC	Avoid, Reduce, Compensate [ERC]
ASNR	Authority for Nuclear Safety and Radiation Protection [<i>Autorité de Sûreté Nucléaire et de Radioprotection</i>]
BNI	Basic Nuclear Installation [INB]
CENTRACO	Waste Treatment and Conditioning Centre [<i>Centre de Traitement et de Conditionnement</i>]
CIRES	Industrial Facility for Waste Collection, Sorting and Storage [<i>Centre Industriel de Regroupement d'Entreposage et de Stockage</i>] 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 [<i>Centre de Stockage de l'Aube</i>]
CSS	Containment Spray System [EAS]
Dangerous accident phenomenon	A dangerous accident phenomenon is one which releases large amounts of energy or substances, leading to consequences that may inflict damage on potential targets
DER	Dose Equivalent Rate
DOCOB	Document of Objectives
DOR	Periodic Review Guidelines [<i>Dossier d'Orientations du Réexamen périodique</i>]
DUS	Ultimate Emergency Diesel Generator (SBO-EDG) [<i>Diesel d'Ultime Secours</i>]
EDF	Electricité de France
EIP	Important Element for the Protection of Interests [<i>Elément Important pour la Protection des intérêts</i>]
EPR	European Pressurised Reactor. A third-generation nuclear reactor.

EPRS	Prospective Evaluation of Health Risks [<i>Évaluation Prospective des Risques Sanitaires</i>]
EQS	Environmental Quality Standards [NQE]
FARN	Rapid Response Nuclear Taskforce [<i>Force d'Action Rapide du Nucléaire</i>]
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 [<i>Groupe Permanents d'experts</i>]
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 [<i>Installation Classée pour la Protection de l'Environnement</i>]
IET	Irreversible Effects Threshold [SEI]
IL	Intermediate Level (radioactive waste) [MA]
INERIS	National Institute for the Environment and Industrial Risk [<i>Institut National de l'Environnement et des Risques</i>]
IRSN	Institute for Radiation Protection and Nuclear Safety [<i>Institut de Radioprotection et de Sécurité Nucléaire</i>]
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 [<i>Ouverture Intempestive d'une Soupape Secondaire à 0%Pn</i>]
OPEL	Loire Water Intake [<i>Ouvrage de Prise d'Eau en Loire</i>]
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	4 th periodic review [RP4]
4PR 900	4 th 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 [<i>Rapport de Conclusion du Réexamen périodique</i>]
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	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 [<i>Zone à Émergence Règlementée</i>]
ZNIEFF	Natural Areas of Interest for Ecology, Fauna and Flora [<i>Zones Naturelles d'Intérêt Écologique, Faunistique et Floristique</i>]