Dampierre-en-Burly Nuclear Power Plant

Route d'Ouzouer
45 570 Ouzouer-sur-Loire

Reactor No. 3

Public inquiry into the 4th periodic review

DOCUMENT 3bis

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

OVERVIEW

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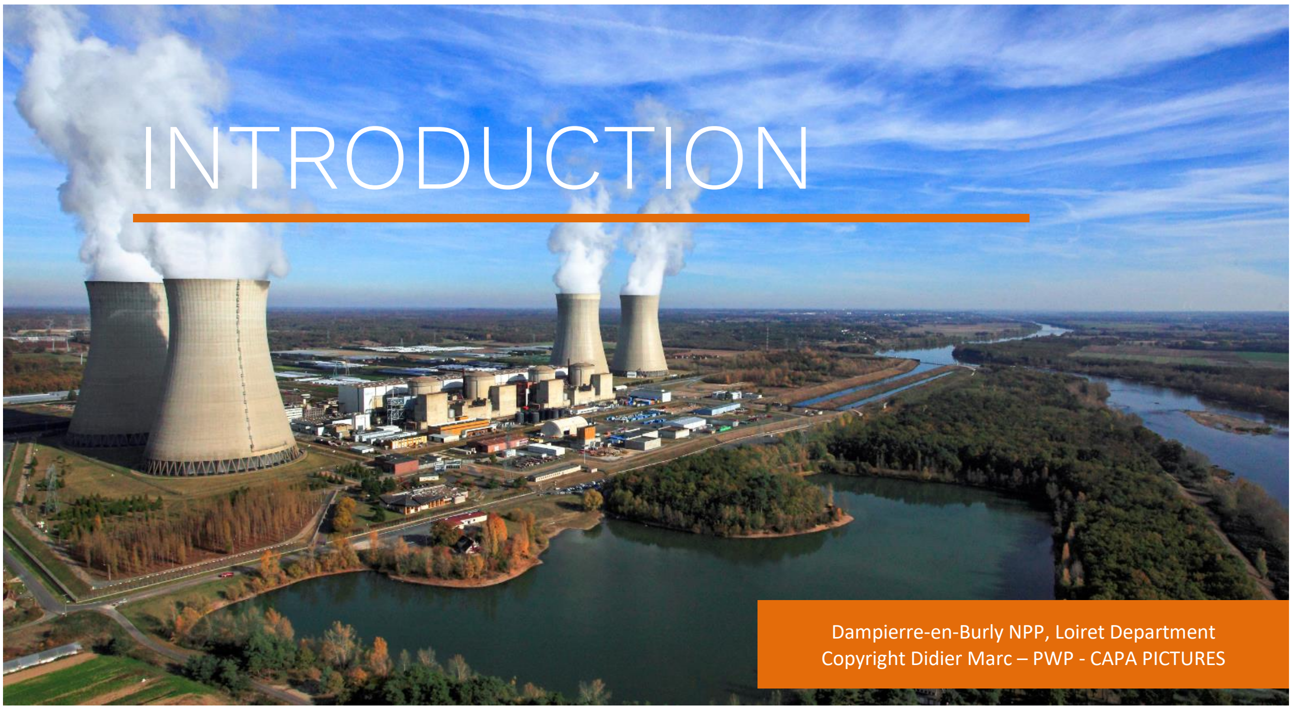

Dampierre-en-Burly NPP, Loiret Department
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In France, the construction of a nuclear reactor is authorised by way of a decree issued by the Minister responsible for nuclear safety. This authorisation places no time limit on service life. Nevertheless,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

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

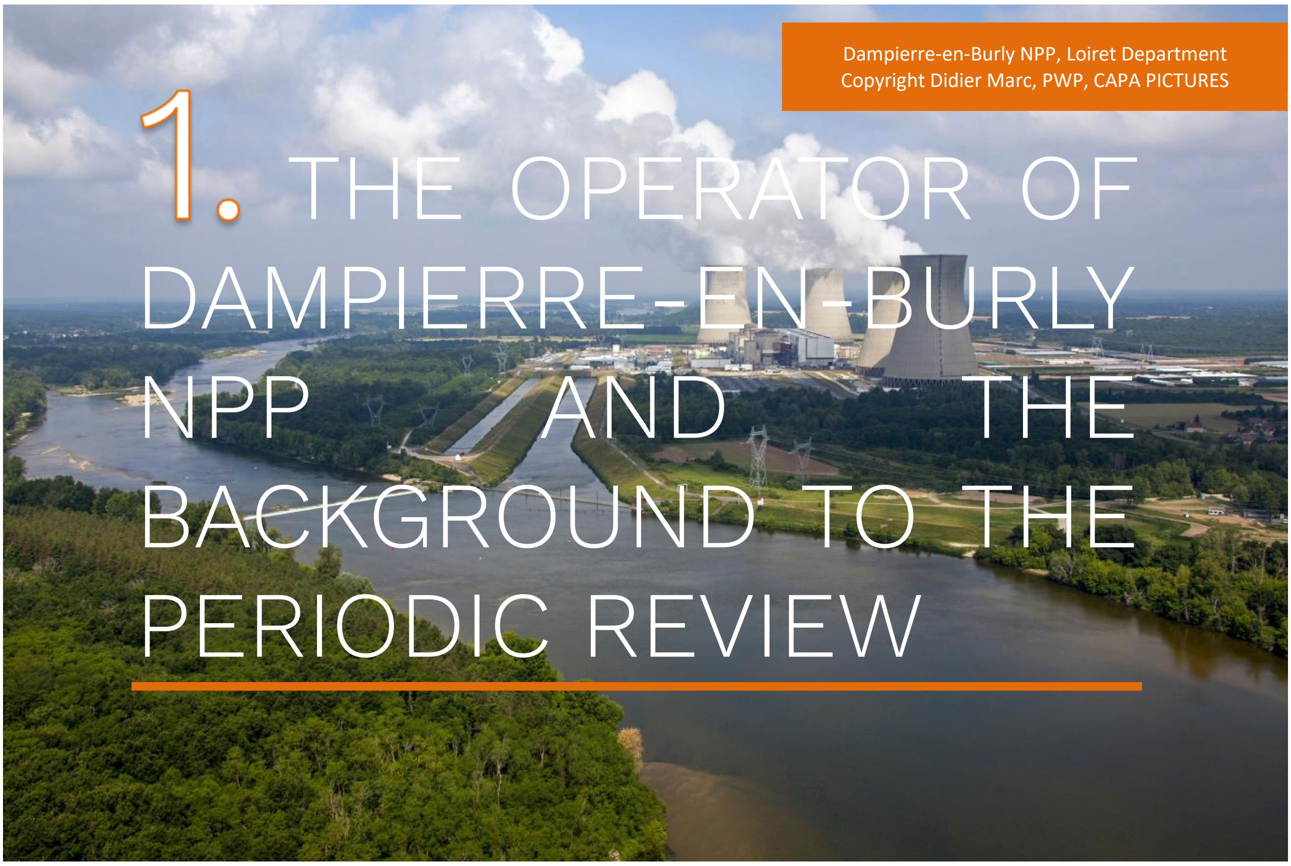
After each review, EDF draws up a Review Findings Report [RCR] setting out its conclusions and proposed measures to strengthen the safeguarding of protected interests. The reports for reactors Nos. 1 to 4 at Dampierre-en-Burly Nuclear Power Plant were submitted to the Government and to the Authority for Nuclear Safety and Radiation Protection (ASNR, www.asnr.fr) on 4 February 2022, 3 November 2022, 27 June 2024 and 8 April 2025, respectively.

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

This document represents one of the supporting documents in the Public Inquiry File for the 4th periodic review of the Dampierre-en-Burly reactors. It is a joint document for all four reactors at the Dampierre-en-Burly 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 Dampierre-en-Burly site.



Dampierre-en-Burly NPP, Loiret Department

1. THE OPERATOR OF DAMPIERRE-EN-BURLY NPP AND THE BACKGROUND TO THE PERIODIC REVIEW

1.1. The operator of Dampierre-en-Burly Power Plant

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

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

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

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

In 2024, Dampierre-en-Burly Nuclear Power Plant (NPP) generated nearly 20.8 billion kilowatt-hours of low-carbon electricity, representing the electricity consumption of close to 4.5 million French households, in other words, 6% of France's nuclear-generated electricity. Dampierre-en-Burly NPP supports the climate goals set by France and the European Union, as well as the objective of security of supply.

Dampierre-en-Burly power plant is a major economic player in the Centre-Val de Loire region. It is one of the leading industrial employers in the region, with close to 2,000 people on site at any given time. It is strongly committed to training young people, taking on around 50 new apprentices and 130 interns in 2024. It is fully invested in local life, and champions numerous initiatives and associations supporting the environment and biodiversity, sport, and young people's access to the labour market.

1.2. Background to the periodic review and regulatory framework

1.2.1. The procedure for periodic reviews

Dampierre-en-Burly NPP is made up of four pressurised water reactors (PWR), each with an electrical output of 900 MWe, cooled by a so-called 'closed' circuit cooling system. These reactors were commissioned between 1980 and 1981. 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 four reactors currently in operation at the Dampierre-en-Burly 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 EDF[2].

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

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

- a **'risks' component** focused on preventing incident or accident events and limiting their potential radiological (radioactive releases) or non-radiological (thermal or toxic releases, overpressure) **consequences**. There are 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.

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[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.

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

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

The 4th periodic review of the Dampierre-en-Burly 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 Dampierre-en-Burly 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-0706[4] governing the generic phase of the 4th periodic review of 900 MWe reactors, accompanied by generic requirements that had first been put to public consultation;
- a second phase specific to each Dampierre-en-Burly reactor.

Following the review[5], EDF submitted the Review Findings Report [RCR] for each of the 4 Dampierre-en-Burly 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 3.3).

In regard to this 4th periodic review of the Dampierre-en-Burly 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 Dampierre-en-Burly reactors.

After the review, the continued operation of Dampierre-en-Burly 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

[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".

issued its position statement: this is referred to as the Decommissioning Decree. The decommissioning stages are as follows:

Preliminary stage: decommissioning preparation operations

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

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

Stage 1: dismantling of electromechanical equipment

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

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

Stage 2: site clean-up

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

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

Stage 3: demolition of buildings

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

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

Stage 4: site remediation and restoration

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

2. THE CONTINUED OPERATION OF THE DAMPIERRE-EN-BURLY REACTORS

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2.1. Dampierre-en-Burly Nuclear Power Plant

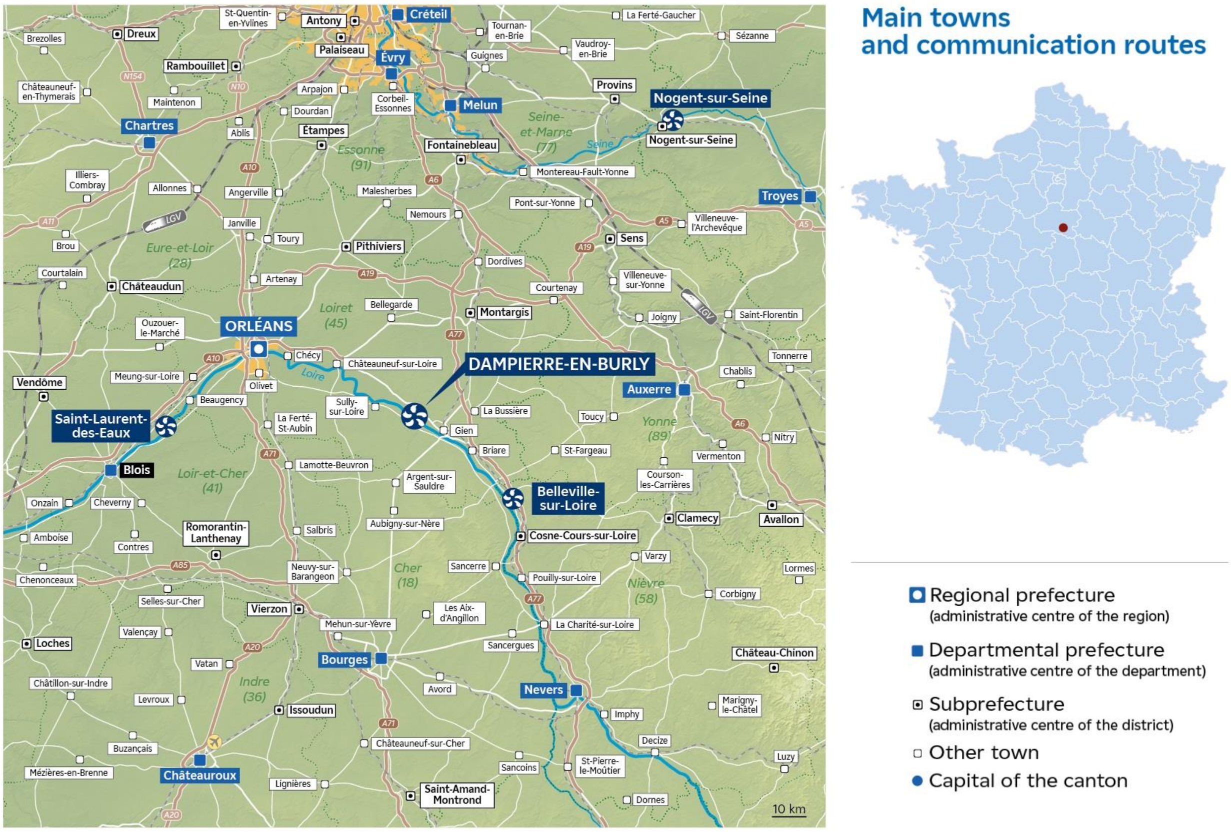
This EDF nuclear power plant is located in the Commune of Dampierre-en-Burly, in the Loiret Department, in the Centre-Val de Loire region. It is sited on the right bank of the Loire River, around 10 km west of Gien.

The largest towns near the power plant are Gien (10 km away), Montargis (45 km) and Orléans (50 km).

The power plant is close to several natural areas of special interest, including a number of NATURA 2000 protected sites.

Dampierre-en-Burly NPP comprises four pressurised water reactors (PWR), which were commissioned between 1980 and 1981, and are all undergoing their 4th periodic reviews.

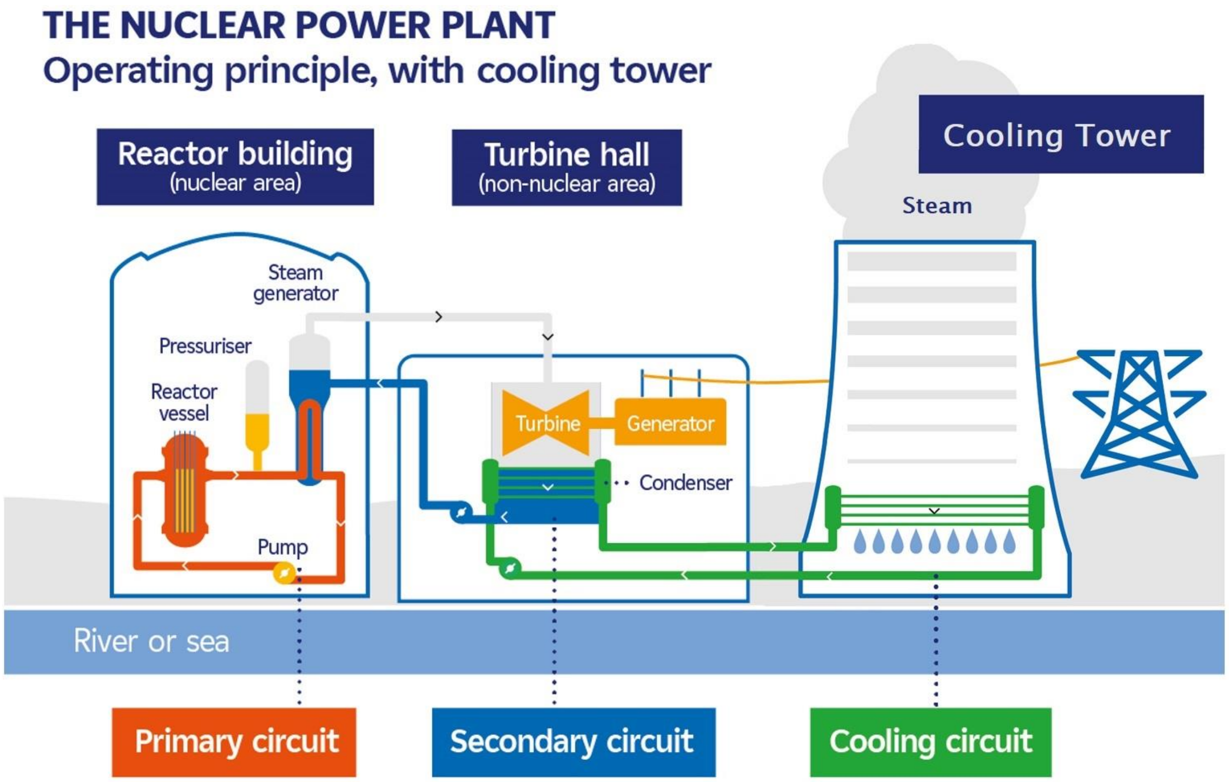
DAMPIERRE-EN-BURLY NUCLEAR POWER PLANT (LOIRET)



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.

Dampierre-en-Burly NPP has four pressurised water reactors, each with a rated electrical output of 900 MWe, cooled by a so-called ‘closed’ circuit cooling system. The working principle of a pressurised water reactor is based on three separate and sealed circuits (see illustration below).



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

In 2024, Dampierre-en-Burly NPP generated around 20.8 billion kilowatt-hours of low-carbon electricity, representing the electricity consumption of nearly 4.5 million households, in other words, 6% of France’s nuclear-generated electricity.

2.3. Continued operation

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

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

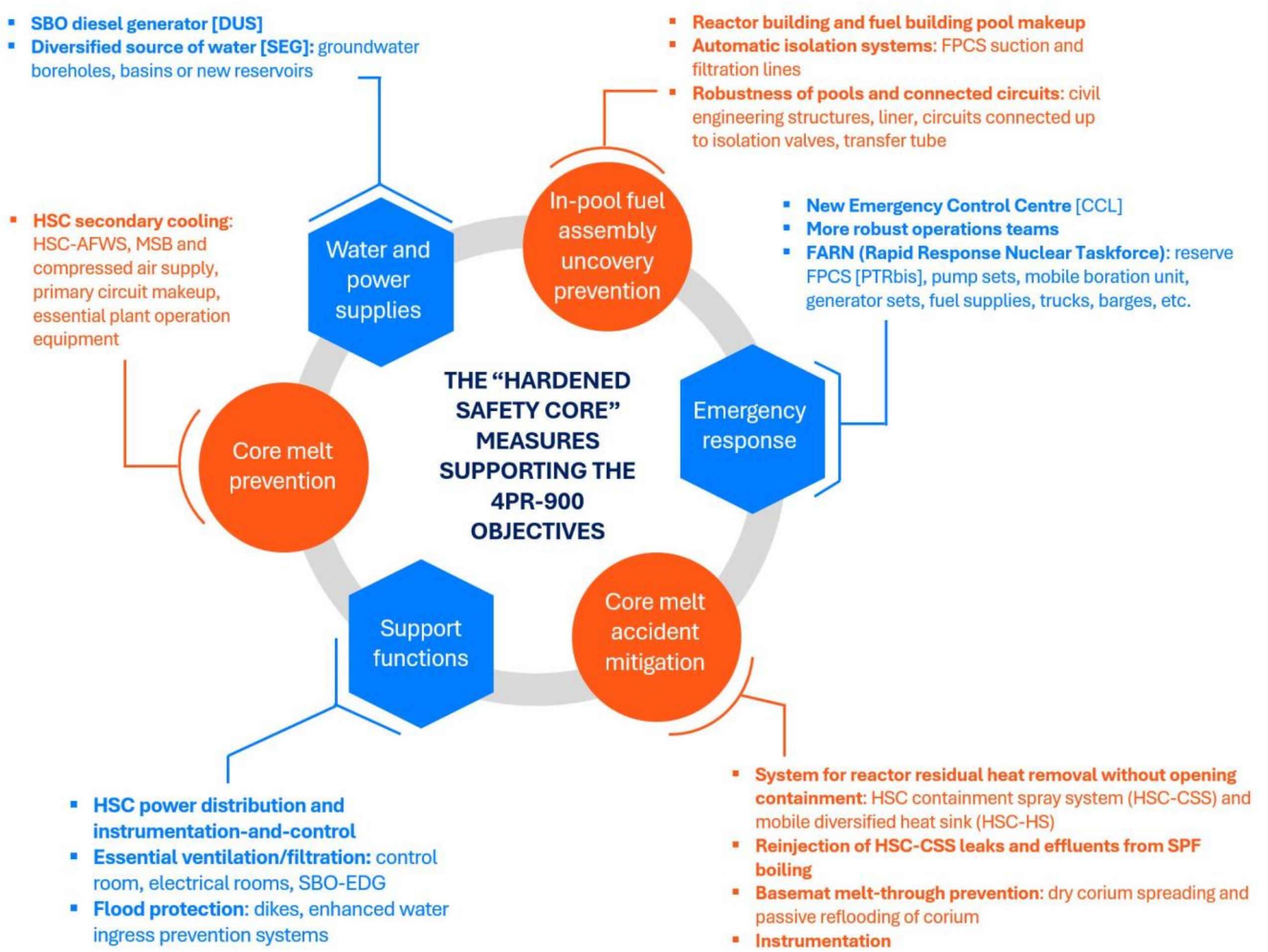
2.3.1. The measures put forward

Given the improvement objectives defined for the 4th periodic review of the 900 MWe reactors, their continued operation for a further ten years will be tied in with the implementation of measures put forward by EDF in the Review Findings Report, supplemented by the requirements laid down by ASNR, which 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 equipment, designed for preventing large radioactive releases and long-term environmental impacts in the conditions following an extreme external natural hazard event. Such events mainly include earthquakes, external flooding and associated phenomena (lightning, hail, high winds, heavy rains), 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 Dampierre-en-Burly 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:

NON-CORE-MELT ACCIDENTS

Objectives

- Comply with the safety requirements stipulated in accident studies by factoring in developments in knowledge.
- Aim for radiological releases that would not necessitate public protection measures.

HAZARDS

Objectives

- Ensure that installations can withstand any revised hazard levels determined during the review, and are aligned with international standards (WENRA).
- Aim for an overall core damage frequency, including hazards, of 10-5 per reactor-year.

CORE-MELT ACCIDENTS

Objectives

- Ensure that the risk of significant, early releases is highly unlikely.
- Avoid long-term environmental consequences.

SPENT FUEL POOL

Objectives

- Ensure that the uncovery of fuel assemblies is highly unlikely in the event of inadvertent draindown and loss of cooling.

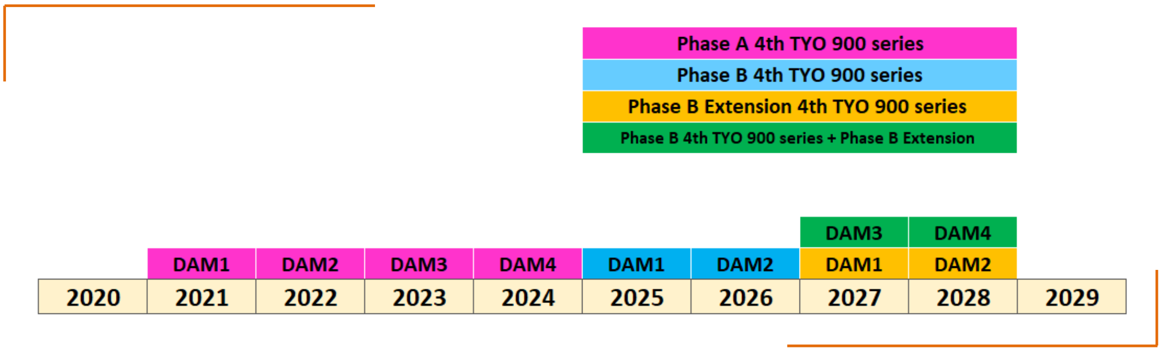
2.3.2. Industrial programme under the 4th periodic review

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

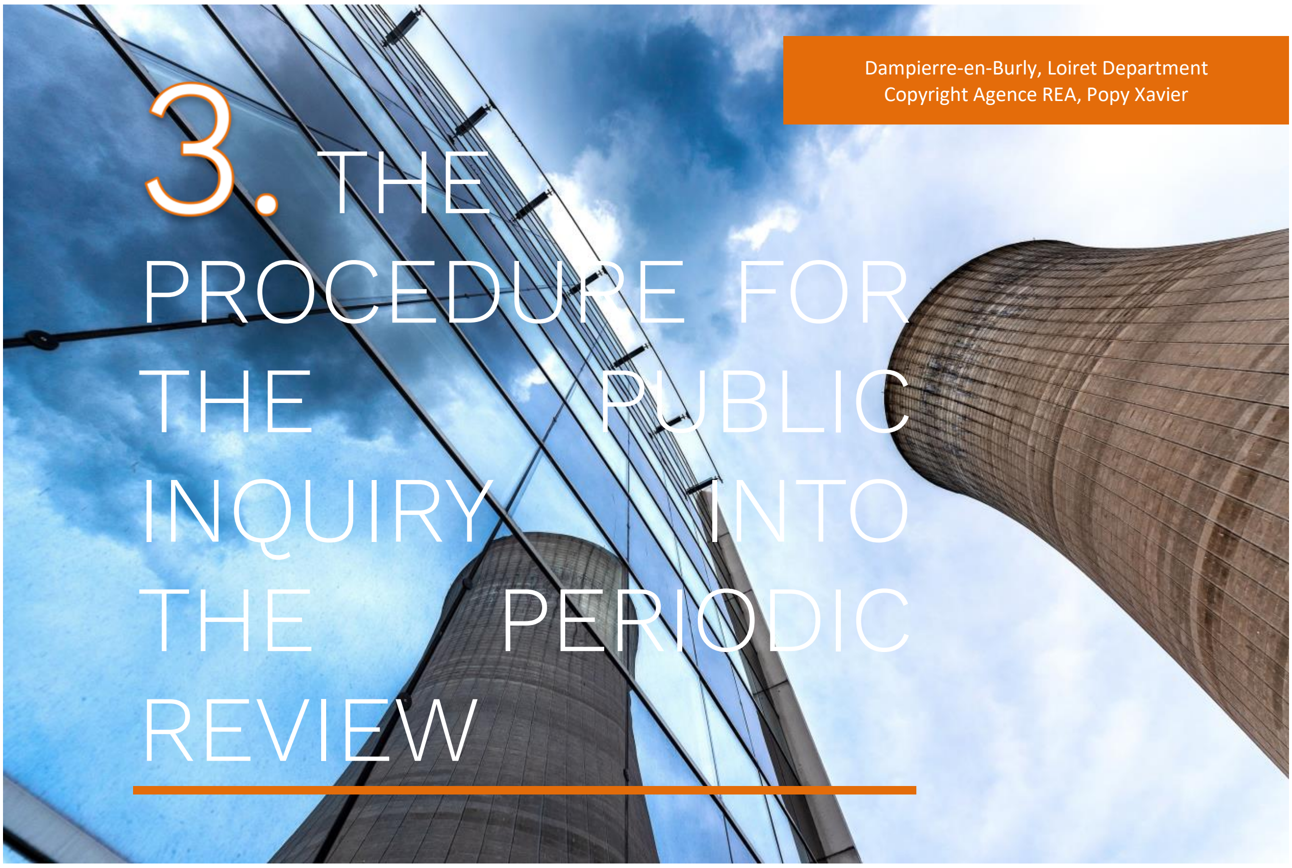
- **Phase A** corresponds to the activities that are carried out during unit operation or during shutdowns such as the ten-year outages. These activities include updating operational documentation;
- **Phase B** corresponds to the activities that are carried out during unit operation or during shutdowns that take place no later than six years after submission of the Review Findings Report;
- **Phase B Extension** covers the implementation of certain actions derived from ASNR'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 ambiant 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.

[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.

The following illustration sets out the annual schedule for modifications related to the 4th review of the Dampierre-en-Burly reactors:



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



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3.1. The regulatory procedure in France

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

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

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

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

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

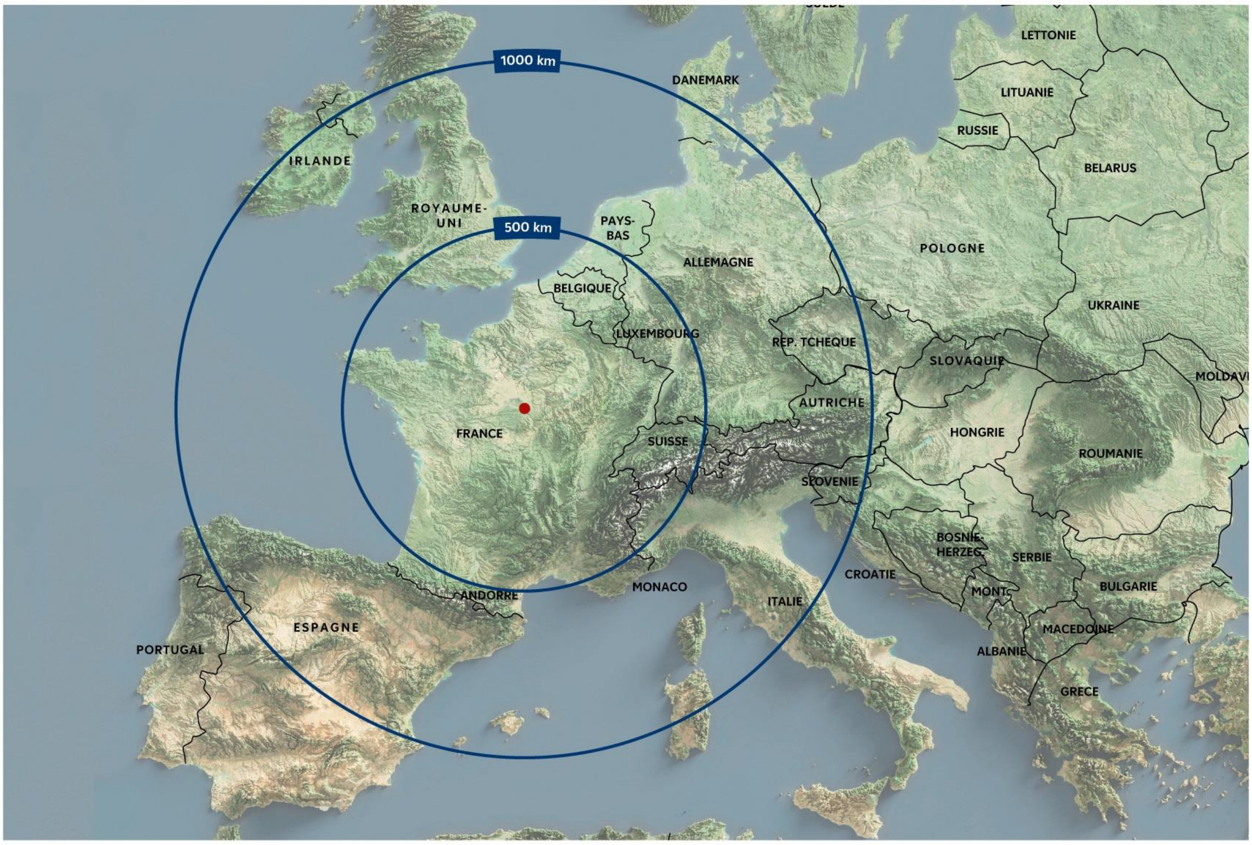
3.2. Cross-border consultation

For the purposes of this public inquiry 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 Dampierre-en-Burly NPP in relation to neighbouring states, up to a distance of 1,000 kilometres.

DAMPIERRE-EN-BURLY NUCLEAR POWER PLANT (LOIRET)

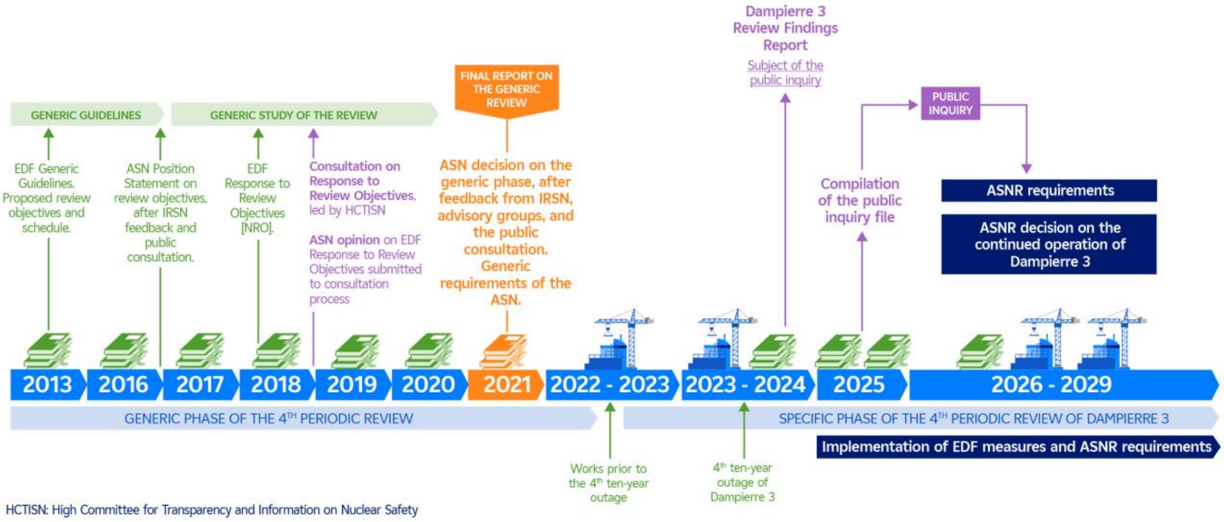


The Dampierre-en-Burly site relative to neighbouring foreign states

3.3. Timeline of the regulatory procedure

The Prefect of the Loiret 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 Dampierre-en-Burly reactor No. 3 is summarised below.



HCTISN: High Committee for Transparency and Information on Nuclear Safety

At the time of writing, the public inquiries for reactors Nos. 3 and 4 could be held mid-year 2026.

4. NUCLEAR POWER PLANT SAFETY

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4.1. Radiation protection

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

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

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

[7] As Low as Reasonably Achievable.

4.2. Operational nuclear safety

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

The design and operation of nuclear power plants aim to control all risks by both reducing the likelihood of equipment failures through prevention measures, and by limiting the consequences of any failures through 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.

The 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 mininise 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:

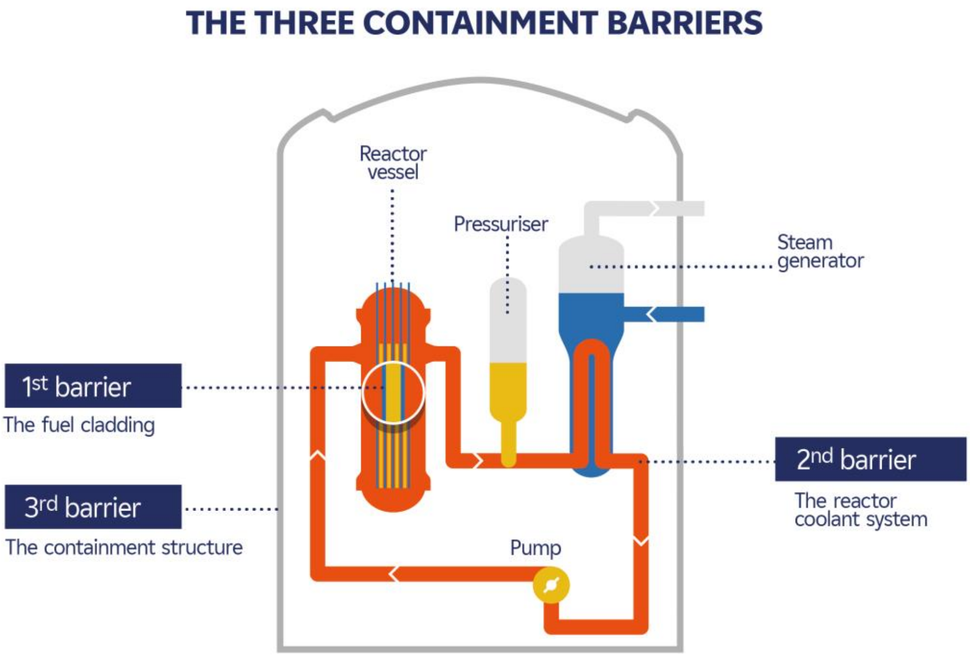
- direct exposure to radiation, known as external exposure,
- radiation exposure by ingestion and/or inhalation of radoactive material, known as internal exposure.

4.2.1. Radiological risk management

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

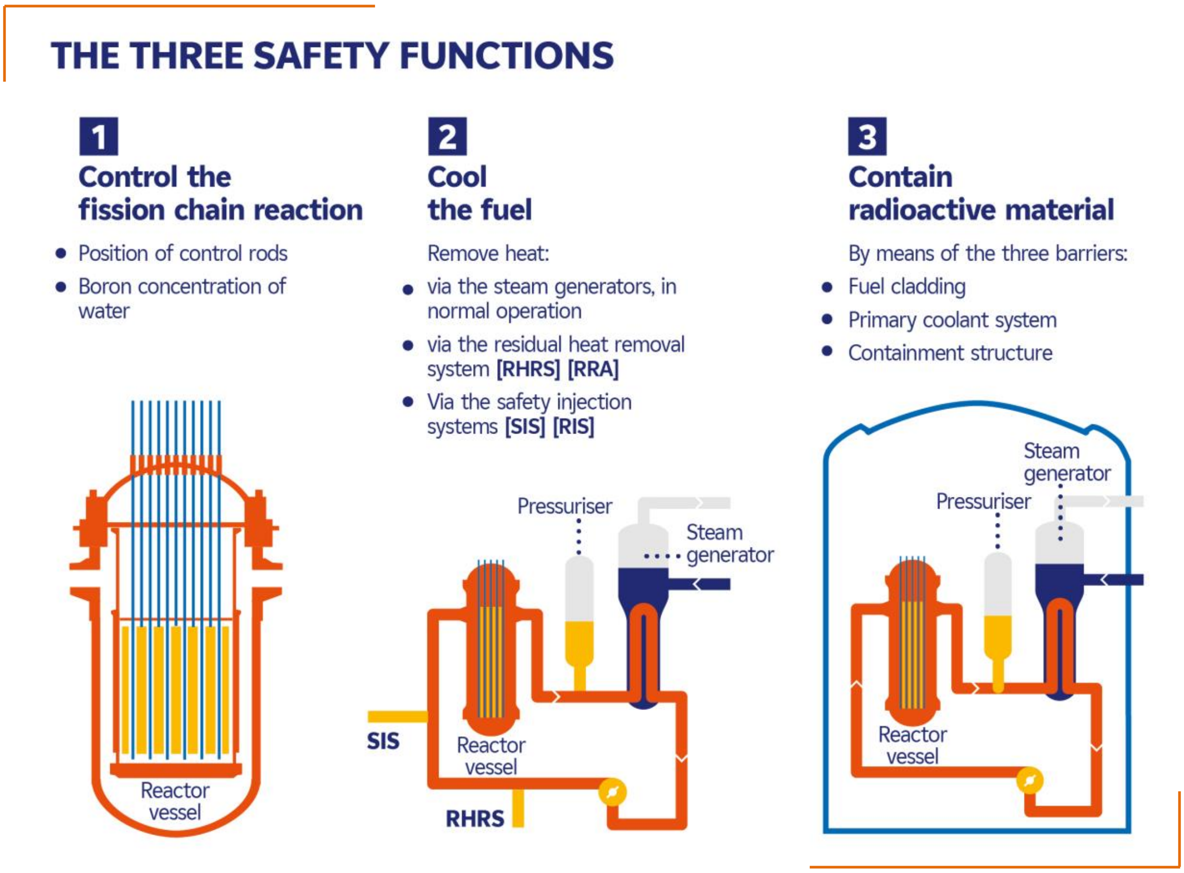
Three distinct, robust, sealed physical barriers thus work together to contain radioactivity:

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



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

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



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

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

The safety case for radiological risk management in relation to the Dampierre-en-Burly 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 Dampierre-en-Burly reactors will incorporate robust design features for withstanding core-melt accidents. The scenarios studied have led to the implementation of provisions[8] to limit the consequences of such accidents by preserving the integrity of the 3rd containment barrier.

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

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

A distinction is made between:

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

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

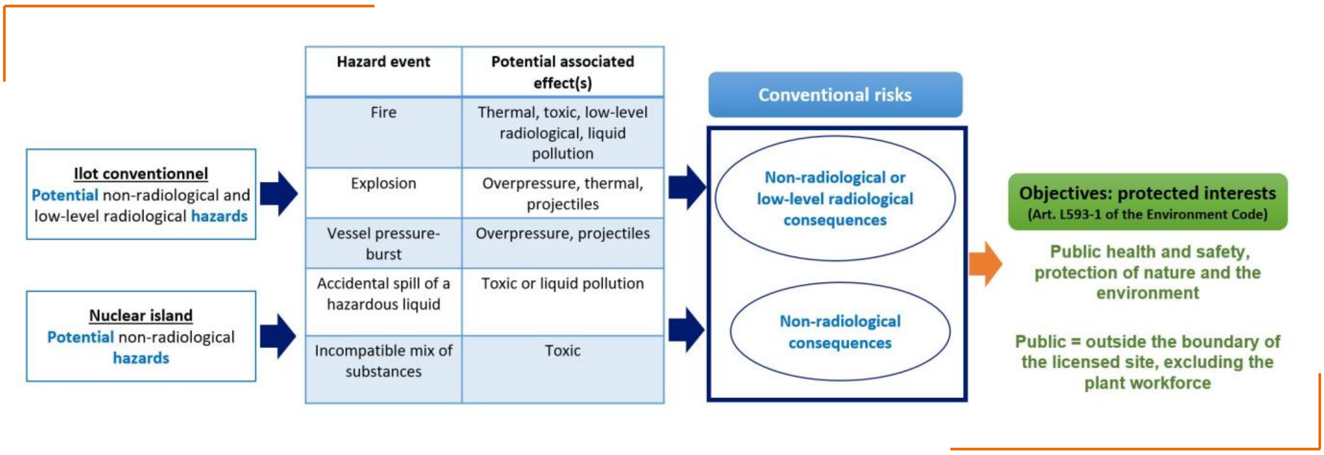
4.2.2. Conventional risk management

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

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



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

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

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

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

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

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

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

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

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

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

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

These measures are monitored during plant operation.

4.2.2.2. Overview for Dampierre-en-Burly

- ***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 Dampierre-en-Burly NPP identified three conventional accident scenarios that may impact the interests to be protected:

- in the monochloramine treatment plant, the formation of a ground-hugging plume of ammonia during tanker-truck unloading in the off-loading area[9] may lead to the dispersion of a toxic cloud of ammonia;

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

The numerous preventive measures that have been implemented defend against such accidents occurring: training of personnel, the implementation of detailed procedures, the use of visual signage, a verification of the Goods Received Note, the use of human error-reduction techniques, etc.

The scenario of a dispersion of a toxic cloud of ammonia following loss of ammonia containment in the monochloramine treatment plant's off-loading area presents a tolerable level of risk. It has a frequency of occurrence categorising it as a very unlikely event (less than 1 in 10,000 years).

In regard to the two scenarios involving the mixing of incompatible substances, targeted preventive measures have been implemented to reduce their likelihood of onset. These risk management measures are defined as Activities classified as Important for the Protection of Interests [AIP] and are specific to each scenario. The following preventive measures are to be carried out prior to off-loading:

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

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

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

Liquid-borne risks

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

The conventional risks posed by Dampierre-en-Burly NPP with respect to the interests to be protected are therefore controlled.

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

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 Dampierre-en-Burly reactor vessels,
    - 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 Dampierre-en-Burly 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 Dampierre-en-Burly 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

Dampierre-en-Burly NPP, Loiret Department
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5.1. Approach

Section 5 presents the assessment of the environmental impact of Dampierre-en-Burly NPP operation, both in its current state and for the next ten years.
The first subsections set out:

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

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

5.2. Impact assessment methods

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

Air and climate factors

The analysis of the impacts of Dampierre-en-Burly 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, using 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, formulated on a comparison between the calculated concentrations in the environment and reference values (theshholds, 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, drawing 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 Dampierre-en-Burly 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 Dampierre-en-Burly NPP operation on biodiversity is based on:

- an examination of the natural areas, habitats, fauna, flora and ecological functionalities present within the study area (bibliographic studies and field investigations);
- an analysis of the effects of each interaction between Dampierre-en-Burly NPP and natural areas, fauna, flora and ecological functionalities.

Population and human health

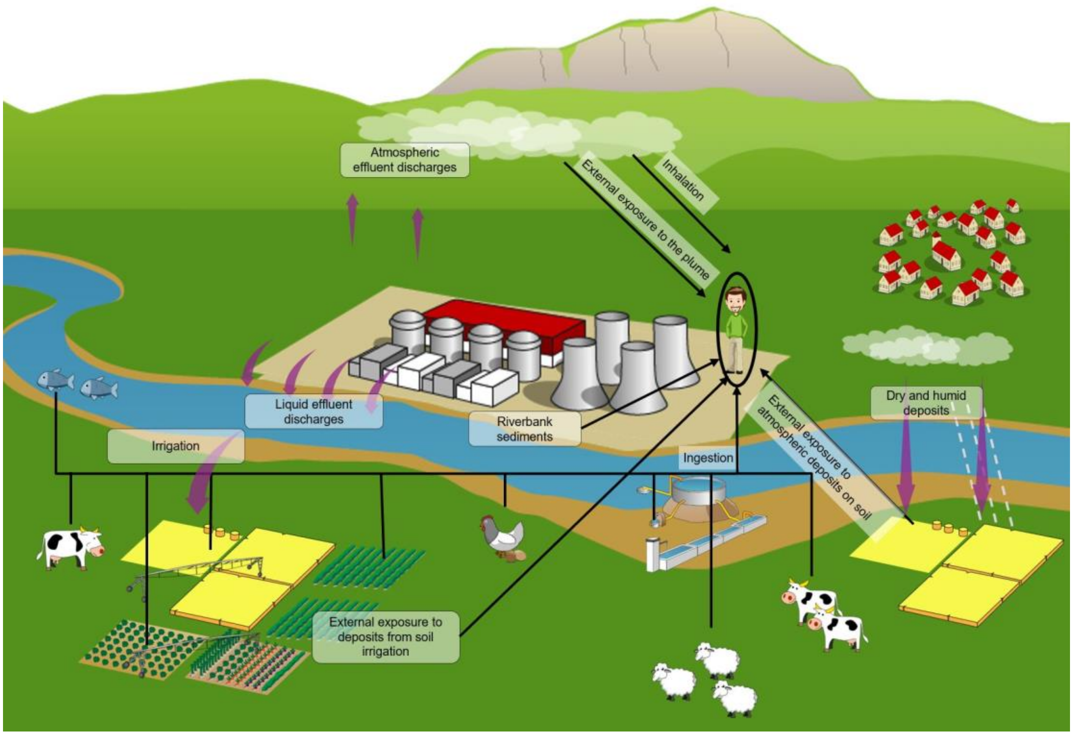
The dosimetry impact of radioactive effluent discharges takes into account both internal and external exposure associated with liquid radioactive effluent discharges and radioactive effluent discharges to atmosphere.
The following exposure pathways are considered (see figure below):

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

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

The assessment is carried out in the following stages:

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



Pathways of exposure to radioactive effluent discharges ©EDF

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

- A Site Pollution Assessment [IEM], based on monitoring data and specific measurements;
- A Prospective Health Risk Assessment [EPRS], drawn up by modelling the discharges attributable to the Dampierre-en-Burly 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 substances of interest with toxicological reference values,
  - 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 Dampierre-en-Burly 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 impact of the waste that is produced is mainly assessed through analysis of the measures implemented for waste zoning, characterisation, sorting, treatment, packaging and inspection, and through analysis of the power plant's operating experience.
The quantification of waste produced, and estimation of projected quantities of waste generated in the coming years, are based on data from the annual waste management reports prepared by the power plant. These reports provide quantitative and qualitative data on the waste generated by the plant, and specify the waste management streams that have been and will be used.

5.3. Uncertainty in the impact assessment

The impact assessment methods presented in the previous section are cutting-edge and developed using available scientific results.
Advances in science are gradually improving environmental monitoring and fostering the development of assumptions and computational tools.
Conservative assumptions are incorporated into the impact assessments. The main conservative assumption is to consider the interactions with the environment to be reasonably 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 Dampierre-en-Burly 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 Dampierre-en-Burly 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.

Dampierre-en-Burly NPP regularly publishes data from its monitoring of discharges and of the environment:

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

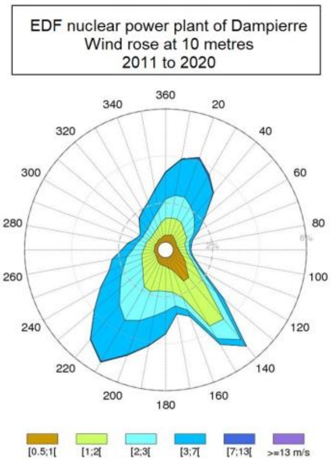
For further information, the guide “Nuclear power plants and the environment” sets out the interactions between nuclear power plants and the environment, and the associated monitoring arrangements.

5.5. Current state of the environment

5.5.1. Air and climate factors

Climate

The area in which Dampierre-en-Burly NPP is sited has a moderated oceanic climate, halfway between the semi-continental climate of eastern France and an Atlantic oceanic climate. It is typified by mild, rainy winters and cool, humid summers. Given the relatively gentle topography, the region is not overly influenced by local phenomena. However, the orographic effects of the Loire Valley must be taken into account in relation to wind patterns.
Between 2011 and 2020, average monthly temperatures in Dampierre-en-Burly ranged from 4.5°C (in February) to 20.3°C (in July); it rains on average 175 days per year; the prevailing winds are from the south-south-west, south-south-east and north-north-east.



Wind rose at 10 metres, at Dampierre-en-Burly NPP's weather station, 2011-2020

Air quality

Air quality in the vicinity of Dampierre-en-Burly NPP is considered to be generally average, mainly due to higher ozone levels in the summer season, and higher fine particulate matter concentrations in the winter months, due in particular to household heating systems. Air quality standards are met.

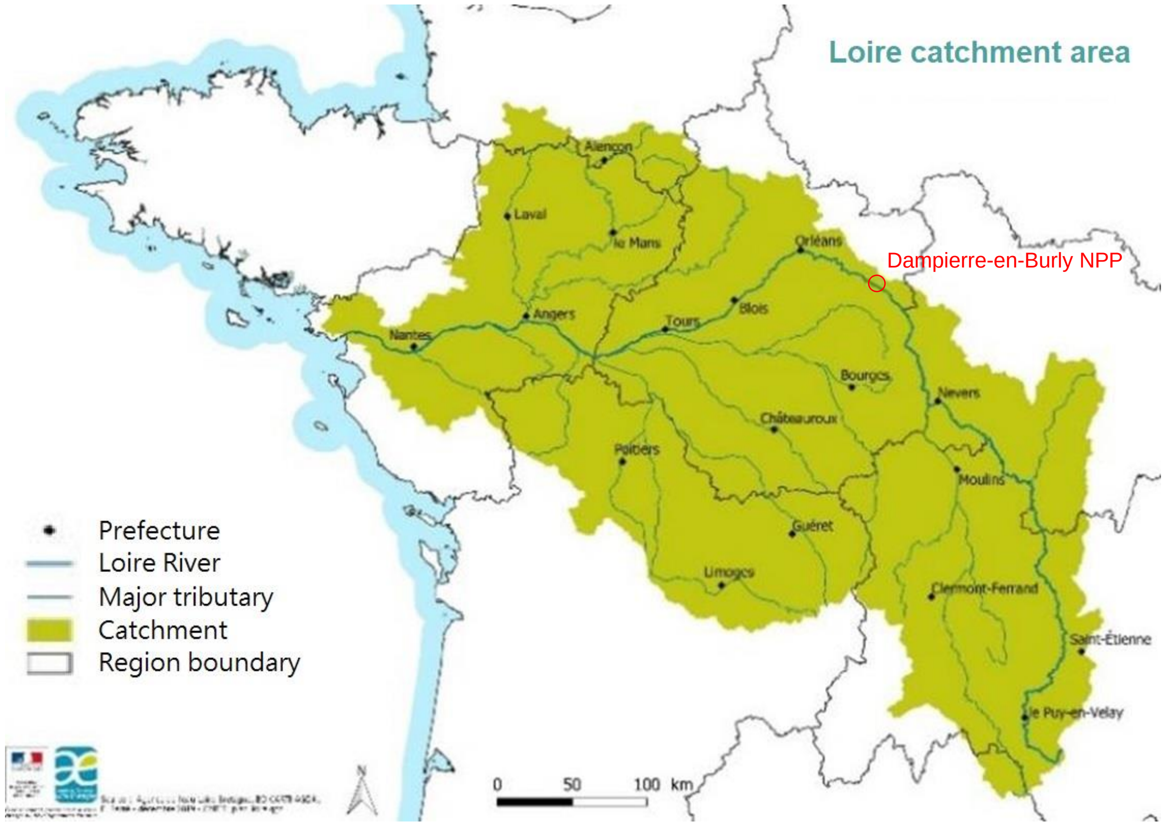
5.5.2. Surface water

Hydrology

Dampierre-en-Burly power plant is located in the Commune of Dampierre-en-Burly (Loiret Department) on the right bank of the Loire River, approximately 10 km downstream from Gien and around 50 km upstream from Orléans. The facilities are sited at a bend in the Loire, on the floodplain. At the location of the power plant, the Loire is between 100 and 300 metres wide and accommodates a few islands, some of which were formed by alluvial deposits.

The Loire has a highly diverse hydrological regime, with very low water levels in the summer, and sometimes severe flash floods, generally between November and May. In a bid to minimise the impacts of extremes of river-flows, low-flow-replenishment and flood-control operations are conducted, in particular by means of two impoundments upstream of Dampierre-en-Burly power plant: the Villerest Dam on the Loire upstream of Roanne, and the Naussac Dam on a tributary of the Allier River near Langogne.

From 1984 to 2017, the average interannual flow of the Loire River at Dampierre-en-Burly power plant was 307 m^3/s. Flows are highest between November and May, and low-water levels are more pronounced in the summer, from August to September.



Loire catchment area (© Plan Loire)

Thermal regime

The analysis of the thermal regime of the Loire River upstream of Dampierre-en-Burly NPP over the period 1977-2019 shows pronounced seasonal patterns of temperatures, with a mean temperature of around 22°C in summer and 5 to 6°C in winter. In the summer season (June to September), the temperature of the Loire is above 25°C for 10% of the time. It exceeds 28°C for less than 1% of the time in July and August. The maximum daily temperature recorded is 30°C.

An analysis of year-to-year variations charted since the late 1970s shows an upward trend in water temperatures. The average change is calculated at around + 0.3°C per decade over the last four decades, with a more pronounced increase in summertime temperatures.

Physico-chemical and biological quality

Dampierre-en-Burly NPP abstracts its water and releases its liquid discharges into surface water body “FRGR0007b”. This natural water body marks off the section of Loire River between Gien and Saint-Denis-en-Val, near Orléans.

A 2019 assessment by the Loire-Bretagne Basin Committee of the condition of surface water body FRGR0007b concluded that it had achieved good ecological status, and poor chemical status including ubiquitous substances*.

**: benzo(a)pyrene, the pollutant downgrading this chemical status, is not a substance that is released by Dampierre-en-Burly NPP.*

The results of chemical and hydroecological monitoring at Dampierre-en-Burly power plant over the period 2010-2019 indicated that the quality of the aquatic environment was satisfactory, in terms of physico-chemical and chemical parameters, as well as biological indicators. The quality of the sediment in the Dampierre-en-Burly NPP channel is representative of the quality of the sediments moving along the Loire River and complies with regulations, allowing for direct return to the river.

The ecological status of a surface water body within the meaning of the Water Framework Directive [DCE] is defined on the basis of several criteria: general physico-chemical elements supporting biology, specific pollutants, 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 (water, biota and/or sediments), compared with the Environmental Quality Standards (EQS).

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

5.5.3. Soil and groundwater

Geology

Dampierre-en-Burly NPP is built on natural topsoil comprising alluvium:

- at the site of the cooling towers and reactors Nos. 3 and 4, the alluvium is 6 to 7 metres deep and sits on around 6 metres of soft limestone (known as Beauce limestone or Gien limestone), succeeded by 8 to 14 metres of clay formations and Eocene puddingstone (Gien puddingstone);
- at the site of reactors Nos. 1 and 2, the alluvium is approximately 10 metres deep, sitting directly on 6 to 23 metres of weathering clay and altered chalk (Cretaceous).

Puddingstone is consolidated detrital sedimentary rock, made up of rounded pebbles bound together by a natural cement.

During construction, earthworks focused on significantly raising ground levels using sand/gravel and sand/clay fill materials extracted from the nearby gravel-quarry. The location of the power plant also required the creation of engineered confinement structures, which were left in place on completion of the works.

Hydrogeology

There are two aquifer layers beneath Dampierre-en-Burly power plant, Loire alluvium and a chalk aquifer. These formations are naturally hydraulically connected at the site: they are not strictly speaking separated in situ by a semi-permeable or impermeable formation. This means that the groundwater moving through these aquifers is in equilibrium. Given this connectivity between the groundwater flowing in the alluvial deposits and in the chalk at the Dampierre-en-Burly site, it is considered to be one single entity (‘water table’) flowing in horizons with varying permeabilities.

The latest updates to the 2016-2021 Water Development and Management Plan [SDAGE] for Loire-Bretagne and to the current revision of SDAGE 2022-2027 both pronounce the underground body of water at the site as having achieved good quality status.

- ***Soil status***

The initial condition of the soil around the power plant is determined using national databases, 'control' soil samples taken in 2020 within the plant boundary, outside the 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).

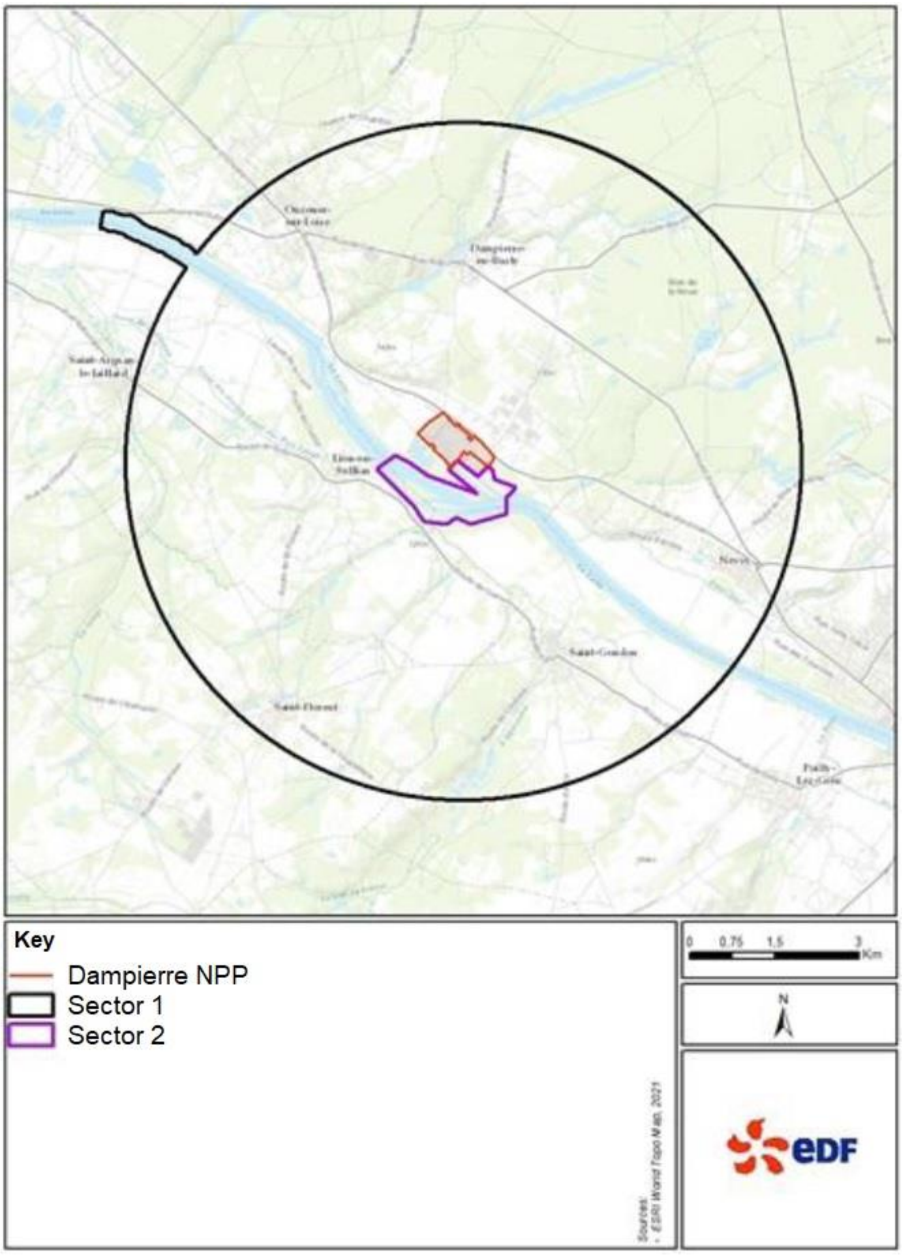
- ***Radiological status of the environment***

Analysis of the results of radioecological surveys carried out by the operator in the environment around Dampierre-en-Burly power plant highlights the predominantly natural sources of radioactivity, primarily potassium-40 and beryllium-7.
Artificial radioactivity mainly originates from the residual effects of the fallout from atmospheric nuclear tests, the Chernobyl accident and, to a lesser extent, the Fukushima accident, as well as the authorised effluent discharges from Dampierre-en-Burly NPP and from Belleville-sur-Loire NPP upstream of the Loire River. The authorised discharges of effluents from Dampierre-en-Burly power plant result in the near-field detection of certain radionuclides, the impact of which is negligible.

5.5.5. Biodiversity

A review of the ecological priorities for the area around Dampierre-en-Burly NPP was carried out:

- firstly, by detailing the areas of special interest and the ecological functionalities within a 10-km radius of the power plant;
- secondly, by conducting an impact assessment in relation to two sectors within this boundary:
- sector 1 corresponds to the area of influence associated with overall plant operation. The bounding area for this sector is defined by a circle with a radius of 6 km, centred in the power plant, reflecting the area of influence on the terrestrial environment, and by a section of the Loire leading to the measurement station the furthest downstream, approximately 8 km from the power plant (9.5 linear km), representing the area of poential impact on the aquatic environment;
- sector 2 constitutes the area of influence more distinctly associated with the maintenance of water abstraction structures (dredging in particular).



Study sectors 1 and 2 adopted for the Dampierre-en-Burly NPP impact assessment

Natural areas of special interest

The following natural areas of special interest have been identified within a 10-km radius of Dampierre-en-Burly NPP:

- five sites in the Natura 2000 protected areas network;
- one area under a Prefectural Biotope Protection Order [APPB];
- eleven type-1 Natural Areas of Interest for Ecology, Fauna and Flora [ZNIEFF] and five type-2 ZNIEFF;
- three sites managed by the Nature Conservation Trust [CEN].

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

Twelve diverse habitat groups have been identified in sector 1, under five habitat complexes: anthropised environments (altered and modified by human activity), aquatic and wetland habitats (waterbodies, pools and rivers), open and grassland habitats (grasslands, meadows, wasteland), semi-open habitats (scrub, heathland, brush) and forest habitats. Wooded areas cover the largest surface area. Mesophilic woodlands on the slopes either side of the Loire Valley remain the most common habitat. Anthropised habitats are also very prevalent around Dampierre-en-Burly NPP.

Sector 2 features 15 distinct habitats, under four habitat complexes: anthropised environments, aquatic and wetland habitats, open and grassland habitats, and forest habitats.

Vegetation

Over 200 terrestrial, semi-aquatic and aquatic species have been registered in the communes within the study area, including 179 and 27 species of special interest in sectors 1 and 2, respectively (protected and/or heritage species). The majority of the plant species are listed as common to very common and thus contribute to the biodiversity of common species, with 62 classified as protected.
More than 400 phytoplankton taxa have been found in the study area. As regards diatoms, the repeat species in the Loire, at the Dampierre-en-Burly site, is *Cocconeis euglypta*. For the most part, it is found alongside *Eolimna subminuscula, Gomphonema pumilum var. rigidum*, and *Achnanthidium eutrophilum.*
In addition, 21 and 10 invasive alien species were recorded in sectors 1 and 2, respectively.


Left, water primrose (Ludwigia grandiflora), right, boxelder maple (Acer negundo) © THEMA Environnement

Fauna

Most of the species in the study area are listed as common to very common, and thus contribute to the biodiversity of common species.

Bibliographic data supplemented by field investigations identified numerous species of macroinvertebrates, including two protected species (the white-clawed crayfish and the thick-shelled river mussel).

Species	Sector 1	Sector 2
Invertebrates	72	36
Fish	30	38
Amphibians	14	3
Reptiles	7	4
Birds	154	74
Chiropterans	13	0
Mammals	5	6

These results reflect the presence in the study area of many species that can be categorised as being of special interest owing to their protected status and/or heritage value. Invasive alien species of macroinvertebrates and fish were also found in the study area (the spinycheek crayfish, the pumpkinseed, etc.).

Bechstein's bat (Myotis bechsteinii) - © R. GRIGNON - Catiche

Eurasian beaver (Castor fiber) - © S. RICHIER - Catiche

Ecological functionalities

There are three ecological landscape units in and near the study area: the Loire River, the accompanying Loire River ecosystems, and the woodlands north and south of the study area.

These environments are home to diverse habitats, as well as flora and fauna of special interest. Several fragmenting features tend to reduce the functionality of these areas (road infrastructure, power lines, weirs, etc.). Dampierre-en-Burly NP sits on the bank of the Loire River, in a man-made and fenced-off area, disconnected from the sector's functional corridors.

Wildlife already moves through the landscape by circumventing the power plant.

Many areas are registered as **biodiversity reservoirs** or **ecological corridors** under the Regional Ecological Coherence Protocol [SRCE] for the Centre-Val de Loire region.

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.

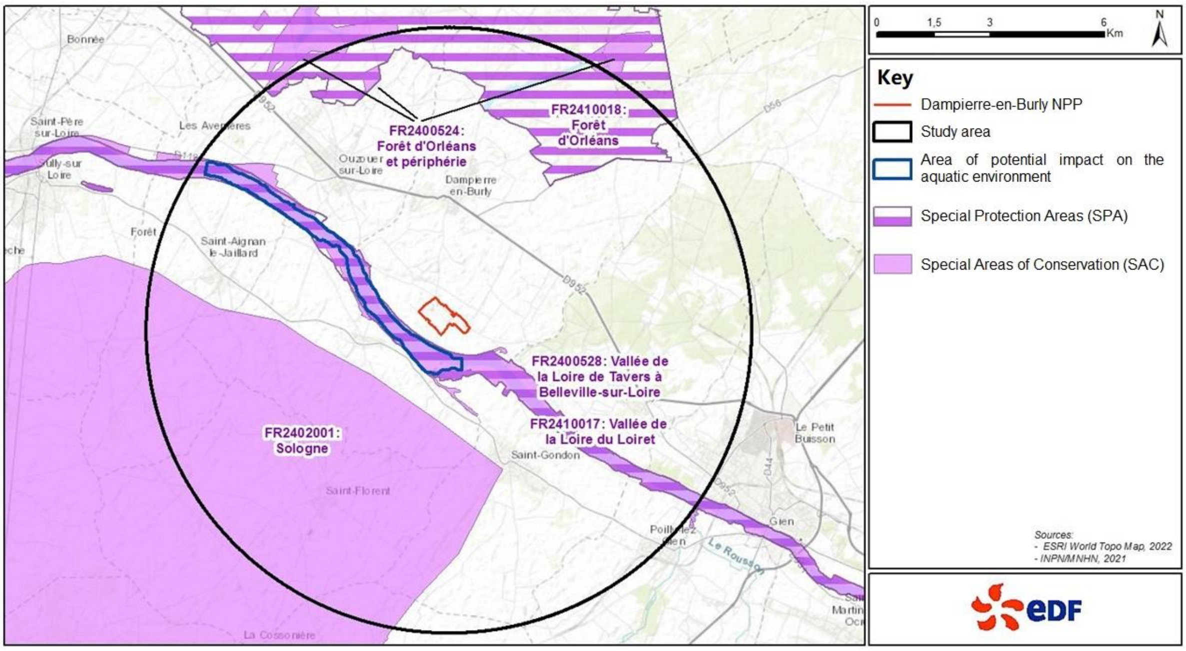
The Natura 2000 sites

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

- SPA FR2410017 – 'Vallée de la Loire du Loiret'
- SPA FR2410018 – 'Forêt d'Orléans'
- SAC FR2400528 – 'Vallée de la Loire de Tavers à Belleville-sur-Loire'
- SAC FR2402001 – 'Sologne'
- SAC FR2400524 – 'Forêt d'Orléans et périphérie'.

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

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



The Natura 2000 sites within a 10-km radius of Dampierre-en-Burly NPP

5.5.6. Population and human health

▪ *Population*

The extended 50-km-radius study area shows the distribution of the population around Dampierre-en-Burly power plant, while the more local 10-km-radius study area focuses on identifying populations of interest.

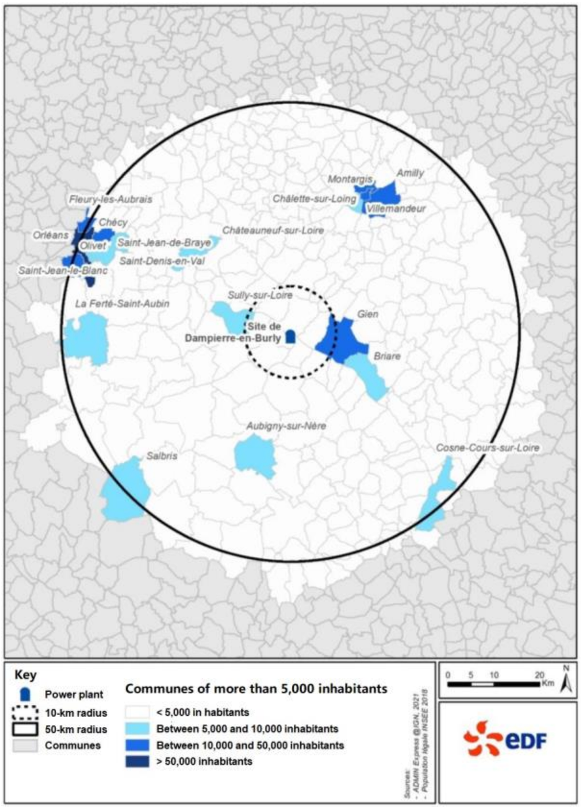
Within the 50-km radius, the average population density is around 67 inhabitants/km², while it is approximately 53 inhabitants/km² within the 10-km radius, which for both radii is significantly lower than the average value for mainland France, at around 119 inhabitants/km² (2018 census).

The largest communes within a radius of 50 kilometres are Orléans (116,238 inhabitants), Olivet (22,168 inhabitants) and Fleury-les-Aubrais (21,070 inhabitants).

Within the narrower study area of 10 kilometres, Gien (13,732 inhabitants) and Sully-sur-Loire (5,286 inhabitants) are the only communes with more than 5,000 inhabitants.

The nearest vulnerable populations (in schools, childcare facilities, healthcare centres and nursing homes) are located approximately 2 kilometres west of the site boundary.

The residential housing closest to Dampierre-en-Burly power plant is situated around 50 metres west of the site.



Communes of over 5,000 inhabitants within a 50-km radius of Dampierre-en-Burly NPP

▪ *Noise and light pollution*

A noise measurement campaign was carried out in 2016 at Dampierre-en-Burly NPP. Noise levels on site comply with the targets set by regulations.
Light emissions in the vicinity of the plant mainly originate from public lighting in the communes of Gien and Sully-sur-Loire.

5.5.7. Human activities

▪ *Land use*

Land use within a 10-kilometre radius of Dampierre-en-Burly power plant falls under two main categories, defined as deciduous woodland (around 33%) and non-irrigated arable land (26%).
Generally speaking, agricultural land, forest surfaces and artificial surfaces account for 50%, 42% and 5% of the study area, respectively.

Landscape and cultural heritage

Five landscape units have been identified within a 10-km radius of Dampierre-en-Burly power plant:

- The Orléans Forest, north of the power plant, sits on the ridge separating the Loire-Bretagne and Seine-Normandie catchment areas, and covers 40% of the study area;
- The plateau of the Sologne forest lands within the Orléanais region, south of the plant, is made up of 60% woodland and covers approximately 29% of the study area;
- The Val Sous Coteaux, a long rivercourse between two hillsides, followed by the Loire, covers around 23% of the study area;
- The Val des Méandres (a plain crossed by the Loire and by meanders), to the west of the power plant, is a recognised ecological landscape covering 5% of the study area;
- Lastly, the Vallon du Berry hollow, extending over most of the left bank of the Loire in the Pays du Giennois microregion, represents approximately 4% of the study area.

There are several protected sites and historical monuments within a 10-km radius of Dampierre-en-Burly NPP:

- One listed site, the 'Crapaud' stone (a Neolithic stone shaped like a toad), about 1 km south of the power plant;
- One listed site, the 'Butte des Druides' tumulus (a druidic burial mound), located 1.2 km west of the plant;
- One heritage site of special interest, the village of Cerdon-du-Loiret, 10.4 km south-west of the plant;
- One historical monument, the church of Saint-Étienne, located 2 km west of the plant.

There are no archaeological sites within a 10-km radius of the power plant.

Water use

The water abstracted within a 10-km radius of Dampierre-en-Burly NPP serves three purposes:

- Drinking water: the first groundwater abstraction point downstream of Dampierre-en-Burly power plant is located around 1.9 km away, in the Commune of Lion-en-Sullias. Water is not abstracted directly from the Loire River;
- Agricultural water: the first groundwater abstraction point downstream of the plant is located around 1.6 km away, in the Commune of Lion-en-Sullias. There are also several abstraction points in the Loire downstream of the plant, the first of which is sited about 5.5 km away, in the Commune of Ouzouer-sur-Loire;
- Industrial water: the first groundwater abstraction point downstream of the power plant is located in the Commune of Ouzouer-sur-Loire. There are no abstraction points directly on the Loire River.

Infrastructure and transport links

Access to Dampierre-en-Burly NPP is via the D953 departmental road. The main roads serving the surrounding area include the D952, which runs around 3 kilometres north of the plant, and the D940, running about 10 kilometres south of the plant.
The only railway line running nearby is the line serving Gien train station, approximately 8.9 kilometres south-east of the power plant.

There are no navigable waterways in the study area.

Industrial environment

There are around fifteen facilities classified for environmental protection [ICPE] within a 10-km radius of Dampierre-en-Burly NPP, none of which is classified under the **SEVESO** directive.

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

Recreation areas and leisure activities

Hunting and fishing take place in the area around Dampierre-en-Burly power plant. Fishing is prohibited along the entire width of the Loire riverbed, from the 50-metre point upstream to the 130-metre point downstream of the Dampierre-en-Burly weir.

The area around Dampierre-en-Burly NPP offers a wide range of sports and leisure activities (hiking, horse riding, golf, etc.), as well as culture and tourism (scenery, nature, museums, historical monuments, etc.).

There are no listed bathing sites within a 10-km radius of the power plant.

Other uses

A freshwater aquaculture company is sited 5.2 kilometres north-east of the power plant, in the Commune of Ouzouer-sur-Loire. At the crossroads of three regions, Sologne, Gâtinais and Val de Loire, the company Pisciculture du Val de Loire operates a total of 1,000 hectares of ponds, applying traditional fishing methods.

Three professional fishermen share the 125-kilometre stretch of Loire River in the Loiret Department.

Energy consumption

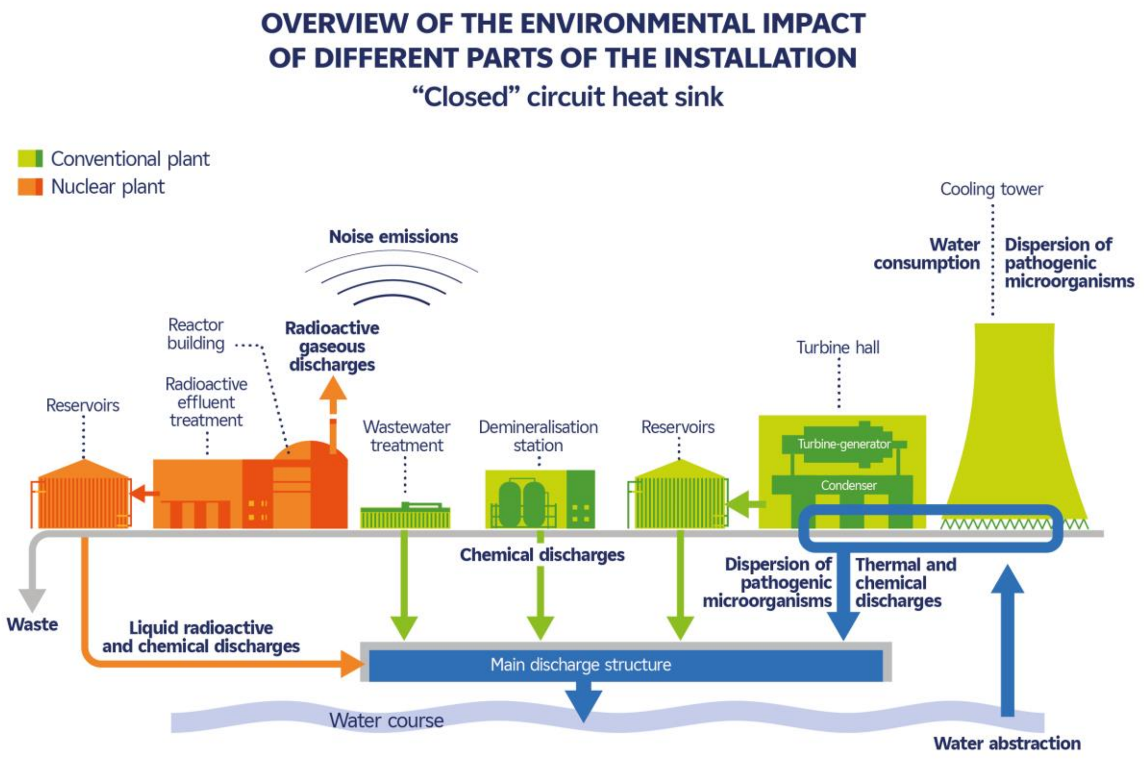
The power plant's annual electricity consumption is of the order of 140 GWh, equivalent to around 0.7% of its annual output (in 2024, it produced 20.78 billion kWh of electricity, representing 6% of France's nuclear-generated electricity). Dampierre-en-Burly NPP's annual output meets its own electricity consumption requirements and covers 100% of the electricity needs of the Centre-Val de Loire region.

5.6. Dampierre-en-Burly NPP interactions with the environment

This section sets out the interactions between Dampierre-en-Burly Nuclear Power Plant operation and the environment, both currently and over the next ten years. These interactions are illustrated in the figure below.

The different types of interactions and their characteristics are detailed in Sections 5.6.1 to 5.6.8.

Section 5.6.9 presents the changes in these interactions over the next ten years.



5.6.1. Water abstraction and consumption

In order to meets its supply requirements for cooling water, demineralised water and industrial water, Dampierre-en-Burly NPP makes use of two separate sources: Loire River water and groundwater.

Drinking water is supplied by the public network serving the Commune of Dampierre-en-Burly.

- Loire River water is drawn via an intake channel, which gravity-feeds the intake structure and then the two pumping stations. A weir in the river, around 200 metres in length, ensures adequate flow in front of this intake structure. The raw water is mostly directed to the plant's condenser cooling systems, as well as the demineralisation station.
- Groundwater is directed to the industrial water systems of various installations, including in particular the ultimate emergency makeup water system.

The **demineralisation station** produces the demineralised water needed for the power plant's primary and secondary circuits.

Dampierre-en-Burly NPP demineralisation station© EDF

An abstraction licence is only required for groundwater and Loire water. Aside from the water evaporating through the cooling towers of reactors 1 to 4, the water drawn from the Loire is returned to the river.

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

Actual volumes of abstraction therefore remain below the regulatory limits (Decision No. 2011-DC-0211[10]).

The table below shows the limits for annual water abstraction, along with recorded abstractions over ten years. No changes in volumes of abstracted water are planned for the next ten years.

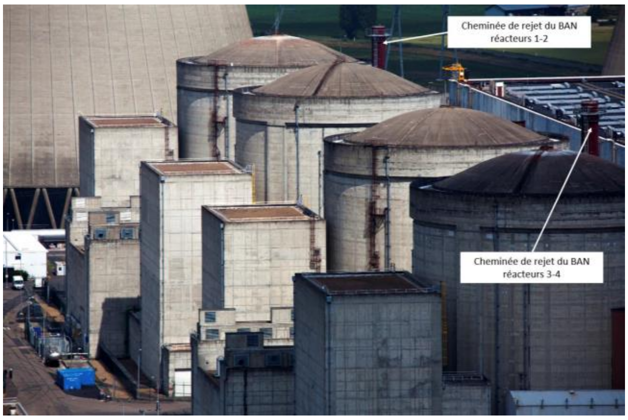
Source of abstraction	Use	Annual volume	
		Regulatory limit (annual abstraction)	Average annual abstraction 2012-2021
Loire River	Cooling water, raw water for industrial uses	245 million m^3	187 million m^3 (consumption: 52 million m^3 for cooling, 421,000 m^3 for demineralised water production)
Groundwater table	Ultimate emergency makeup, raw water for industrial uses	56,000 m^3	32,429 m^3

Regulatory limits and water abstraction volumes for Dampierre-en-Burly NPP

5.6.2. Liquid and gaseous radioactive effluent discharges

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

The power plant's liquid radioactive effluents are discharged via the dilution system built into the receiving weir in the Loire River.
Gaseous radioactive effluents are released into the atmosphere via the two stacks on top of the nuclear auxiliary buildings (NAB).



© EDF
The power plant's nuclear auxiliary building stacks

[10] Nuclear Safety Authority Decision No. 2011-DC-0211 dated 3 March 2011 setting out the requirements for water abstraction and consumption, and for liquid and gaseous effluent discharges to the environment, directed at basic nuclear installations No. 84 and No. 85 operated by Électricité de France (EDF-SA) in the Commune of Dampierre-en-Burly (Loiret Department).

The power plant discharges five categories of radionuclides:

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

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

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

The limit values for radioactive effluent discharges from Dampierre-en-Burly NPP are defined in regulations set out by the Authority for Nuclear Safety and Radiation Protection (Decision No. 2011-DC-0210[11]).

- Iodine is a by-product of uranium fission, and remains mostly contained within the fuel rods. A small quantity of iodine may nevertheless migrate into the primary circuit water in the event of fuel cladding failure. Iodine present in liquid radioactive effluents is trapped efficiently by the effluent treatment systems, and its short half-life ensures that it disappears quickly.
- The other beta or gamma emitting fission or activation products (‘other FPs/APs’) are formed by fission (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 FPs/APs’ present in the form of aerosol particles in the effluents discharged to atmosphere are treated in decay tanks, and/or are captured by iodine traps (activated carbon) and high-efficiency filters. In liquid effluents, the ‘other FPs/APs’ are largely contained in the treatment systems (filters or resins) of the reactor coolant continuous cleanup system and effluent treatment system.
- Rare gases are produced by fission and remain mostly contained within the fuel rods. However, a small quantity of rare gases may migrate into the primary circuit water for the reasons mentioned above, and may end up in the radioactive gaseous effluents. These effluents are discharged to atmosphere after sufficient radioactive decay in storage tanks.

[11] Nuclear Safety Authority Decision No. 2011-DC-0210 dated 3 March 2011 stipulating environmental discharge limits for the liquid and gaseous effluents produced by basic nuclear installations No. 84 and No. 85 operated by Électricité de France (EDF-SA) in the Commune of Dampierre-en-Burly (Loiret Department).

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 Dampierre-en-Burly 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 Dampierre-en-Burly NPP's radioactive discharges over a 10-year period (average discharges between 2012 and 2021).

- Overview of liquid radioactive discharges between 2012 and 2021

	Annual limits (GBq/yr)	Annual average activity released GBq/yr
Tritium	100,000	46,000
Carbon-14	260	44
Iodine	0.6	0.015
Other beta or gamma emitting fission and activation products	36	1.258

- Overview of gaseous radioactive discharges between 2012 and 2021

	Annual limits (GBq/yr)	Annual average activity released GBq/yr
Tritium	10,000	1,470
Carbon-14	2,200	721
Rare gases	72,000	1,424
Iodine	1.6	0.167
Other beta or gamma emitting fission and activation products	0.8	0.006

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 (derived from circuit-conditioning substances, from the demineralisation station and purification plant, and from **antiscaling and biocide treatments**) and, to a lesser extent, to discharges to atmosphere (from circuit and equipment operation).

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

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

Liquid chemical effluents

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

- Boric acid, hydrazine, morpholine and total nitrogen, from primary and secondary circuit conditioning;
- Phosphates, from the conditioning of some nuclear and conventional island auxiliary systems, primarily the component cooling and superheated water circuits;
- Sulphates, from the processes aimed at inhibiting scale formation in cooling circuits;
- Polyacrylates and sodium, derived from the scale-inhibition treatment of cooling systems;
- AOX (organic halogens formed when a halogen-based oxidising biocide reacts with organic matter), TRC (total residual chlorine), sodium, chlorides, ammonium, nitrites and nitrates, from cooling circuit biocide treatment operations;
- AOX, THM and sulphates from sulphuric-acid shock-treatment chlorination;
- Copper and zinc derived from brass condenser tube wear-and-tear.

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 that can be applied for plant operation. The assessment of the impact of the discharges, carried out on the basis of these maximum values, is therefore bounding of the plant'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[12] into the Loire River (stipulated in the decisions, specifying limits and conditions, that are currently in force or determined from additional characterisations based on OPEX or design data), and an overview of past discharges of higher-impact chemical substances, over a 10-year period.

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[12] The limit values shown above are those set out in Nuclear Safety Authority Decision No. 2011-DC-0210 dated 3 March 2011 stipulating environmental discharge limits for the liquid and gaseous effluents produced by basic nuclear installations No. 84 and No. 85 operated by Électricité de France (EDF-SA) in the Commune of Dampierre-en-Burly (Loiret Department).

Substances	Annual flow (kg)	
	Maximum discharge values	Actual discharges (2012-2021 average)
Boric acid	24,200 kg	10,983 kg
Hydrazine	30 kg	2 kg
Morpholine From effluent treatment tanks, backup tanks and inspection tanks	4,000 kg	746 kg
Total nitrogen (ammonium, nitrites, nitrates) From effluent treatment tanks, backup tanks and inspection tanks	9,800 kg	2,145 kg
Phosphates From effluent treatment tanks, backup tanks and inspection tanks	730 kg	287 kg
Sulphates	1,360 kg/day, so 496,400 kg*	0 kg**
Ammonium (monochloramination)	90 kg/day, so 32,850 kg*	326 kg
Nitrates (monochloramination)	1,520 kg/day, so 554 800 kg*	86,882 kg
Nitrites (monochloramination)	70 kg/day, so 25,500 kg*	246 kg
AOX	1,245 kg	260 kg
Total residual chlorine	4,500 kg	185 kg
Copper From condenser wear-and-tear	40 kg/day, so 14,600 kg*	9,559 kg
Zinc From condenser wear-and-tear	25 kg/day, so 9,125 kg*	3,614 kg

**: Given that Decision No. 2011-DC-0210 does not stipulate an annual discharge limit for these substances, the maximum discharge values are extrapolated by multiplying the daily limit by 365.*

***: Dampierre-en-Burly NPP did not carry out any chemical cleaning over the period 2012-2021.*

■ *Chemical effluents discharged to atmosphere*

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

- exhaust gases (sulphur and nitrogen oxides - SOx and NOx) emanating from emergency combustion plant during surveillance testing;
- formaldehyde and carbon monoxide emissions from new glass wool insulation, produced when first heated;
- ammonia emissions from the turbine bypass system, originating from the auxiliary feedwater system and from the thermal decomposition of hydrazine in the steam generator layup solution at reactor startup;
- morpholine or ethanolamine emissions;
- ammonia from the extraction system for non-condensable gases from the secondary circuit, when the condenser is kept under vacuum, which is discharged from the nuclear auxiliary building stack;
- emissions of total residual chlorine (TRC), ammonia, hypochlorous acid (HOCl) and trihalomethanes (THM) from the cooling towers, during biocide treatment operations;
- exhaust gases from the vehicles and lorries used for waste disposal and for transport of goods and materials (delivery and dispatch). Due to the limited use of these vehicles on site and thanks to regular maintenance checks, the quantities of gases released annually are low;

- diffuse emissions of refrigerants and SF_6 used in chiller units (for the production of chilled water and for cooling technical and tertiary facilities) and in the site's power transmission switchyards, respectively. These emissions are quantified during maintenance of these installations;
- emissions of dust into the atmosphere, from mechanical workshops, in negligible quantities.

5.6.4. Thermal discharges

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

Thermal discharge limits for Dampierre-en-Burly NPP	
Conditions	**Average daily temperature increase (°C)**
Normal conditions	≤ 1°C
Specific conditions: Loire River flow below 100 m³/s and T°$_{\text{Loire upstream}}$ < 15°C	< 1.5°C

In a nuclear power plant, as per Carnot's principle of thermodynamics, around one-third of the thermal energy that is produced by the reactor is converted into electricity. The remainder, so around two-thirds of this energy, is transferred as heat through the condenser to a heat sink, which can be a body of water (a so-called 'open-circuit' heat sink) or the atmosphere (via cooling towers, a so-called 'closed-circuit' heat sink). This therefore results in thermal discharges into the environment.
At Dampierre-en-Burly NPP, the condensers are cooled by way of a 'closed' circuit: the raw water flowing through the cooling circuits is reheated in the condensers, and then cooled on contact with the heat transfer packing in the cooling towers. Most of the thermal energy is transferred to the atmosphere through evaporation and convection. The thermal discharges into the Loire originate from the continuous blowdown from the cold basins of the cooling towers, aimed at controlling the cycle of concentration.

Between 2012 and 2021, the power plant increased the temperature of the water between intake and discharge points by an average 0.15°C, with a maximum recorded value of 0.91°C.

5.6.5. Management of sediment from intake channel maintenance dredging

In order to ensure a supply of raw water for its facilities, and thus maintain them in a safe state, Dampierre-en-Burly NPP has to conduct dredging operations in the intake channel, using a suction dredger to extract accumulated sediment.

Dredged sediments are preferably returned to the Loire River during these operations, though they can be temporarily laid in settling mudflats if the hydrological conditions of the Loire do not allow for immediate discharge in keeping with the criteria for suspended matter concentrations added to the Loire.

5.6.6. Waste production

The operation of Dampierre-en-Burly 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

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

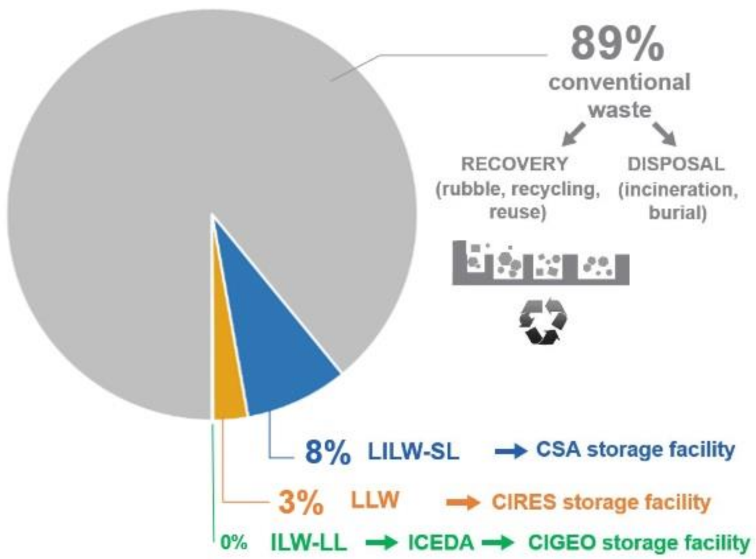
* The half-life of the radioactive material (radionuclides) in the waste to decay.
** The level of radioactivity of the radioactive waste.

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

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

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

Activities related to the operation of Dampierre-en-Burly NPP generate conventional waste (89% of total waste produced) and radioactive waste (11% of total waste produced).



Breakdown of waste categories and waste disposal routes for waste generated by Dampierre-en-Burly NPP operation

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

Overall, the volume of waste produced is likely to change in the next ten years. More specifically, the following changes are anticipated:

- An increase in the volume of VLLW, on account in particular of the plant refurbishment works linked to the Grand Carénage[13] programme;
- An increase in the volume of solid SL-LLW sent to Centraco (incineration/melting) for environmental reasons. Using this disposal route reduces the volume of waste stored at the Aube Disposal Facility [CSA] by a factor of 15 as regards incinerated waste, and by a factor of 6 for melted waste. This strategy also explains the smaller volume of SL-LLW intended for direct storage at CSA.
- A reduction in the volume of liquid SL-LLW, driven by the power plant's determination to minimise the quantities of liquid waste that it generates. When feasible, this waste is processed in the units, by way of evaporation.

No significant changes are expected in either the categories of waste generated, or their disposal routes.

Radioactive waste	Average annual waste-package volume (m^3) (average for 2010-2019)	Projected average annual waste-package volume (m^3) (average for 2025-2028)
Solid VLLW for storage at CIRES	107	440
Solid SL-ILW for storage at CSA	229	215
Solid SL-LLW for direct storage at CSA	170	75
Solid SL-LLW for processing (melting)	87	320
Solid SL-LLW waste for processing (incineration)	298	540
Liquid SL-LLW for processing (incineration)	97	16

5.6.7. Noise and vibration emissions

Dampierre-en-Burly NPP conducts a noise emission measurement campaign every ten years. The noise emission measurement campaign carried out in 2016 concluded that recorded noise levels complied with the targets set by regulations.
Dampierre-en-Burly power plant may generate vibrations related to its industrial activities (from rotating machinery, construction equipment, vehicles, etc.). Owing to the design of the buildings and the composition of the soil, these vibrations are felt inside site facilities but are not perceptible off-site.

5.6.8. Land use

Dampierre-en-Burly power plant covers an area of 225 hectares in which a range of industrial activities take place. Most of the land is anthropised. There are no plans for any changes in the land surface required for operating Dampierre-en-Burly NPP's 4 reactors over the next ten years.

[13] EDF's Grand Carénage nuclear fleet refurbishment programme is driving the investments/upgrades needed for continued operation of existing facilities and the implementation of post-Fukushima measures, thereby supporting performance through enhanced fleet safety and competitiveness.

5.6.9. Other interactions

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

5.6.10. Ten-year projection of interactions between Dampierre-en-Burly and the environment

The past and current interactions between Dampierre-en-Burly NPP operation and the environment are presented in Sections 5.6.1 to 5.6.9 above.
As shown in the table below, the interactions between Dampierre-en-Burly 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	Dampierre-en-Burly NPP's various requirements for water are covered by Loire River and groundwater abstraction, or by the public water supply network. Regulated abstraction (of surface water and groundwater) has always remained below stipulated limits (Decision 2011-DC-0211).	There are no plans to change the sources of water supplies. Over the next ten years, the projected volumes abstracted for purposes of Dampierre-en-Burly plant operation will remain of the same order of magnitude as during the previous decade, and within regulatory limits.
Liquid radioactive effluent discharges	Radioactive effluents are discharged into Loire River water, via the dilution system built into the receiving weird in the Loire. The discharges are regulated by Decision No. 2011-DC-0210.	There are no plans to change the discharge point in the Loire. Over the next ten years, the projected volumes discharged for purposes of Dampierre-en-Burly 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. 2011-DC-0211 and 2011-DC-0210.	There are no plans to change the sites of discharges to atmosphere. Over the next ten years, the projected discharges for purposes of Dampierre-en-Burly 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. 2011-DC-0211 and 2011-DC-0210.	Over the next ten years, the projected liquid chemical effluent discharges for purposes of Dampierre-en-Burly plant operation will remain of the same order of magnitude as during the previous decade, and within regulatory limits.

Interaction with the environment	Past operation	Ten-year projection
Thermal discharges	Thermal discharges are governed by regulations that limit the temperature increase of water between the intake and discharge structures.	There are no plans for changes to thermal discharges, which will remain within regulatory limits.
Radioactive waste production	Annual volumes of waste (in m^3) Very low level waste: 107 Low level waste: 652 Intermediate level waste: 229	Overall, the volume of radioactive waste generated over the next 10 years is expected to change in comparison to the quantities of waste produced during the reference period. This projected change in waste generation is due to planned maintenance works under the Grand Carénage programme, as well as the power plant's waste management strategy (prioritising incineration and melting over direct storage).
Noise emissions	Dampierre-en-Burly NPP carries out a noise emission measurement campaign every ten years. The last measurement campaign in 2016 concluded that noise levels comply with the targets set by regulations.	No major changes, though temporary noise and vibrations may be caused by possible modification and construction work.
Land use	Dampierre-en-Burly power plant covers an area of 225 hectares.	There are no plans for any changes to the land surface required for operating Dampierre-en-Burly NPP's four reactors in the next ten years.
Other interactions	Other interactions with the environment include odours, light emissions, road and rail traffic, and energy consumption.	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 Dampierre-en-Burly 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, 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 Dampierre-en-Burly NPP and the environment will remain similar in the next ten years to those of the previous decade.

The environmental effects of Dampierre-en-Burly NPP operation are presented by area (Section5.7.1 to 5.7.9); 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 (CO_2), the main **greenhouse gas**.
According to a 'life cycle analysis' by EDF R&D, each kWh produced by EDF's nuclear fleet emits the equivalent of **4 grammes of CO_2**. This figure substantiates the fact that nuclear power is a very low carbon energy source: ACV du kWh nucléaire (LCA of a nuclear kWh).
The gaseous discharges linked to Dampierre-en-Burly 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 Dampierre-en-Burly NPP, during normal operation, only the discharges of nitrogen oxide and sulphur oxide and the emissions of carbon monoxide are subject to an air quality standard. The assessment of the impact of these emissions on air quality shows that the power plant has no 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 Dampierre-en-Burly plant operation are not likely to degrade air quality.
Dampierre-en-Burly NPP is not covered by an Air Protection Plan (APP) [PPA].

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].

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

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

- ***Climate change sensitivity***

Local projections by Météo-France of the main climate factors show an upward trend in future average annual air temperatures, with temperature increases that may exceed + 1.3°C by 2035, compared with the historical period of 1982-2012.
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 Dampierre-en-Burly NPP’s discharges to atmosphere.

5.7.2. Surface water

- ***Impact on hydrology***

Given that the power plant’s cooling system operates as a closed circuit, most of the water abstracted from the Loire is returned to the river. However, part of the flow evaporates via the cooling towers. The average rate of evaporation at Dampierre-en-Burly NPP is around 0.57 m^3/s per reactor, in other words, around 2.3 m^3/s for all four reactors, in normal operating conditions, which corresponds to about 0.7% of Loire average flow and around 4.6% of Loire minimum average flow over three consecutive days. The rates of evaporated flows are therefore low compared to the average flow rate of the Loire and do not affect continuity with regard to river uses.
What is more, the two features of the power plant’s water intake (the weir in the Loire and the weir in the intake channel) do not alter river flow.

Lastly, the release of dredged sediments into the low-water channel of the Loire helps maintain fluvial dynamics. These operations therefore do not affect the hydrology of the Loire River.

Impact on surface water temperature

Analysis of the operating experience on thermal discharges from Dampierre-en-Burly NPP over a ten-year period (2012-2021) indicates an average increase in post-mixing water temperature of 0.15°C, with a maximum value of 0.91°C. The thermal plume created by the power plant's discharges is located along the right bank over the first few kilometres, in the direction of discharge, and then gradually spreads across the entire width of the Loire, further downstream. At the regional level, the residual warming associated with the operation of Dampierre-en-Burly power plant is quickly undetectable, on account of the precision of temperature measurements and the natural temperature variations of the Loire.

Impact on surface water quality

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

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

Impact on morphology-sedimentology

The focal potential impact stems from sediment return to the Loire River, downstream of the weir in the Loire and on the right bank of the main river channel. The temporary restriction of the cross-sectional area resulting from deposit formation is negligible compared to the wet surface of the river. Furthermore, the spot where sediment is returned is an area that provides favourable conditions for the physical remobilisation of materials. In addition, the offsetting release of sediments into the low-water channel of the Loire helps maintain fluvial dynamics.
The impact of the return of dredged sediments on the hydrology and morphology of the Loire is considered to be negligible.

Climate change sensitivity

The climate change developments that may have a bearing on the results of this study are tied to increases in the water temperature and changes in the flow rate of the Loire River. The study of the local impacts of climate change is a topic of extensive ongoing research aimed at establishing methodologies for generating climate projections at a local scale, factoring in notably the changes in watercourse temperature and flow.
Among the different climate variables that are likely to influence changes in the aquatic environment, water temperatures are one for which a trend has been observed, particularly in the summer, associated with changes in air temperatures.

Measurements taken since the late 1970s establish an overall increase in Loire River temperature, as evidenced by a number of statistical parameters.
What is more, EDF's projections for future climate conditions confirm the upward trend in average annual Loire temperatures, with increases of between + 0.7 and + 1°C on average, over the period 2020-2050, compared with the historical period selected (1982-2012).
Past observations and 30-year projections thus estimate the climate-change related increase in average annual Loire water temperature at around + 0.3°C per decade.
However, given the scenarios adopted in this study (water temperature is not used directly in assessments of impacts on the aquatic environment) and this slight increase over the next decade (in light of the interannual variability), it is considered that this change will not alter the conclusions of this study.

With regard to Loire River flow rates, the trends, including for the longer term, are less clear-cut than those for temperatures, with greater uncertainty owing to the more complex modelling of a river basin's hydrological cycle.
EDF projections for future climate show that the Loire River's average annual flows would be lower on average over the period 2020-2050, with a decrease of around 10% compared to the 1982-2012 reference period, and a more pronounced seasonal pattern in flow rates (slightly higher flow rates in winter and lower flow rates in summer).
These results are associated with significant inherent uncertainty in the model chain, due in particular to the spread of global climate model results, but also to the complexity of flow modelling for the Loire basin. Although developed using cutting-edge methods, these results should therefore be considered as trends. It is therefore considered that potential decreases in flow over the study period (ten years) will be relatively small compared to the seasonal and inter-annual variations already observed in the Loire River.

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

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

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

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

5.7.3. Soil and groundwater

- ***Impact on soil***

The earthworks for Dampierre-en-Burly NPP included in particular raising ground elevation using fill, so as to establish a plant platform at a height of 126.1 m NGF (levelling datum) and building engineered confinement structures to keep excavations dry, as well as creating an intake and discharge channel.

An in-depth study of historical and environmental monitoring data improved understanding of the site subsoil by itemising and locating past and current activities, and by assessing their level of risk in relation to the soil and groundwater environments. No evidence of radiological contamination was found within the perimeter of the Basic Nuclear Installation [BNI].

Further investigations were carried out between August 2020 and January 2021, which included 24 surveys to a depth of 10.5 m as well as 369 soil samples for chemical and radiological analyses. Results showed that these samples were generally consistent with the anthropogenic background levels, aside from a few samples that revealed slightly higher concentrations for C10-C40 hydrocarbons, phenols, chlorophenols, and trace metal elements, and for some eluate parameters. These exceeded values did not call for special management measures.

The radiological analyses did not find evidence of contamination in the surveyed areas. Hydrocarbon contamination identified near a piezometer in 2017 was contained within a radius of 3 metres. A subsequent survey in 2020-2021 confirmed that there had been no lateral migration of contamination.

In conclusion, normal plant operation does not have any adverse impact on site soils. Incidents such as spills may have temporary consequences, but response measures are systematically implemented to minimise any impacts, both on- and off-site.

▪ ***Impact on groundwater***

Since its commissioning, Dampierre-en-Burly NPP has been routinely monitoring the groundwater beneath its footprint by running a network of 34 piezometers. Analysis of close to 16,700 samples taken between 2011 and 2019 revealed several isolated cases where certain chemical and radiological parameters had exceeded monitoring thresholds.

There were isolated occurrences of limit values exceeded for heavy metals such as cadmium, lead and nickel. The threshold overruns were observed on an ad-hoc basis and were generally located upstream of the power plant, so they could not be attributed to the NPP but rather to the site's geochemical background.

There were also one-off cases where limit values were exceeded for nitrogen compounds (ammonium, Kjeldahl nitrogen, nitrates and nitrites), particularly at one piezometer located downstream in an agricultural area, thereby indicating an external source.

There were isolated occurrences of thresholds exceeded for phosphates, except for one piezometer downstream of reactor No. 3, which detected more frequent threshold overruns, but not increasing values, leading to the reporting of an environment related event in June 2017.

With regard to hydrocarbons, persistent contamination readings since 2008 south of the transformer of reactor No. 2 gave rise to a significant event in December 2017; a skimmer boom has been in place since 2009 to limit dispersion during the free-product phase.

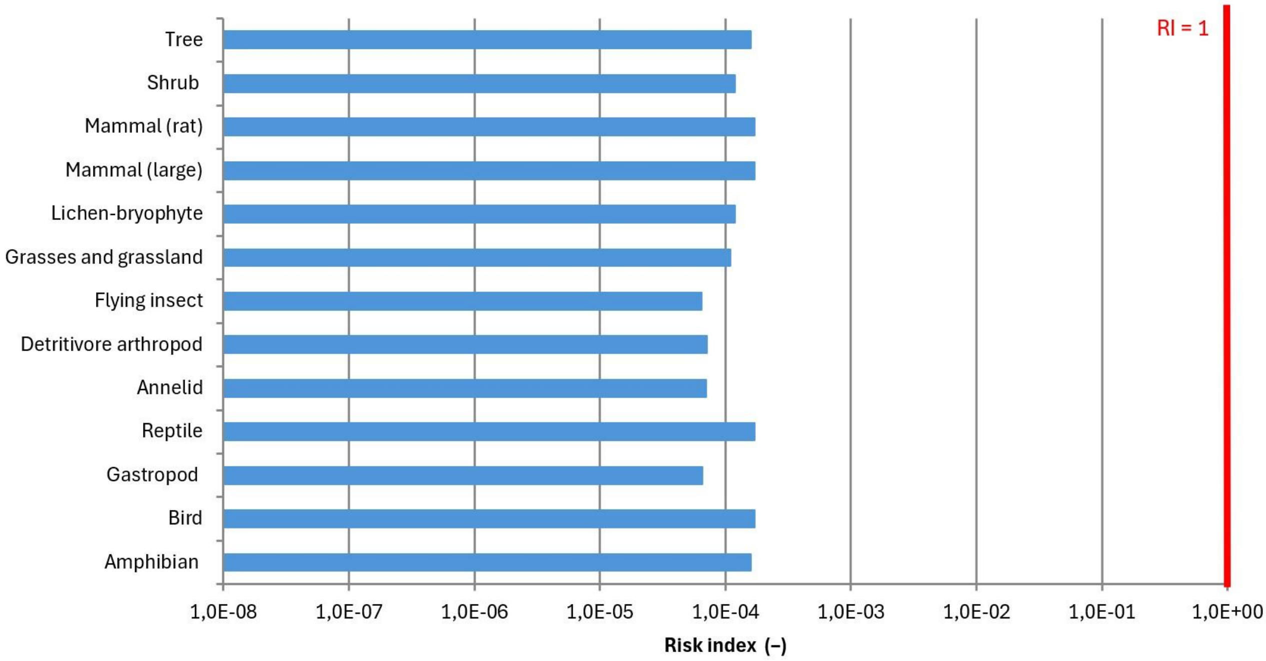
In addition, concentrations regularly overshoot the quality reference values for aluminium, iron and manganese, in keeping with the geochemical background.

As regards radiological results, investigation-level and action-level thresholds were exceeded for tritium, mainly as a result of a spill of radioactive borated water in 2012, which gave rise to a significant event, as well as a subsequent radiation related event in 2015, the cause of which remains unclear. The most recent measurements indicate a return to below-threshold values.

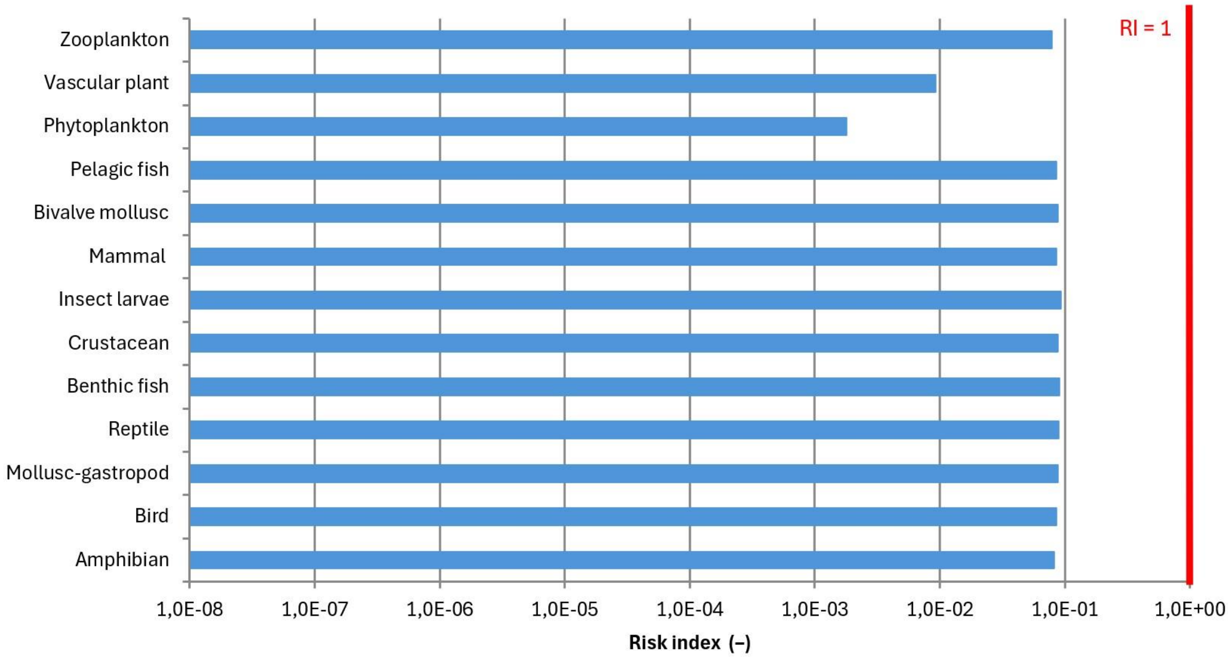
In all cases, the contamination readings led to the implementation of enhanced monitoring programmes and action plans aimed at reattaining concentrations that complied with regulatory requirements. Lastly, the presence of engineered confinement structures provides lasting groundwater protection from potential breaches.

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 Dampierre-en-Burly NPP is negligible, both now and for the next ten years.

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

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The study was based on two complementary approaches:

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- a quantitative method of assessing the environmental and health impacts by modelling the cumulative impact of actual discharges from the facilities and actual river flows in 2016 and 2018, which represented an average year and a year with pronounced low water levels, respectively.

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

5.7.5. Biodiversity

The analysis of the impacts of Dampierre-en-Burly NPP operation on air and on climate factors, surface water, and the radiological state of the environment, as presented above, does not reveal any significant power plant impact on the ecological characteristics of the environment, which are required to foster biodiversity in the study area.
The operation of Dampierre-en-Burly power plant therefore has no impact on the natural areas of special interest, and does not jeopardise the ability of plant species (aquatic, semi-aquatic, or terrestrial) and animal species (invertebrates, fish, amphibians, reptiles, birds, mammals) in the study area to successfully complete their biological life cycle.
What is more, plant operation has no significant effect on species that may move within or migrate to the study area (migrating fish, migrating and nesting birds), and does not compromise the ecological functionalities of the habitats present in the study area.

5.7.6.Population and human health

Evaluation of the dose impact on humans

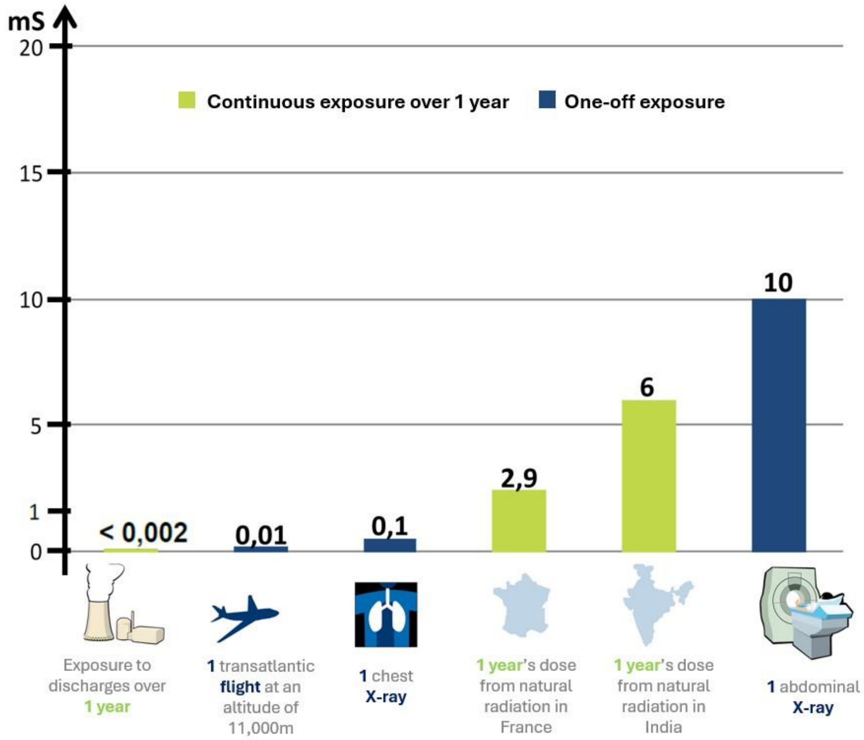
The overall impact on the general public of radioactive effluent discharges from Dampierre-en-Burly NPP factors in the internal and external exposure associated with both liquid effluent discharges and effluent discharges to atmosphere. It is determined for a set of representative individuals, that is to say, for those likely to be most exposed, living within a 5-km radius of the power plant.
The total annual **effective dose** associated with internal and external exposure to radioactive effluent discharges from the site is estimated to be:

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

- for an adult, at $1.8.10^{-3}$ mSv/year, in other words, below 2 µSv/year;
- for a 10-year old child, at $1.4.10^{-3}$ mSv/year, in other words, below 2 µSv/year;
- for a 1-year old child, at $1.5.10^{-3}$ mSv/year, in other words, below 2 µSv/year.

Each of these doses represents less than 0.2% 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.



Scale of radiation exposure

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

It was found that the current discharges from Dampierre-en-Burly NPP have no impact on the chemical status of the Loire.

The prospective health risk assessment [EPRS] (see Section 5.2) does not identify any health risk, resulting from the liquid chemical discharges attributable to Dampierre-en-Burly power plant, for neighbouring populations potentially exposed to the substances through consumption of Loire River water, land-based foods (vegetables, meat and milk) and fish caught in the Loire downstream of the plant.

Likewise, the assessment does not indicate any health risk, due to chemical discharges to the environment linked to Dampierre-en-Burly plant operation, for neighbouring populations potentially exposed to the substances through inhalation.

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

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- a quantitative method of assessing the environmental and health impacts by modelling the cumulative impact of actual discharges from the facilities and actual river flows in 2016 and 2018, which represented an average year and a year with pronounced low water levels, respectively.

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

- ***Justification of microbiological risk control measures***

The prevention, monitoring and control measures implemented by Dampierre-en-Burly NPP to minimise the proliferation and spread of legionella bacteria comply with regulatory requirements.
Dampierre-en-Burly power plant's monitoring of legionella concentrations confirms that the preventive water treatment strategy of monochloramine injection delivers effective control of the risk of Legionnaires' disease.

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

A noise measurement campaign was carried out around Dampierre-en-Burly NPP in February 2016. The results of the compliance analysis show that noise levels at the power plant conform to the limits set by regulations.
In addition, plant operation gives rise to vibrations (mainly from rotating machinery) that are only felt inside the facilities thanks to the design of the buildings and the composition of the soil. The existing facilities therefore do not cause any disturbance for neighbouring populations.

- ***Evaluation of the impact of light emissions***

The power plant's light emissions are mainly related to site security lighting (intruder protection system, aviation obstruction lighting, etc.). They are therefore unavoidable; however, the beam angle of the lighting minimises the visual impact outside the plant. The impact of these light emissions is negligible.

5.7.7. Human activities

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

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

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

Dampierre-en-Burly NPP was built between February 1975 and November 1981. It has therefore been in situ for around forty years and is now firmly embedded in the landscape. Dampierre-en-Burly plant operation has no impact on the landscape or on cultural heritage. As detailed in Section 5.6, there are no site development plans that would call these conclusions into question over the next ten years.

- ***Analysis of impacts on water use***

Dampierre-en-Burly NPP operation gives rise to various requirements for water supplies, the most important of which is for condenser cooling. The four reactors are equipped with a so-called semi-closed-circuit condenser cooling system, with a cooling tower. The use of cooling towers limits the volume of water drawn from the Loire River for condenser cooling. Aside from the water that is evaporated in the cooling towers of reactors 1 to 4, the water taken from the Loire is returned to the river.
The health impact assessment of radioactive and chemical discharges (including through consumption of water and ingestion of food, considering in particular the pathway of irrigation water) does not reveal any health risk, attributable to the operation of Dampierre-en-Burly NPP, for potentially exposed neighbouring populations.
Consequently, Dampierre-en-Burley plant operation has no impact on the availability of water resources, and the discharges do not compromise water use in the vicinity of Dampierre-en-Burly NPP.

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

Dampierre-en-Burly NPP operation gives rise to the daily movement of around 2,500 vehicles, the majority of which are staff vehicles. Heavy goods vehicles account for 5.9 % of this flow.
The volume of traffic generated by Dampierre-en-Burly plant operation represents 49.6% and 32.2% (light vehicles and heavy goods vehicles, respectively) of the total volume of traffic on the D952 (5,040 vehicles) and D940 (7,761 vehicles) departmental roads.
The vehicle traffic generated by the power plant could be seen as a significant proportion of the traffic flows on nearby road infrastructure. The plant does not generate any rail or river traffic.

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

Dampierre-en-Burly NPP operation has no interaction with other industry in the study area, and it therefore has no impact on the industrial environment.

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

The health impact assessment of radioactive and chemical discharges (including through food ingestion, fishing, etc.) linked to Dampierre-en-Burly NPP operation does not reveal any health risk, attributable to the power plant, for potentially exposed neighbouring populations.
Consequently, Dampierre-en-Burly NPP operation has no significant impact on recreation areas and leisure activities.

- ***Evaluation of impacts on other uses***

Other identified uses are mainly focused on commercial fishing and aquaculture. The health impact assessment of radioactive discharges (including through food ingestion, fishing) and chemical discharges (resulting from water consumption, fishing etc.) associated with Dampierre-en-Burly plant operation does not reveal any health risk for potentially exposed neighbouring populations.
The operation of Dampierre-en-Burly NPP therefore has no significant impact on the other identified uses (commercial fishing and aquaculture).

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

The primary objective of Dampierre-en-Burly NPP is to generate electricity: in 2024, gross electricity production was 20.78 TWh.
The power plant's electricity consumption sits at around 140 GWh, which is equivalent to less than 0.7% of its output.
It should be noted that Dampierre-en-Burly NPP has emergency diesel generators, which undergo periodic operability testing. Between 2017 and 2019, fuel-oil consumption for these tests amounted to around 234 m^3 a year.

5.7.8. Waste management

5.7.8.1. Waste generation

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

- Radioactive waste is classified by its level of activity and by the lifespan of the radionuclides it contains. It may be derived from:

- the treatment of radioactive effluents: filters, activated carbon, evaporation concentrates, water filters, ion exchange resin sludge, etc.;
- fuel handling operations: clusters, fuel rod capsule-canisters, skeleton assemblies, etc.;
- routine maintenance operations: discarded radioactive mechanical parts, tooling, laundry waste, etc.

- Conventional waste is waste produced in areas that do not contain any radioactive material. It consists of inert waste (rubble, soil, etc.), non-hazardous non-inert waste (wood, packaging, paper, cardboard, glass, plastic, metal, etc.) and hazardous waste (paint, oil waste, asbestos, etc.).

FIND OUT MORE: THE NUCLEAR FUEL CYCLE IN FRANCE

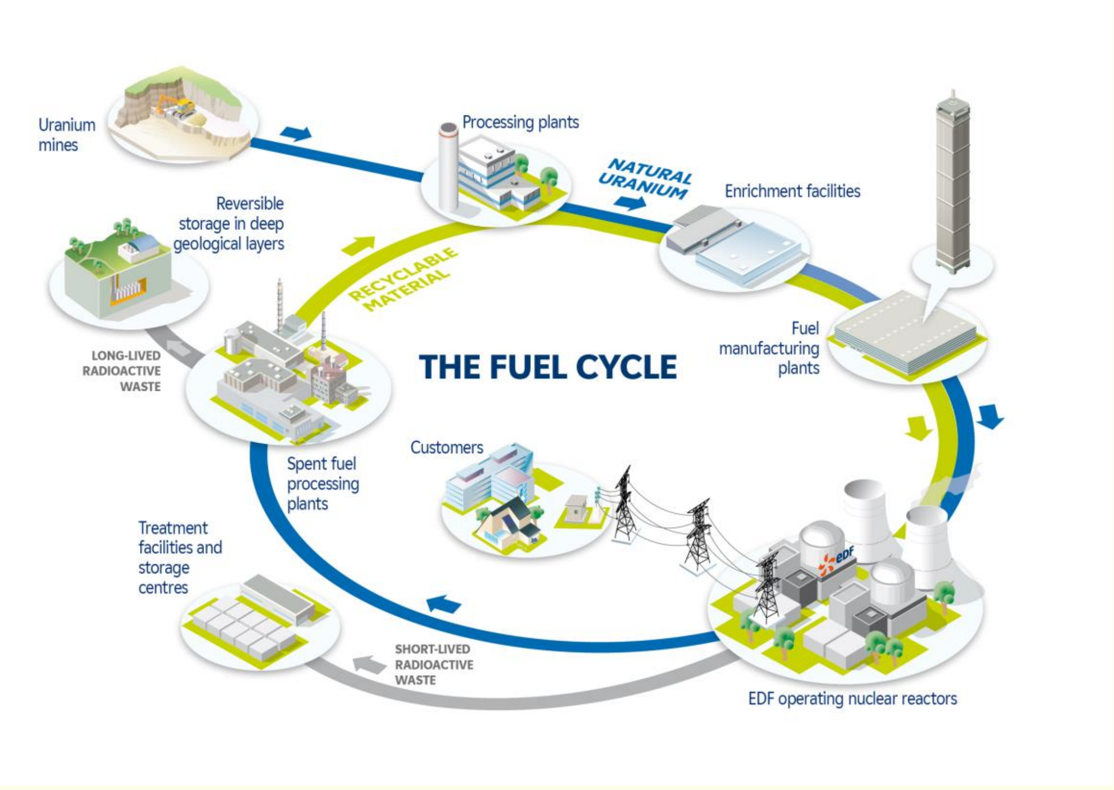
A nuclear reactor uses uranium, a natural resource, as its main fuel. The ‘fuel cycle’ refers to all the industrial steps associated with fuel operations, from the extraction of the ore to the storage of radioactive waste from spent fuel.
The fuel cycle can be broken down into three stages:

- The front end of the cycle: uranium ore is extracted from the ground, converted into a gaseous form by way of a chemical process, and then enriched. This material is incorporated in the form of pellets into sealed metal tubes, which are assembled to form ENU (enriched natural uranium) fuel assemblies.

- The core of the cycle: these assemblies are loaded into the reactor and used for four to five years to produce electricity.

- The back end of the cycle: after this period, the assemblies are unloaded and stored in the spent fuel pool located in the plant's fuel building for an initial phase of heat decay and radioactive decay. The assemblies are then recycled after treatment, in a ‘closed cycle’ where the recyclable energy materials are extracted from the spent fuel (plutonium and uranium). It is only what cannot be recovered that is considered as waste.

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



5.7.8.2. Waste management strategies and streams

The various stages of waste management are designed to ensure that waste is acceptable to the stream(s) for which it is intended, and to limit its impact. 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

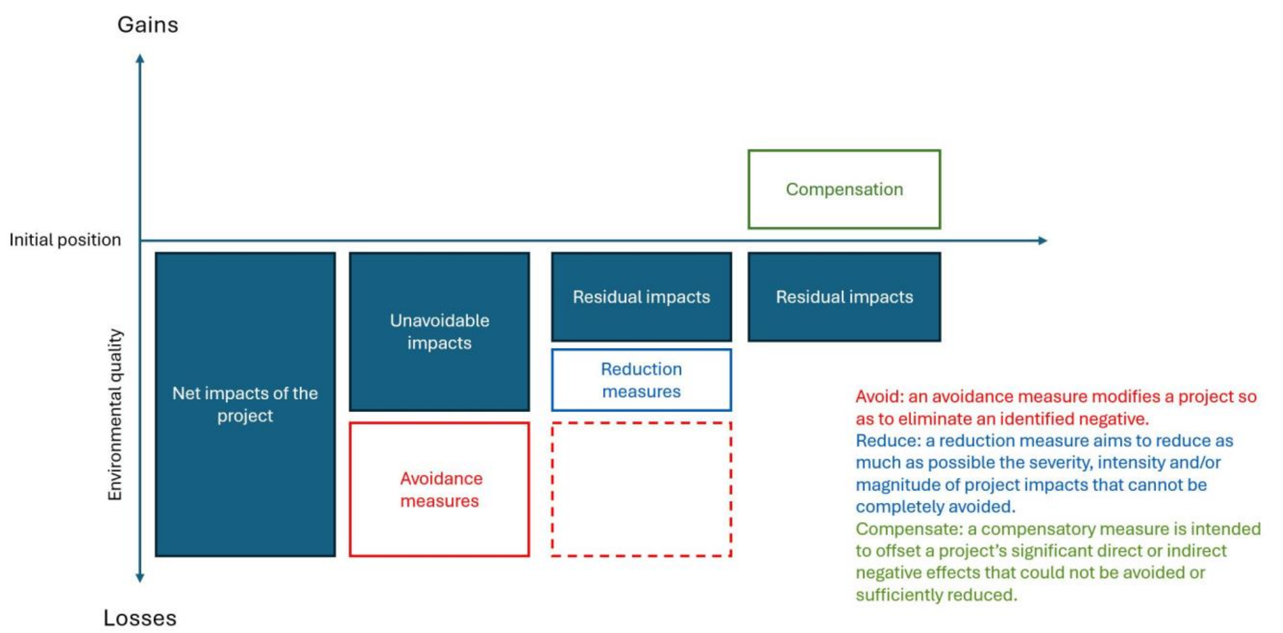
Conventional waste is collected as close as possible to the production premises. Some of it is grouped together and stored in the site's conventional waste transit area, and then removed after being checked at the C3 portal monitors (radiological monitoring equipment at site exit points, used to check for contamination).
Dampierre-en-Burly 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***

Given that Dampierre-en-Burly NPP has no significant impact on air quality or on climate, no impact avoidance or reduction measures, and no compensation measures, have been put forward.
The power plant has taken steps to limit greenhouse gas emissions (with the deployment of a corporate leak management plan for SF6, a gas used as an electrical insulator in electrical equipment).
It should also be noted that Dampierre-en-Burly power plant has implemented the following CO2-emission limitation measures focused on staff transport:

- Purchase of electric vehicles for daily environmental monitoring rounds.
- Provision of buses and bus routes.
- Creation of 12 charging stations to encourage electrical vehicle use.
- Provision of a pool of bicycles for the staff of some departments to move around site.
- Installation de 200 charging points on site, for electric or hybrid vehicles, as part of the EDF Group's EV100 initiative.

What is more, EDF ENR will soon install solar photovoltaic canopies for green electricity generation.

Surface water

For several years now, Dampierre-en-Burly NPP has been taking steps to reduce its consumption of water drawn from the Loire River by optimising its management of water abstraction (leak detection, pumping systems, etc.), its strategies for the shutdown and startup phases of reactors requiring large volumes of water, its use of the demineralisation station (a local preventive maintenance programme, awareness-raising actions for personnel conducting water-related operations), or by modifying equipment (a freshwater suction system).
The power plant is also deploying measures 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 discharges of chemical substances to the absolute minimum, ensuring compliance with regulatory provisions, and fostering the involvement of all stakeholders.
The Environment Management System (EMS), established by the power plant for the purposes of ISO 14001 certification, encourages every discipline group on site to manage its impacts on surface water.

Soil and groundwater

The main impact avoidance and reduction measures taken to protect soil and groundwater focus on minimising the risk of spills into soil and groundwater by building, operating and maintaining all equipment in which substances are handled that may present a potential risk of soil and groundwater contamination.
The storage and use of hazardous products is strictly regulated. Therefore, all necessary precautions are taken during storage to prevent any accidental releases into the environment (retention tanks, transfer to sealed areas), with environmental spill kits on standby at strategic locations for deployment in the event of a spill.
The design of the groundwater pumping stations comprises a seal that creates a barrier between the external environment and the underground environment, thereby preventing groundwater contamination in the event of an accidental spill near the structure.
In addition, Dampierre-en-Burly NPP has measures in place, either built into the design or implemented as part of continuous improvement, to prevent and reduce the potential impact of operating the facilities. A network of piezometers was set up to effectively monitor the condition of the groundwater and to provide early detection of any type of incident.

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 (recycling primary circuit effluent, improving the integrity of fuel cladding, opting for zirconium-alloy cladding that retains in the fuel rods almost all the tritium produced by fission reaction);
- by carrying out **filtration** or targeted treatment prior to discharge (ion exchange resins, for example);
- by optimising the activity concentration of the radionuclides present in effluents, through the **radioactive decay** of these radionuclides;
- by checking discharges.

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

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

Biodiversity

In addition to the measures set out above, special provisions are in place for fauna and flora in relation to dredging operations in the intake channel, including, in particular, measures to prevent dredging during the breeding seasons of aquatic invertebrates, fish and amphibians that may be adversely affected.

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: beams are angled if possible towards the site and towards the ground, and lighting is limited to the strict minimum needed for site perimeter security, both within and outside of working hours.

- ***Human activities***

Given that none of the discharges or abstractions have any noticeable impact on human activities, no additional impact avoidance or reduction measures are implemented, beyond those detailed in the sections above.
However, in order to minimise the footprint of Dampierre-en-Burly NPP, the layout of the facilities, which was drawn up at the design stage, allows for the use of existing facilities, as far as possible, and thus precludes the need for additional surface area.

- ***Waste management***

Dampierre-en-Burly NPP is structured to ensure optimised waste management based on:

- reduction at source of waste volume and harmfulness;
- separate waste collection and sorting;
- compliance with the regulatory provisions for waste management;
- reduction of the harmfulness of conventional industrial waste;
- optimisation of waste processing strategies, primarily by reducing the volume of waste where possible (compacting, shredding, crushing) or by ensuring that waste fulfils the conditions for disposal in the appropriate waste stream (skips for conventional waste, metal or plastic drums for low-activity technological waste);
- reduction of waste storage time on site, by removing packages as quickly as possible. Among other benefits, this approach ensures more effective management of peaks in production (particularly during maintenance operations, when the reactor is shutdown) or of periods when waste disposal streams are temporarily unavailable;
- prioritisation of recycling and recovery.

5.7.10. Climate change impacts of decommissioning

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

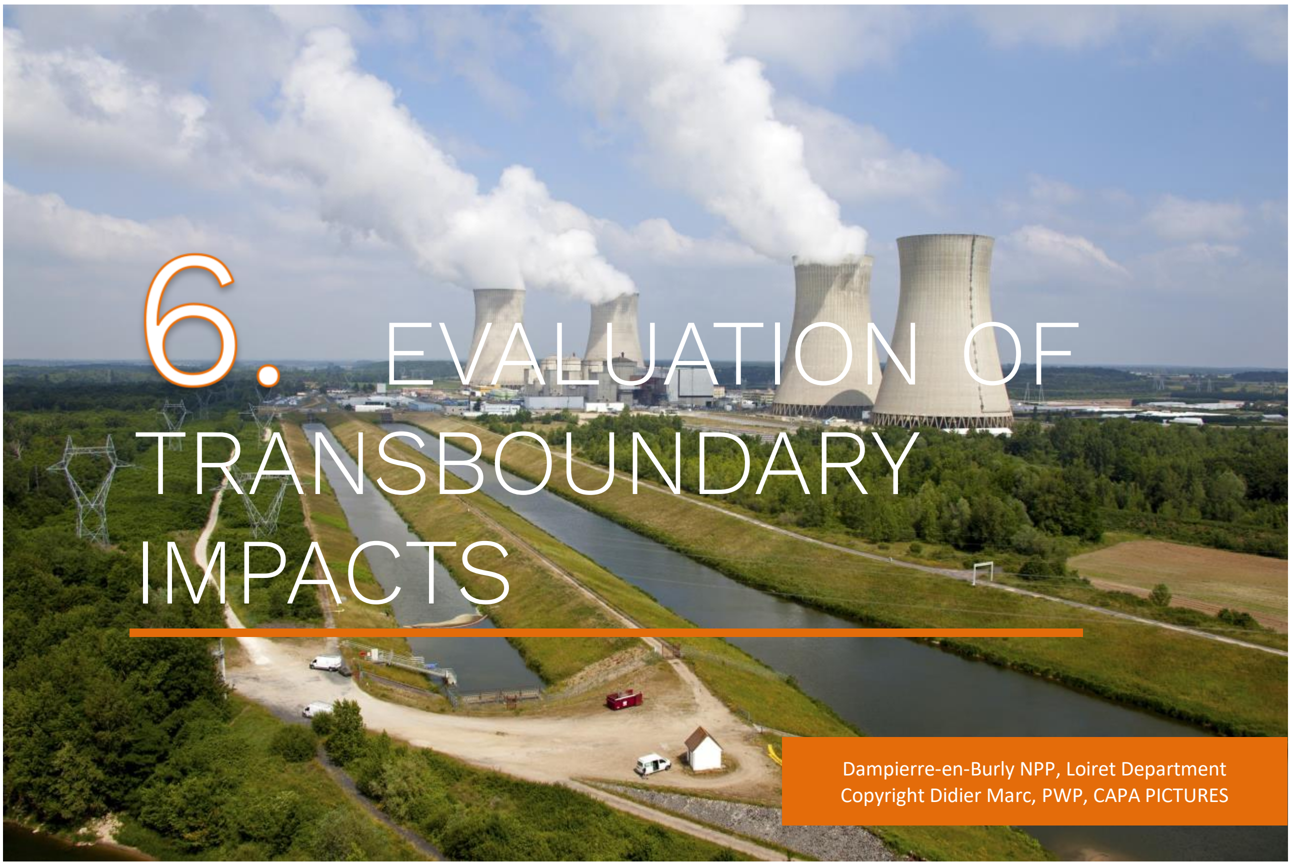
Nuclear power generation emits very little greenhouse gas: the equivalent of 4 grammes of CO_2 per kWh for the current French nuclear fleet, according to EDF's ACV du kWh nucléaire (LCA of a nuclear kWh), compared to an average 224 grammes of CO_2 for the European electricity mix (https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/chiffres-cles-du-climat/fr/).

Dampierre-en-Burly power plant produces on average around 20 TWh/year of electricity, emitting less than 80,000 tonnes of CO_2.

Should Dampierre-en-Burly NPP be decommissioned, producing the same amount of electricity using the European energy mix would increase CO_2 emissions by around 4.5 million tonnes[14].

[14] Based on the CO_2-absorbtion capacity of a deciduous forest of around 4 tonnes of CO_2/ha/yr. A forest area of more than 1,100,000 hectares (110 km by 100 km) would need to be planted to offset this additional CO_2 in the atmosphere.

6. EVALUATION OF TRANSBOUNDARY IMPACTS



Dampierre-en-Burly NPP, Loiret Department
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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 (see Section 4.4).

6.1. Requirements governing radiological consequences

6.1.1. Radiological consequences assessment process

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

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

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

These doses are calculated for a distance corresponding to the residential housing closest to the reactors, for all the 900 MWe series plants (650 m), or for the standard distances of 2.5 km and 10 km. For the Dampierre-en-Burly reactors, the residential housing is sited at a distance of 650 metres.

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).

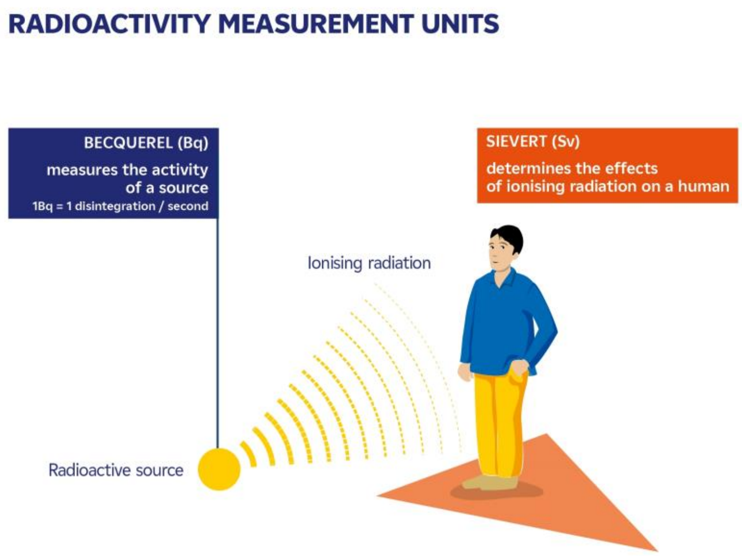
In order to obtain a more comprehensive understanding of the impact of radioactive discharges on humans and the environment, the dose calculations are supplemented by an assessment of the distance below which contamination of food items (milk and vegetables in particular) exceeds the limits for marketed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



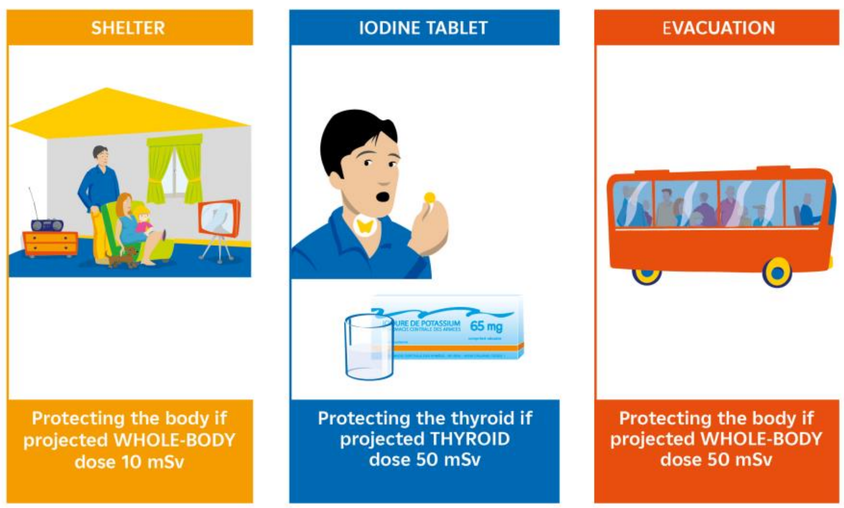
Only the two most commonly used units are shown here:

- **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.

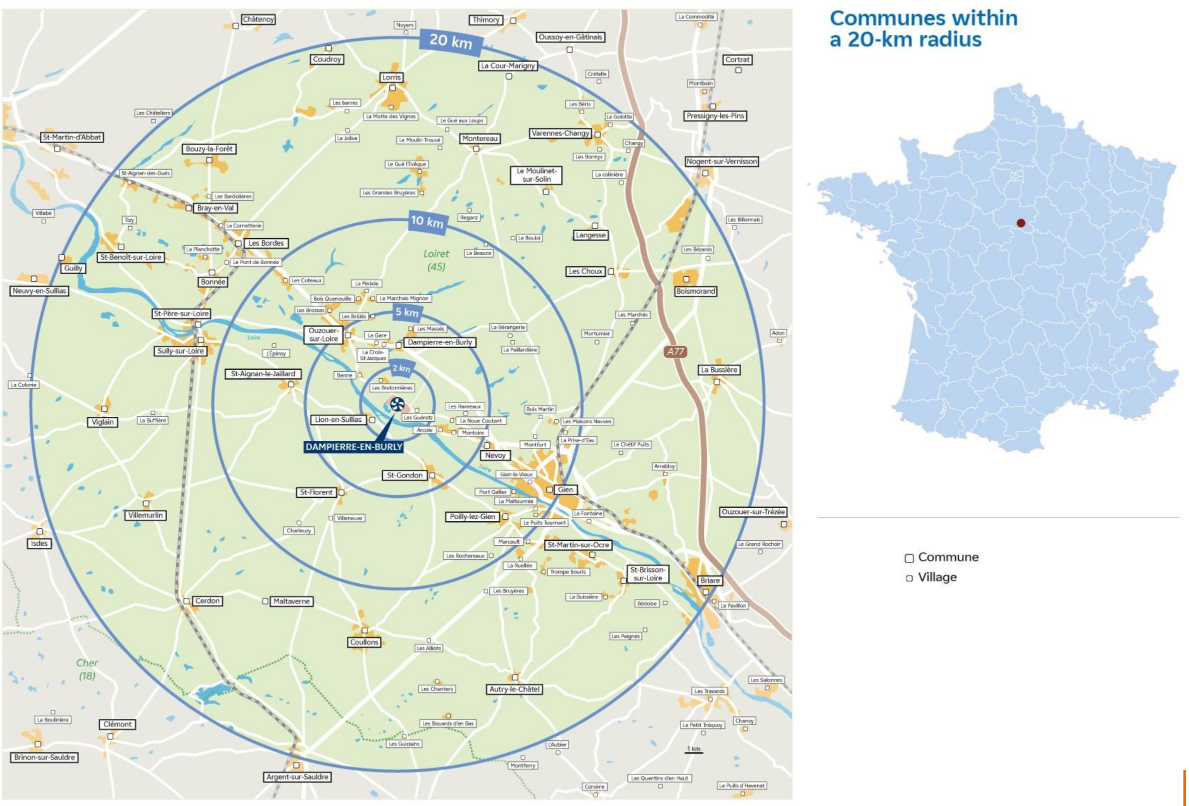


As regards the **long-term total effective doses** resulting from accidents, the reference value adopted is the dose limit specified in the Labour Code, that is to say, 1 Sv (limit for the total effective dose received by a worker over a lifetime in the event of a radiological emergency, Article R4451-9).

6.2. Radiological consequences

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

DAMPIERRE-EN-BURLY NUCLEAR POWER PLANT (LOIRET)



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	$5.0\ 10^{-4}$ mSv
Inadvertent opening of a secondary-side relief valve or steam line break	$1.5\ 10^{-3}$ mSv

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

Results for category-3 accidents

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

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

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

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

Results for category-4 accidents

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

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

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

The steam generator tube rupture accident leads to a thyroid equivalent dose of less than 50 mSv for populations beyond a 1-km radius. Risk control measures were taken 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 Dampierre-en-Burly reactors. These studies analyse scenarios involving combinations of independent failures that are considered to be plausible, but very rare (with a return period of 1 in ~5,000,000 years of operation). The scenarios are categorised by frequency of occurrence, established using probabilistic safety assessments (PSA). In order to safeguard against these situations involving combined failures, beyond-design-basis provisions are defined, along with safety requirements, with a focus on guaranteeing functional operability and thus reducing the frequency of occurrence of this scenario. This approach has identified more than 30 improvement measures that were not included in the initial design.

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

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

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

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

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

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

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

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

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

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

6.2.3. Radiological consequences of hypothetical core-melt accidents

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

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

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

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

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

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

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

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

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

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

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

Transboundary effects of core-melt accidents

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

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

		Bounding long-term total effective dose (mSv)			
Pays	Minimum distance from the source (km)	Very young child age bracket [1-2[	Young child age bracket [2-7[	Child age bracket [7-12[	Adult age bracket [17+[
Belgium	275	0.24	0.24	0.22	0.22
Switzerland	310	0.18	0.18	0.16	0.16
Luxembourg	315	0.24	0.25	0.23	0.24
United Kingdom	370	0.10	0.10	0.09	0.08
Germany	370	0.12	0.12	0.11	0.11
Italy	390	0.04	0.04	0.03	0.03
The Netherlands	405	0.14	0.15	0.13	0.13
Austria	525	0.08	0.08	0.08	0.07
Liechtenstein[15]	525	0.08	0.08	0.08	0.07
Spain	560	0.04	0.04	0.04	0.03
Andorra	570	0.04	0.04	0.03	0.04
Czech Republic	760	0.04	0.04	0.04	0.04
Ireland	800	0.05	0.05	0.04	0.04
Slovenia	835	0.02	0.02	0.02	0.02
Croatia	875	0.02	0.02	0.02	0.02
Denmark	915	0.04	0.04	0.03	0.03
Poland	950	0.03	0.03	0.03	0.03
Portugal	965	0.01	0.01	0.01	0.01

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

The bounding dose value is obtained for Luxembourg and Belgium, and corresponds to approximately 0.25 mSv over 50 years for the various age groups. In comparison, natural radioactivity is 3.5 mSv per year in Luxembourg, and 2.7 mSv per year in Belgium.

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 four 900 MWe reactors at the Dampierre-en-Burly 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.

[15] The figures for Liechtenstein were 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 Dampierre-en-Burly 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 ASNR in the course of drawing up these objectives (see Sections 1.2 and 2.3.1).

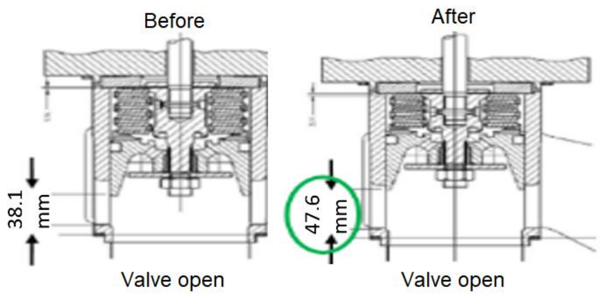
6.3.1. Main measures for non-core-melt accidents

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

- Increased flow rate in atmopheric steam discharge valves.

Description of the provision

En 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 Dampierre-en-Burly 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 asssembly 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].

Basic principle

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

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

Description of the provision

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

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

Basic principle

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

6.3.2. Main measures for hazards

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

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

The operating and/or design provisions of the 4th periodic review of Dampierre-en-Burly 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 Dampierre-en-Burly 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 Dampierre-en-Burly reactors to be able to withstand these extreme conditions, new water and power supplies have been installed, which are hazard-resistant, diversified and separate from existing systems:

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


3-MWe station blackout diesel generators [DUS]


Diversified source of water [SEG]

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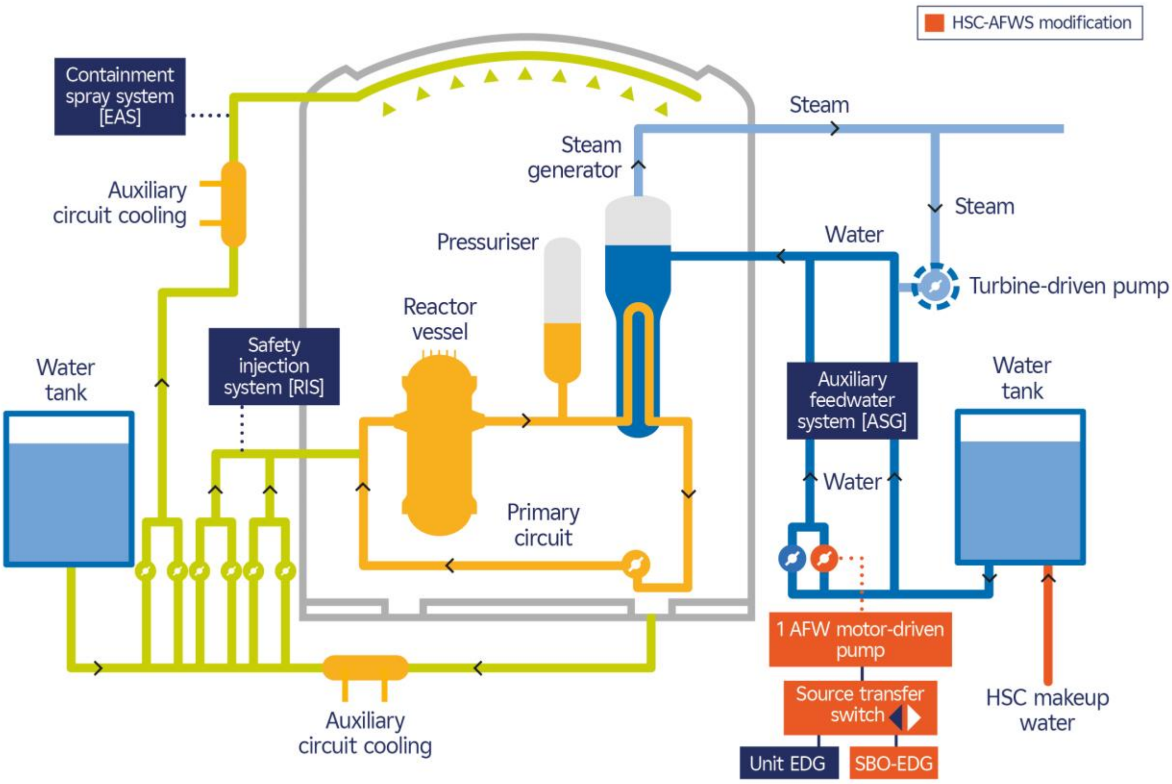


Working principle of the HSC-AFWS

6.3.3. Main measures for fuel assembly storage

The main operating and/or design provisions of the 4th periodic review of Dampierre-en-Burly 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.

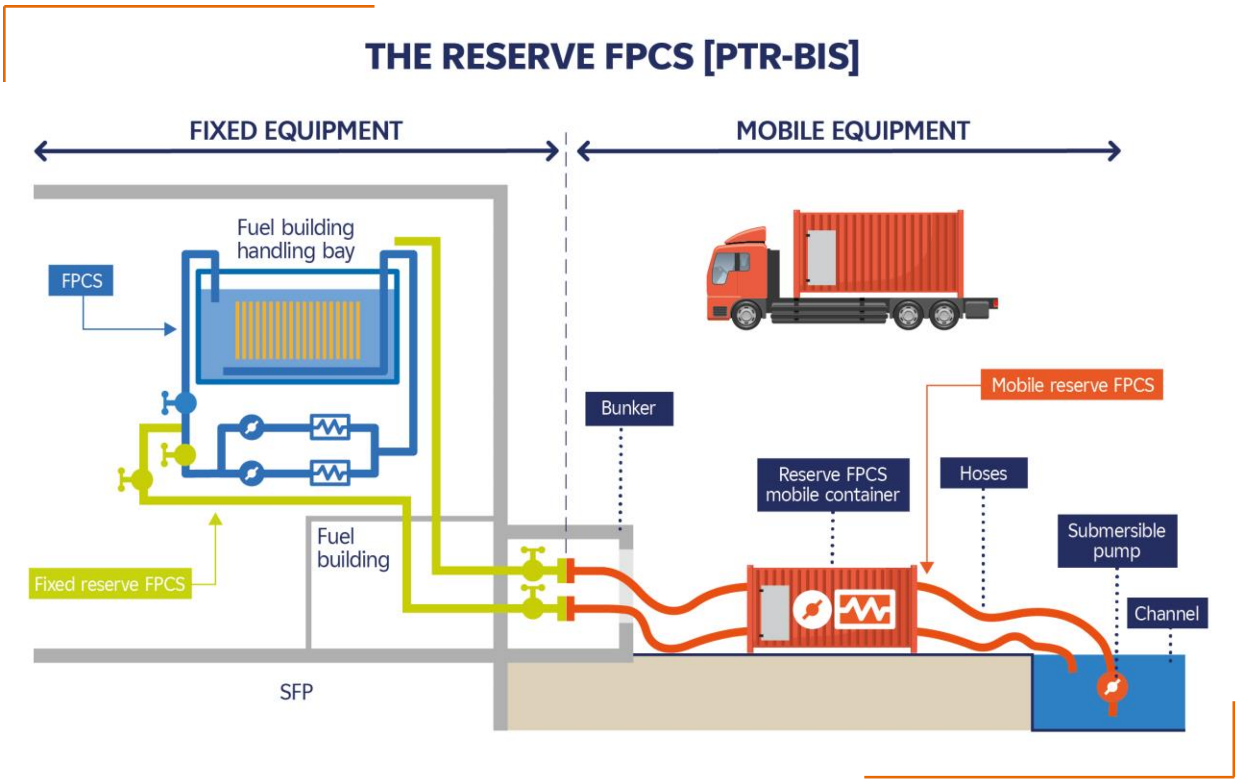
Review of 900 MWe series plants in consideration of FLA3 EPR accident conditions

The assessment of the behaviour of the spent fuel pools in 900 MWe power plants, including for the Dampierre-en-Burly 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 Dampierre-en-Burly 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.

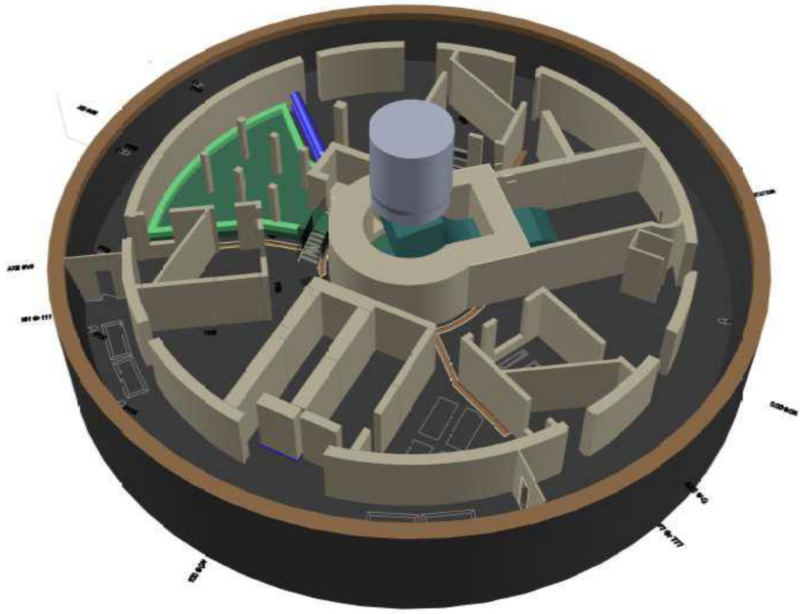
The management of core-melt accidents provides for the ‘dry-spreading’ of the corium, i.e. without water, at the bottom of the reactor building, the basemat. Spread out in this way, the layer of corium presents a large exchange surface and can be stabilised by the injection of borated water, which will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

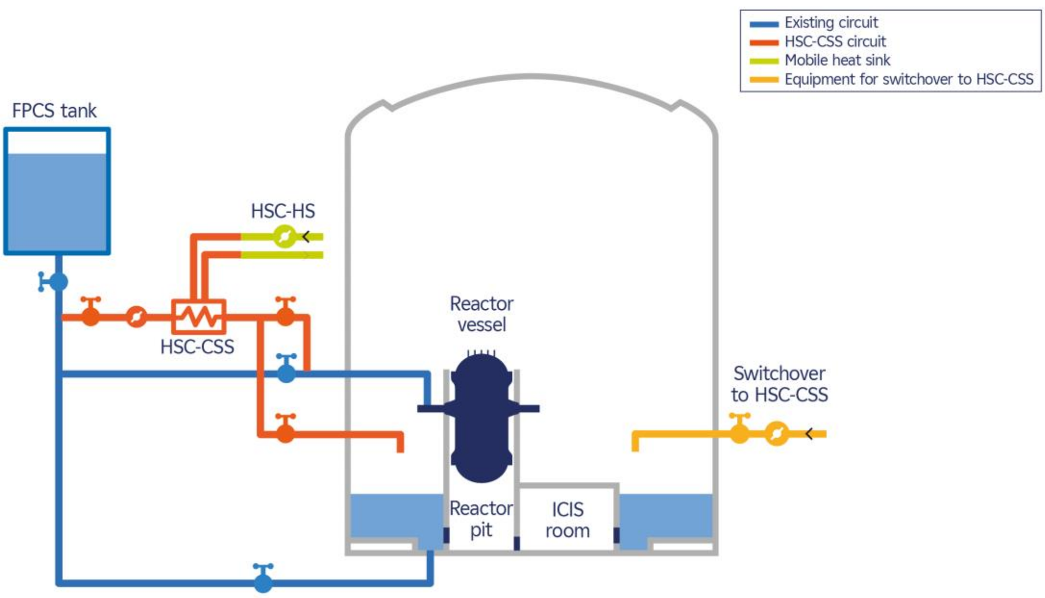
Thus, the measures implemented for the management of a core-melt accident in a Dampierre-en-Burly reactor are the following:

- 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

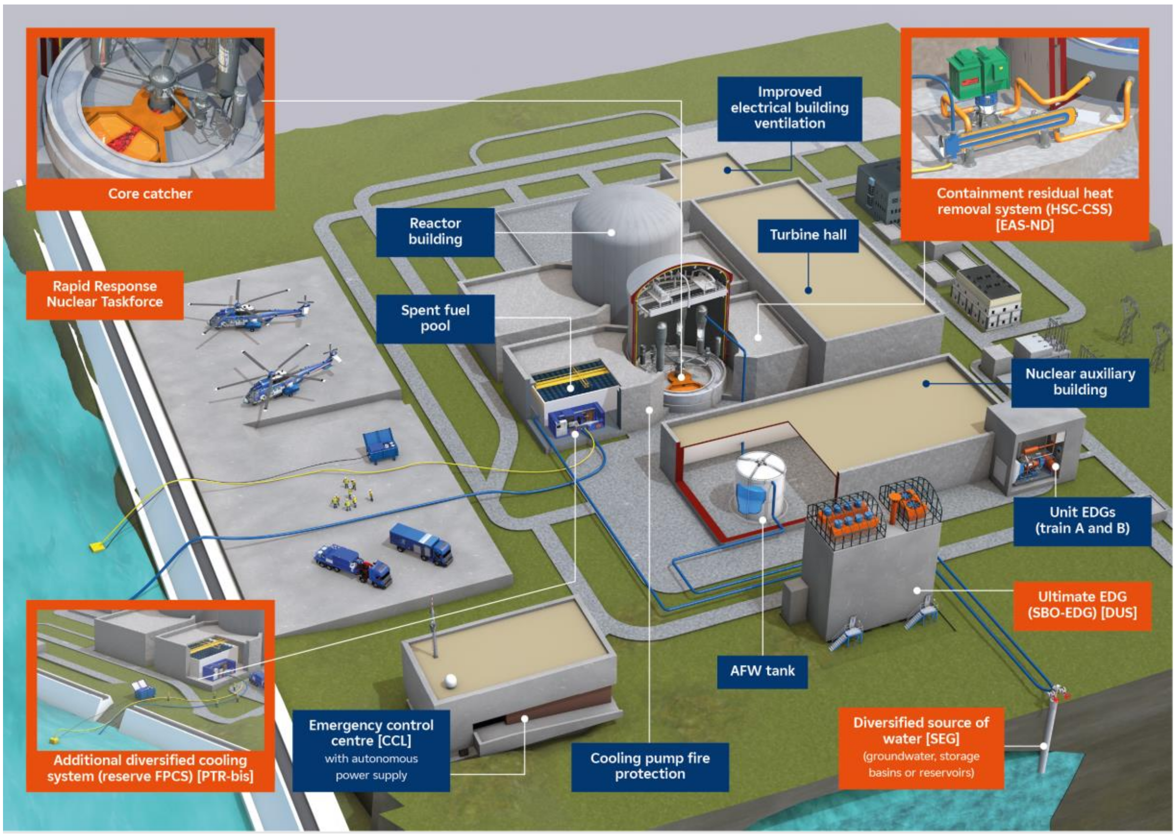


The 'HSC-CSS' [EAS-ND] involves the deployment of:

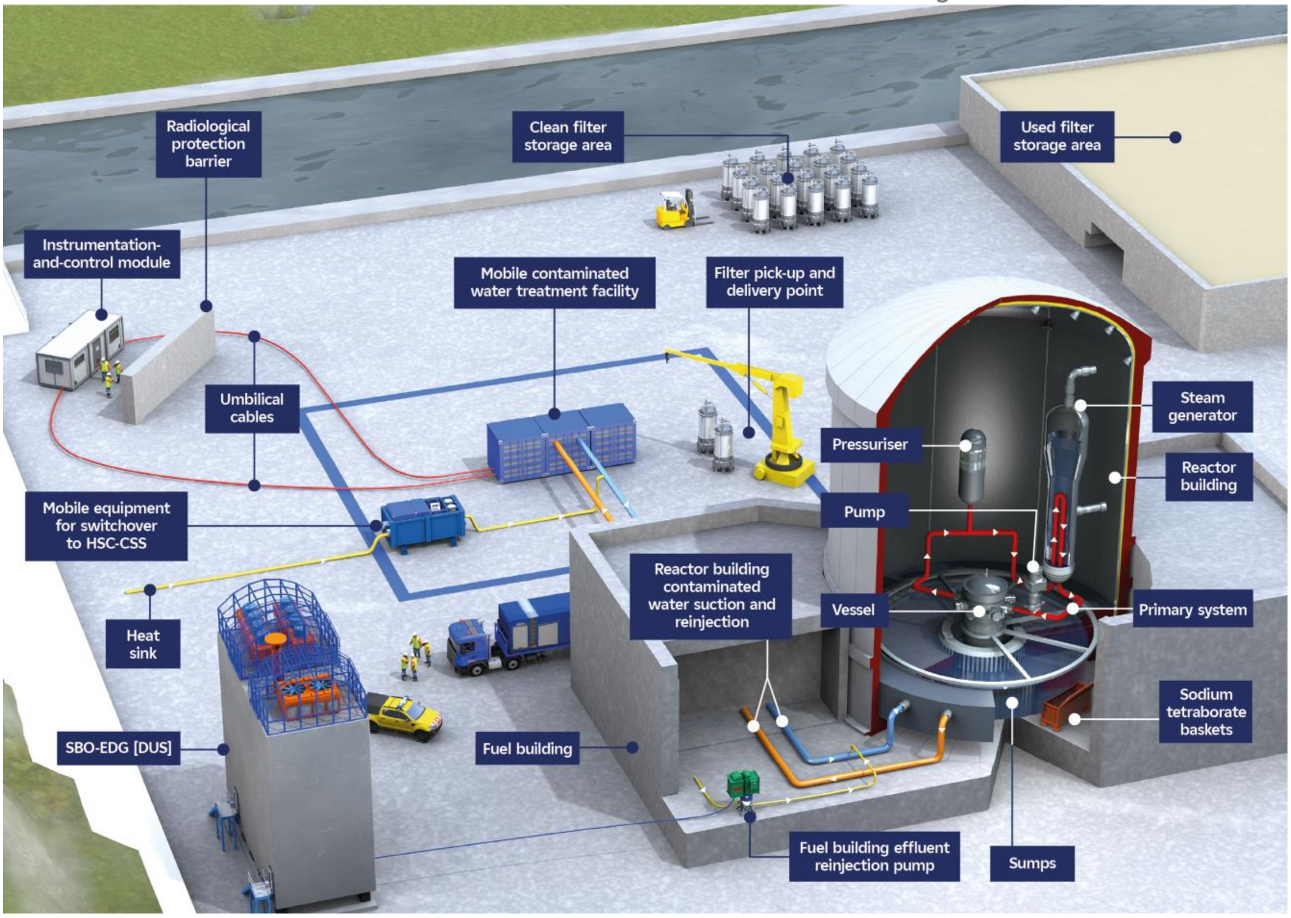
- a pump (powered by the SBO-EDG [DUS]),
- an exchanger, to remove heat from the containment,
- a Hardened Safety Core heat sink (HSC-HS) [SF-ND], made up of mobile pumping equipment.

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

Main Hardened Safety Core measures



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



7. ENVIRONMENTAL MONITORING

Dampierre-en-Burly NPP, Loiret Department
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7.1. Monitoring measures for normal operation

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

Air and climate factors

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

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

Dampierre-en-Burly NPP also has a weather monitoring programme, collecting observations from an automatic station (for temperature, relative humidity, and rainfall metrics) as well as from an 80-m-high weather mast fitted with an anemometer (for wind direction and speed measurements).

© EDF

Examples of rainfall, temperature and wind measurement equipment ©EDF

Surface water

Dampierre-en-Burly NPP runs:

- a programme for monitoring surface water abstraction and consumption levels, derived either by calculation or using measuring systems, to determine the flows and volumes extracted from the Loire, the groundwater table and the public water supply network, as well as cooling tower water evaporation losses;
- a programme for monitoring its discharges (including thermal discharges and the dispersion of pathogenic microorganisms) by means, in particular, of an effluent analysis laboratory, and data from discharge-quality measurement points on tanks and at the exits of controlled outfalls.

Liquid effluent analysis *©EDF*

Dampierre-en-Burly NPP also keeps the aquatic environment under observation through chemical, physico-chemical and hydroecological monitoring using autonomous multi-parameter measuring stations and sampling campaigns, deployed at yearly intervals depending on parameters:

- for chemical monitoring, the objective is to determine the concentration in the water of chemical substances discharged by the site;
- for hydroecological monitoring, the objective is to track the natural changes in the receiving environment in order to detect any abnormal changes that may be caused by plant operations.

In addition, special dredging-related monitoring measures are implemented before, after and during each dredging campaign.

Soil and groundwater

Dampierre-en-Burly NPP runs a programme monitoring groundwater quality in terms of chemical and radiological parameters, with the aim of detecting any potential groundwater contamination linked to plant operation. Piezometers sited upstream of the power plant also provide data used to define the reference condition for groundwater quality. This programme was rolled out in 2011.

Furthermore, soil quality at the power plant is checked through survey campaigns:

- in the event of an operating incident that may have contaminated underlying soils;
- in areas of special focus at the power plant, in relation to regulatory processes such as the soil status assessment required under Article 3.3.7 of Nuclear Safety Authority Decision No. 2013-DC-0360 dated 16 July 2013.

Groundwater abstraction flows and volumes are also monitored and recorded to ensure compliance with regulatory limits.

Radioecology

Dampierre-en-Burly NPP has a programme for monitoring radioactive discharges, at key locations:

- the nuclear auxiliary building stacks used for effluent discharges to atmosphere;
- the extraction circuits of ventilation systems in premises that may be contaminated, to ensure that there is no artificial radioactivity;
- the steam dump to atmosphere circuit, the storage tanks used before effluent discharge to atmosphere, and the spent fuel pool cooling water tanks;
- the storage tanks used prior to the discharge of liquid effluents;
- rainwater, sewage and waste water, to ensure that there is no artificial radioactivity.

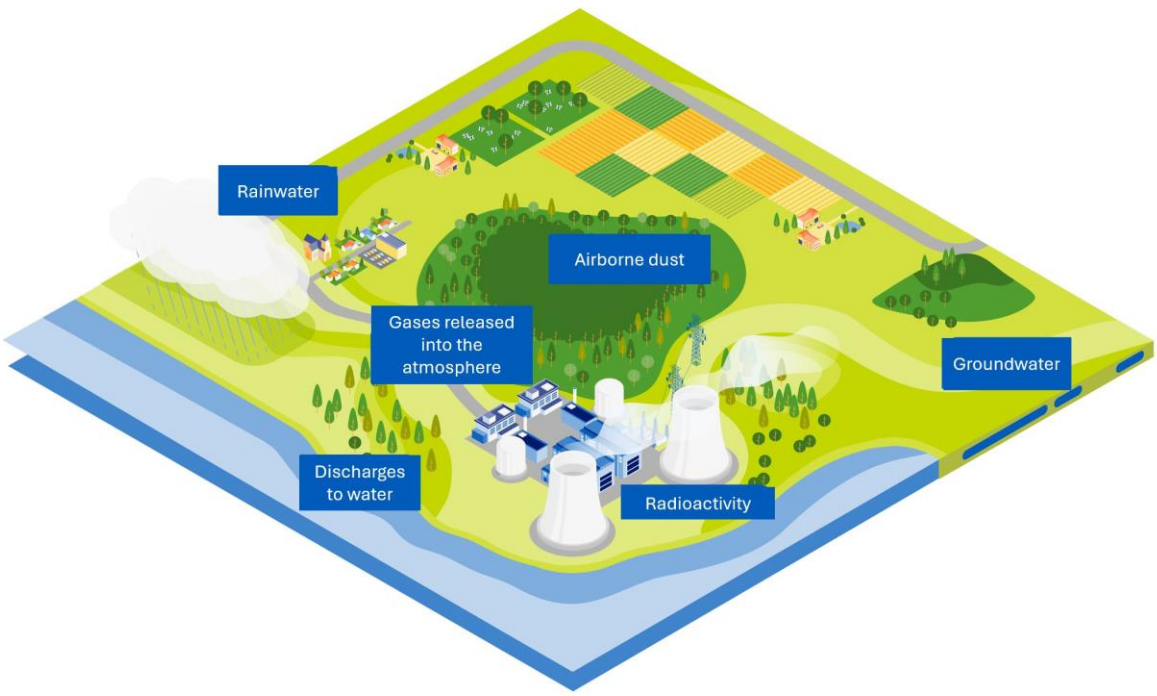

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Illustration of radiological monitoring of the environment

Radioactivity in the environment around the Dampierre-en-Burly 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 ASNR, for its own account, which it assigns to its department of subject-matter specialists.

Population and human health

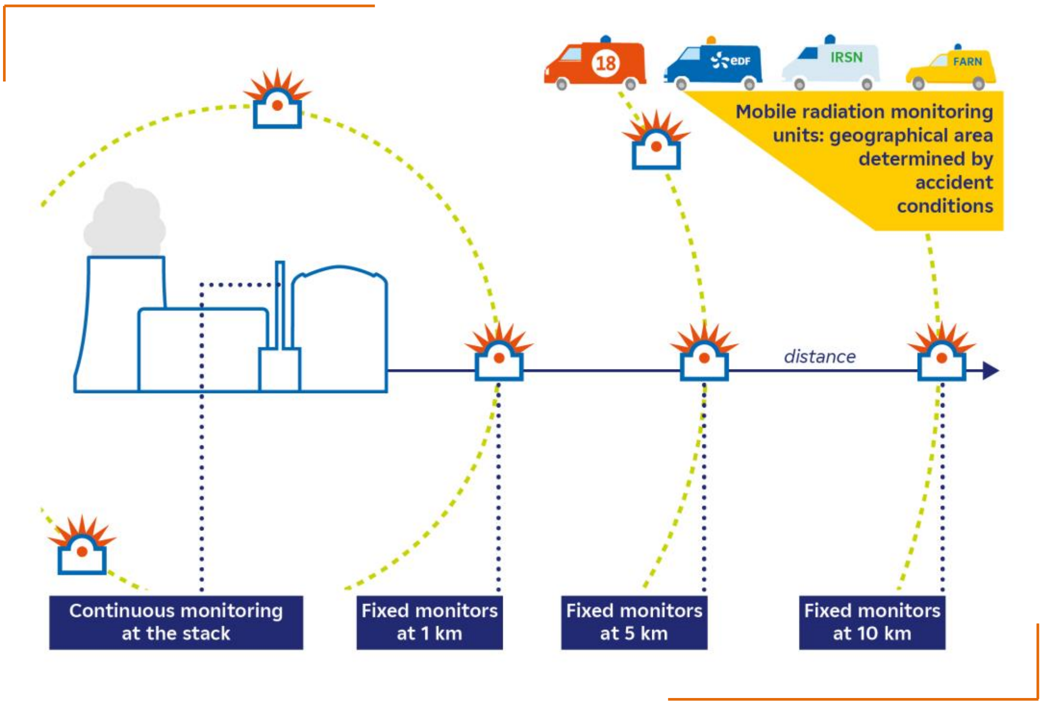
The impact of Dampierre-en-Burly NPP operation on neighbouring populations, and on their health, is monitored by keeping track of environmental compartments, namely, the atmosphere, surface water, groundwater and radioecology (as described above).

Noise emission is monitored and subject to periodic measurement campaigns to verify compliance with regulations.

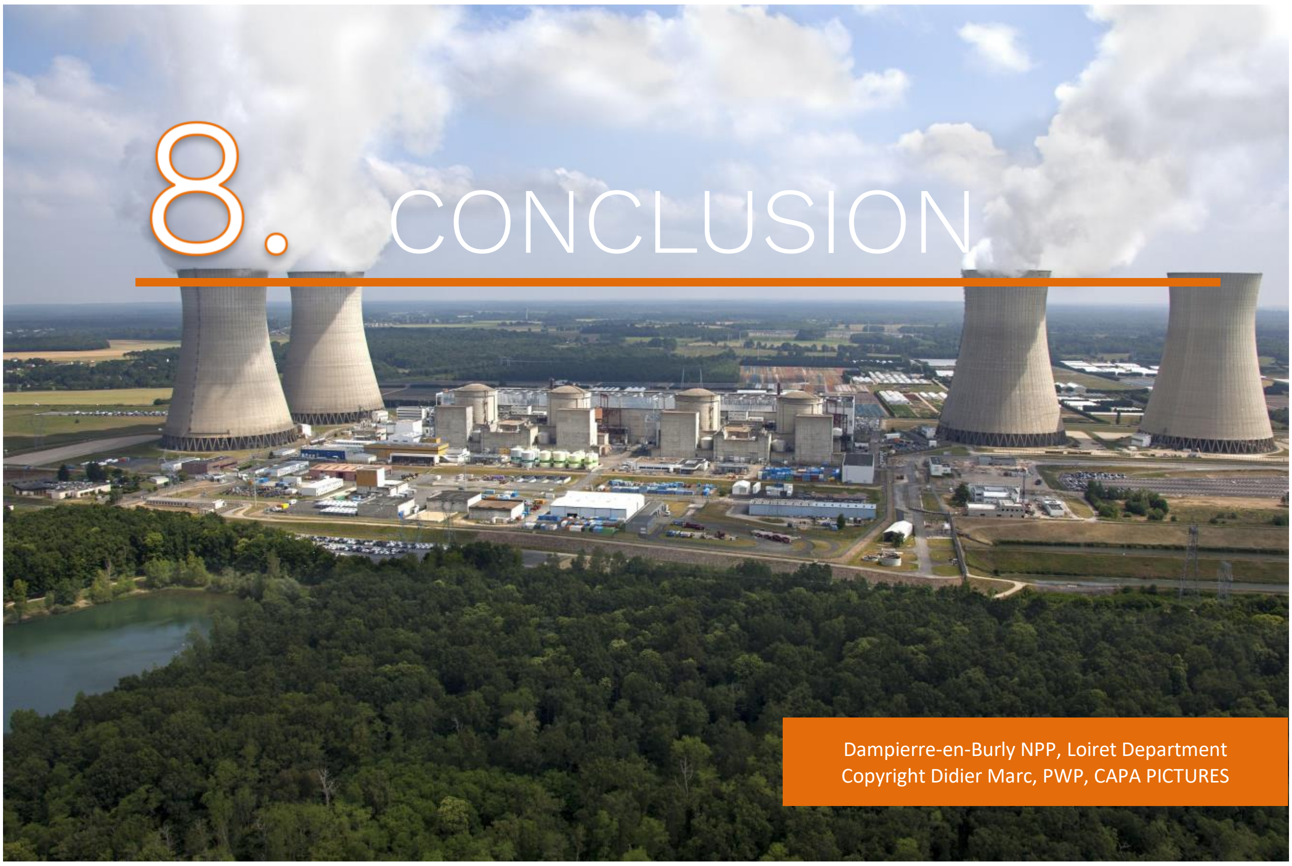
The power plant also conducts microbiological monitoring of its facilities and aquatic environment (monitoring the *Naegleria fowleri* amoeba and *Legionella pneumophila* bacterium) with a view to preventing the aerosol dispersal and environmental spread of pathogenic microorganisms via the cooling circuits.

7.2. Monitoring measures for radiological risks

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



8. CONCLUSION



Dampierre-en-Burly NPP, Loiret Department
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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 four 900 MWe reactors at Dampierre-en-Burly 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 Dampierre-en-Burly reactors. It is a joint document for all four reactors. It addresses the environmental impacts of operating these reactors for the ten years following their 4th periodic review, and covers both the radiological and non-radiological consequences of any incidents or accidents.

Impacts of normal operation

The interactions between the plant in normal operation and the environment, that is to say, water abstraction and discharges, waste production (except for some categories of waste), 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:

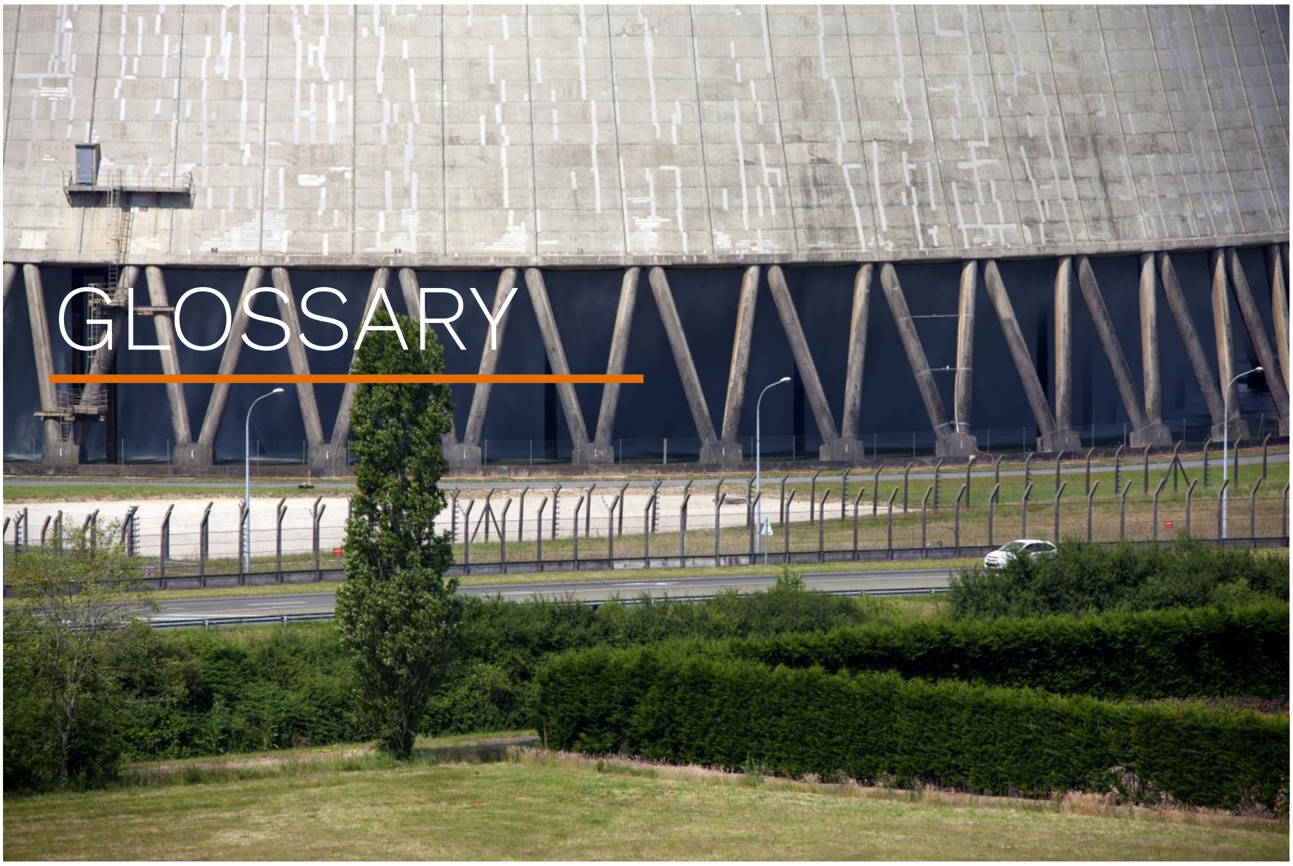
- **non-core-melt accidents:** measures to further reduce the radiological consequences of non-core-melt accidents, bringing them below the population protection thresholds;
- **hazards:** measures to take into account higher-level hazards, including in particular drought, heatwaves, flooding, earthquakes, 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 Dampierre-en-Burly 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 Dampierre-en-Burly reactors for up to fifty years, thereby contributing to ongoing low-carbon electricity generation, with less than 4 grammes of CO_2 per kWh produced over the entire life cycle of the power plant.

Over the next ten years, the normal operation of Dampierre-en-Burly 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 4.5 million households. Compensating for this lost electricity generation using the European energy mix would increase CO_2 emissions by around 4.5 million tonnes a year.



Acronym	Description
AP	Activation products
ARC	Avoid, Reduce, Compensate [ERC]
ASNR	Authority for Nuclear Safety and Radiation Protection [*Autorité de Sûreté Nucléaire et de Radioprotection*]
BNI	Basic Nuclear Installation [INB]
CENTRACO	Waste Treatment and Conditioning Centre [*Centre de Traitement et de Conditionnement*]
CIRES	Industrial Facility for Waste Collection, Sorting and Storage [*Centre Industriel de Regroupement d'Entreposage et de Stockage*] operated by the National Radioactive Waste Management Agency [ANDRA]
Conventional accident	The term 'conventional accident' is used to refer to an accident that may have non-radiological and/or low-level radiological consequences.
CSA	Aube Disposal Facility [*Centre de Stockage de l'Aube*]
CSS	Containment Spray System [EAS]
Dangerous accident phenomenon	A dangerous accident phenomenon 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 [*Dossier d'Orientations du Réexamen Périodique*]
DUS	Ultimate Emergency Diesel Generator (SBO-EDG) [*Diesel d'Ultime Secours*]
EDF	Electricité de France

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

PSA	Probabilistic Safety Assessment [EPS]
PWR	Pressurised water reactor [REP]
Reserve FPCS	Reserve Fuel Pool Cooling System [PTR-bis]
Risk	Risk, inherent in all human activities, is defined as the combination of the likelihood of a harmful event occurring and the severity of its consequences.
RCR	Periodic Review Findings Report [*Rapport de Conclusion du Réexamen Périodique*]
SAC	Special Area of Conservation [ZSC]
SEG	Diversified source of water
SG	Steam Generator [GV]
SGTR	Steam Generator Tube Rupture [RTGV]
SIS	Safety Injection System (primary system safeguard and protection system) [RIS]
SL	Short Lived [VC]
SLB	Steam Line Break [RTV]
SLB + nSGTR	Steam line break combined with multiple steam generator tube ruptures [RTV + nRTGV]
SM	SM Suspended matter [MES]
SPA	Special Protection Area [ZPS]
SPA	Site Pollution Assessment [IEM]
THM	Trihalomethanes
VHE	Very High Efficiency [THE]
VLLW	Very Low Level Waste
VSL	Very Short Lived [VTC]
WENRA	Western European Nuclear Regulators Association
ZER	Regulated Noise Aggravation Zones [*Zone à Émergence Règlementée*]
ZNIEFF	Natural Areas of Interest for Ecology, Fauna and Flora [*Zones Naturelles d'Intérêt Écologique, Faunistique et Floristique*]

EDF SA
22-30, avenue de Wagram
75382 Paris cedex 08
Capital de 1868 467 354 euros
552 081 317 RCS Paris

www.edf.fr

EDF
Direction Production Nucléaire
CNPE de Dampierre-en-Burly
BP 18
45570 DAMPIERRE-EN-BURLY

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