Non-technical summary of the

Environmental Impact Assessment

As provided for in Directives 2011/92/EU, 92/43/EEC and 2009/147/EU in the context of postponing the deactivation of Doel 1 and 2 nuclear power plants

On behalf of the Federal Public Service Economy, SMEs, Self-employed and Energy

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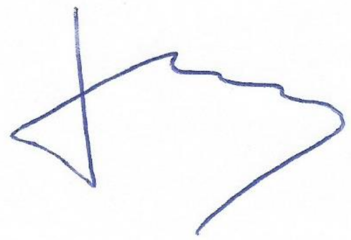
Koen Couderé Accredited EIA Coordinator Accreditation nr. LNE/ERK/MERCO/2019/00033 Accredited EIA Expert Water, sub-domains geohydrology, marine waters and surface- and waste water Accredited EIA Expert Climate Accreditation nr. EDA-222	
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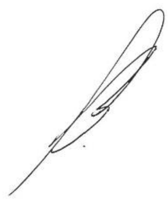
Geert Boogaerts Accredited EIA Expert Human, sub-domains toxicology and psychosomatic aspects Accrediation nr. EDA-624	

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1 Reason for this environmental impact assessment

1.1 The Law on the Nuclear Phase-out and its amendments

The gradual phasing out of the use of nuclear energy for electricity generation on Belgian territory is regulated by the law of 31 January 2003 (the so-called "Law on the Nuclear Phase-out"). This law stipulated that nuclear power plants would be deactivated 40 years after the date of their industrial commissioning, and that all individual permits relating to electricity generation by these plants would expire at the same time. The Law also states that no new nuclear power plant for the industrial generation of electricity by nuclear fission can be constructed and/or put into operation.

Table 1 shows for the different Belgian nuclear power plants the date of industrial commissioning and the date on which the 40-year period provided for in the Law on the Nuclear Phase-out would expire. In order to guarantee the continuity of the energy supply, it was decided to implement a gradual phasing-out.

Table 1: Deactivation calendar according to the Law on the Nuclear Phase-out of 31 January 2003.

Nuclear plant	Date of industrial commissioning	Date of deactivation (after 40 years)
Doel 1	15 February 1975	15 February 2015
Doel 2	1 December 1975	1 December 2015
Doel 3	1 October 1982	1 October 2022
Doel 4	1 July 1985	1 July 2025
Tihange 1	1 October 1975	1 October 2015
Tihange 2	1 February 1983	1 February 2023
Tihange 3	1 September 1985	1 September 2025

This overview shows that the working life of the Doel 1 nuclear reactor would end on 15 February 2015 and that of Doel 2 on 1 December 2015.

In the course of 2012, a deactivation programme was indeed launched for Doel 1 and 2, which provided for the definitive closure of the plants. As of mid-February 2015, electricity was no longer generated at the Doel 1 nuclear power plant; electricity generation at the Doel 2 nuclear power plant was to be discontinued that same year.

However, the Law on the Nuclear Phase-out provided that in the event of a threat to the security of electricity supply, the King could take the necessary measures by decree.

Accordingly, on 28 June 2015, the Belgian federal legislature passed a law amending the Law on the Nuclear Phase-out on that basis. This legislative amendment stipulated that the Doel 1 nuclear power plant (which was already shut down at the time) could once again generate electricity and would be deactivated on 15 February 2025 (i.e. 10 years later than originally planned). This "Amended Law on the Nuclear Phase-out" also gave the dates on which the other nuclear power plants would be deactivated. For Doel 2, there was a 10-year extension. For Tihange 1, a law had already been passed on 18 December 2013 postponing the closure of this reactor unit for 10 years. For the other power plants, neither the law of 18 December 2013, nor the law of 28 June 2015 changed anything with respect to the Law on the Nuclear Phase-out of 31 January 2003.

The resulting deactivation calendar (as set forth in the Amended Law on the Nuclear Phase-out) is shown in

Table 2.

Table 2: Deactivation calendar according to the Law on the Nuclear Phase-out (28 June 2015).

Nuclear plant	Date of industrial commissioning	Date of deactivation
Target 1	15 February 1975	15 February 2025
Doel 2	1 December 1975	1 December 2025
Doel 3	1 October 1982	1 October 2022
Doel 4	1 July 1985	1 July 2025
Tihange 1	1 October 1975	1 October 2025
Tihange 2	1 February 1983	1 February 2023
Tihange 3	1 September 1985	1 September 2025

As already indicated, the reason for opting to extend the working life of the oldest nuclear power plants was the fact that security of supply could not be guaranteed in the event of closure in the run-up to the originally planned deactivation date. In the years prior to 2015, security of supply depended to a large extent on the power supplied by the nuclear power plants, as shown in Figure 1. This figure shows the distribution of gross electricity generation in the 10 years prior to 2015. The share of nuclear energy in total generation fluctuated between 46% and 55% during this period.

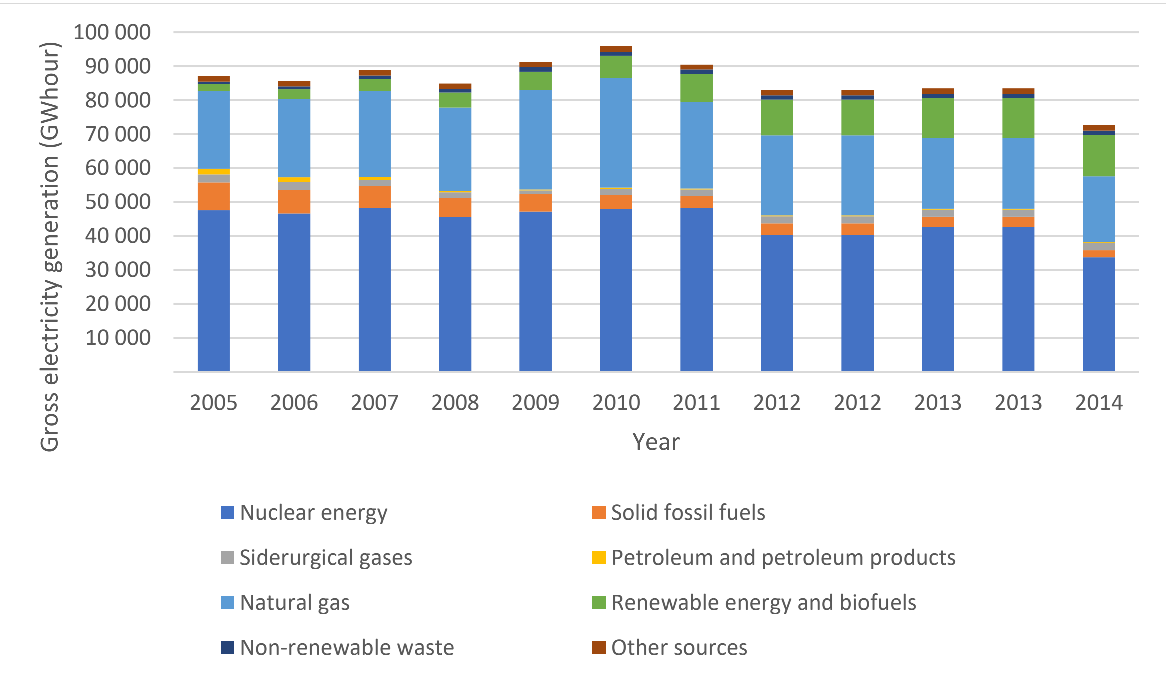

Figure 1: Gross energy generation (gigawatt hours) in Belgium for the period 2005-2014, and the share of the various sources in this (source: Statbel).

The Doel 1 and 2 reactor units together account for around 15% of the nuclear generation capacity, and their share in nuclear energy generation in the period 2015-2018 was between 9% and 16%, or between 3.5% and 8% of the total electricity generation (source: Electrabel NV).

The loss of such a share in generation could obviously only be justified if there was certainty that this shortfall could be fully made up for. If this was not the case, the resulting socio-economic cost would be significant (see box section).

The social cost of blackouts in Belgium

The loss of energy supply potentially carries a significant economic and social cost.

In a 2014 study[1] by the Federal Planning Bureau, a quantitative evaluation of the effect of blackouts in Belgium was made, based on an Austrian model (Black-out Simulator). A 1-hour power outage on Belgian territory during a working day, at a time when all Belgian companies are active, would cause total social economic damage of approximately €120 million (both in winter and in summer). Several alternative methods were also calculated and resulted in a range between €61 million (the "GDP" method) and €278 million (the "RTE" method). The stated economic damage includes the damage suffered by families, which, however, amounts to 'only' €8 million per hour. The industrial sector has the largest share of the total cost with 49%; the tertiary sector accounts for about 40% of the cost. The model used also made it possible to allocate the calculated damage in terms of location. This showed that by far the greatest loss was recorded in the province of Antwerp (€24.74 million, or almost 21% of the total), followed at some distance by the Brussels Capital Region (€15.67 million, or 13%).

It is important to note that this estimate was always based on a 1-hour outage. The impact of a 2-hour outage is not necessarily twice as large. This could also be seen in the Simulator figures: the damage from a 2-hour outage for the whole of Belgium amounts to 'only' €170 million (or 42% more than a 1-hour outage). However, the longer the disruption lasts, the more its consequences increase linearly with time, and after about 8 hours the damage will increase exponentially. An outage of more than 8 hours can be considered a disaster situation: the consequences, and especially the severity of these consequences, will then be difficult to visualise (and estimate).

As such, the explanatory memorandum to the Law of 28 June 2015 highlights the potentially problematic situation in terms of short-term security of supply as the motivation for the law, and refers to various studies in which this situation has been demonstrated.

It also highlights to the considerable uncertainty surrounding the restart of the Doel 3 and Tihange 2 power plants (which were shut down at the time), to the announced closure of conventional generation units in 2015, and to the fact that the integration of foreign generation capacity into the Belgian electricity grid is not possible in the short term.

One of these studies on which the decision taken in the Law of 28 June 2015 is based is the so-called GEMIX study from 2009[2]. This report recommends postponing the closure of the Doel 1, Doel 2 and Tihange 1 nuclear reactors by 10 years[3]. The study justifies this recommendation by claiming that the schedule for deactivation of the first three (and oldest) nuclear units by 2015 (as provided for in the Law of 2003), would result in a shortfall of both energy and capacity. It argues that it is not certain whether imports can make up this growing shortfall, due to the limited capacity of the interconnected grids and the available generation capacity abroad. The report points out that the closure of the Doel 1, Doel 2 and Tihange 1 generation units in 2015 should lead to the commissioning, from 2014, of non-nuclear replacement units, representing 50% of the nominal capacity of the three reactors mentioned[4], taking into account a minimum commissioning period of 4 years for new gas-fired power plants. According to the GEMIX study, there were insufficient guarantees that such capacity would indeed be available in 2015.

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[1] Belgian blackouts calculated. A quantitative evaluation of power outages in Belgium. Federal Planning Bureau, March 2014.

[2] "Welke ideale energiemix voor België tegen 2020 en 2030" (Which ideal energy mix for Belgium by 2020 and 2030) (GEMIX Group, 2009).

[3] The study also recommended postponing the closure of the other more recent reactors (Doel 3, Doel 4, Tihange 2 and Tihange 3) by 20 years. No further action was taken as regards this recommendation.

[4] A 2014 study (Laleman and Albrecht, 2014[4]) estimated that the shortfall in installed capacity (if Doel 1 and 2 are closed) in 2017 would be between 2.42 and 3.16 GW, depending on the assumption regarding the level of peak demand, if a 5% reserve margin were maintained (and no structural additional reliance on electricity imports).

1.2 Action for annulment before the Constitutional Court

On 5 January 2016, 'Inter-Environnement Wallonie' and 'Bond Beter Leefmilieu Vlaanderen' brought an action for annulment of the Law of 28 June 2015 before the Constitutional Court. This appeal was based on the fact that the extension of the nuclear power plants was adopted without an environmental impact assessment and without a public consultation procedure.

In an interim judgement of 22 June 2017, the Constitutional Court referred preliminary questions regarding the interpretation of the treaties and directives cited in the appeal to the Court of Justice of the European Union.

Upon receipt of the judgement of the Court of Justice of the European Union of 29 July 2019[5], the Constitutional Court overturned the Amended Law on the Nuclear Phase-out of 28 June 2015, on 5 March 2020.

The Constitutional Court considered that the law and the necessary works carried out on the Doel 1 and 2 power plants (in order to modernise them and ensure compliance with safety regulations) should be subject to an environmental impact assessment. The Law of 28 June 2015 is inextricably linked to the necessary modernisation works and together they constitute a 'project' within the meaning of Directive 2011/92/EU. The environmental impact assessment should have been carried out before the law extending the working life of the plants was adopted. In addition, since the power plants are located close to the border between Belgium and the Netherlands, the project must also be subject to the assessment procedures for cross-border projects provided for in Directive 2011/92/EU.

The Court also ruled that the said modernisation works and the decision on postponing the deactivation should also be subject to an appropriate assessment under the provisions of the Habitats Directive, given the possible effects on sites protected under the Habitats Directive and Birds Directive.

However, the Constitutional Court ruled (translated), "*in order to avert the real and serious risk of disruption to the country's electricity supply*" to maintain the effects of the annulled law until a new law is adopted, preceded by the required environmental impact assessment and appropriate assessment, including public participation and cross-border consultation. The Court ruled that the strictly necessary period to complete the required assessments expired on 31 December 2022, and therefore the effects of the annulled law would continue until that date.

2 Objective of this environmental impact assessment

In order to comply with the ruling of the Constitutional Court, an environmental impact assessment must be drawn up for the decision to keep the nuclear power plants open for a further ten years, as well as for the modernisation and safety works required to ensure the optimal functioning of the Doel 1 and 2 nuclear power plants, before any new law is drafted. These works are in fact inextricably linked to the decision, and together they form a single Project.

The environmental impact assessment of this Project has a dual character, since it pertains to a strategic decision on the one hand, and specific works on the other; it is therefore split into two parts.

The environmental impact assessment (EIA) to which this non-technical summary refers comprises an assessment of the impacts caused by the strategic policy decision to postpone the deactivation of Doel 1 and 2 by 10 years (EIA Decision).

A separate environmental impact assessment, commissioned by the operator of the nuclear power plants, assesses the impacts of the specific work to be carried out as a result of the law on extended electricity generation (EIA Works).

Both environmental impact assessments have been drafted separately, but together form the environmental impact assessment of the Project as defined above. In order to distinguish between the two parts of this overall

[5] Judgement in Case C-411/17 Inter-Environnement Wallonie ASBL and Bond Beter Leefmilieu Vlaanderen v Ministerial Council.

environmental impact assessment, we refer respectively to the environmental impact assessment concerning the decision (EIA Decision) and the environmental impact assessment concerning the works (EIA Works).

The environmental impact assessment of the strategic decision to postpone the deactivation of Doel 1 and 2 involves identifying, describing and assessing the direct and indirect impacts of the Project. In accordance with Article 3 of the EIA Directive (Directive 2011/92/EU, as amended by Directive 2014/52/EU of 16 April 2014), this assessment must take into account the following factors:

a) population and human health;
b) biodiversity, with particular attention [to the impact on Natura 2000 sites];
c) land, soil, water, air and climate;
d) material assets, the cultural heritage and the landscape;
e) the interaction between the factors referred to in points (a) to (d).

Annex IV of the (amended) Directive further clarifies that the factors listed in Article 3 that may be significantly affected by the Project include "population, human health, biodiversity (for example fauna and flora), land (for example land take), soil (for example organic matter, erosion, compaction, sealing), water (for example hydromorphological changes, quantity and quality), air, climate (for example greenhouse gas emissions, impacts relevant to adaptation), material assets, cultural heritage, including architectural and archaeological aspects, and landscape".

The environmental impact assessment pertains to both non-radiological and radiological environmental impacts for the factors listed above. Below, we indicate which impacts are emphasised in the assessment, and why.

3 Initiator and team of experts

The initiator of the environmental impact assessment of the decision is the Belgian Federal Public Service Economy, SMEs, Self-Employed and Energy, Rue du Progrès 50, 1210 Brussels.

The environmental impact assessment has been prepared by a team of recognised radiological and non-radiological EIA experts.

4 Subject of the environmental impact assessment

4.1 The Project

The Project that is the subject of the environmental impact assessment presented in this summary (and of the separate environmental impact assessment concerning the associated works) consists of the "postponement of the deactivation" of the Doel 1 and 2 nuclear reactors. Both are part of the site of the Doel Nuclear Power Plant (DoelNPP), operated by Electrabel NV, and located in the Scheldemolenstraat, Haven 1800, 9130 Doel. DoelNPP comprises 4 nuclear reactors in total, the necessary auxiliary buildings and installations for the generation of electricity and the storage of spent fissile material.

The site is in the municipality of Beveren (East Flanders) along the left bank of the Scheldt river and 3.15 km from the Dutch border at the closest point (see Figure 2). The operation of the nuclear power plant, with a focus on the operation of the Doel 1 and 2 units that are part of the Project, is further described in §4.2.

Figure 2: Location of DoelNPP.

The Project is considered separate from other projects ongoing and/or planned for the DoelNPP site, including the SF² project (construction of a new facility for the temporary storage of spent nuclear fuel) and the shutdown of Doel 3 on 1 October 2022[6].

The strategic-level environmental impact assessment presented in this summary concerns the strategic policy decision on the continued operation of the Doel 1 and 2 units for energy generation over the period 2015-2025.

The post-operational phase and decommissioning are not part of the Project as considered here, although certain aspects of the operation of the Doel 1 and 2 units over the period 2015-2025, which may be important in the context of the decommissioning, are considered.

As stated above, for Doel 1 and 2 the period 2015-2025 is an additional period of operation beyond the initial period of 40 years. In accordance with the Royal Decree of 25 January 1974 and the Royal Decree of 30 November 2011 on the safety requirements for nuclear installations, the operator must carry out a periodic safety review at intervals of no more than 10 years. This is called the Ten-Year Review, or Periodic Safety Review. For the period commencing in 2015, this is the fourth review and the two units have moreover been in operation for 40 years. In the context of the operation after 40 years, also known as Long Term Operations (LTO), an action plan was drawn up and integrated into the fourth Ten-Year Review. The aim of this action plan is to enhance the safety of the oldest nuclear units in Belgium (including Doel 1 and 2) to the level stipulated for the most recent plants. Furthermore, this LTO Action Plan also integrated actions resulting from a comprehensive programme of Stress Tests set up in the wake of the accident at the Fukushima nuclear power plant on 11 March 2011. The main actions of the LTO plan are the following:

- The construction of a new seismic pumping station to improve fire safety, to provide more effective protection to Doel 1 and 2 from any fire caused by an earthquake;

[6] As stipulated by the Royal Decree of 31 January 2003 on the gradual phase-out of nuclear energy.

- The installation of a Containment Filtered Venting System (CFVS) to perform a depressurisation of the containment (reactor building) in the event of an accident with a nuclear meltdown (major accident), in order to preserve the integrity of the building and to limit the radiological consequences for the environment.

The works therefore primarily pertain to safety measures that do not affect the operation of the plant under normal conditions (such as the thermal capacity).

The works carried out in the context of these integrated action plans are not the subject of the strategic part of the environmental impact assessment of the Project presented in this summary. However, they are studied in the environmental impact assessment of the works (EIA works) performed on behalf of the operator of the nuclear power plant (Electrabel NV).

4.2 Functioning of a nuclear power plant

The Doel Nuclear Power Plant (DoelNPP) consists of four nuclear reactors for the generation of electricity and all the necessary auxiliary infrastructure for the operation thereof.

Doel 1 and 2 are twin reactors, the so-called Pressurized-Water Reactors (PWR) designed by Westinghouse. An overview with basic data for these two generation units is given in Table 3. For the sake of completeness, the data for Doel 3 and 4 are also included.

Table 3: Overview of the basic data of the Doel nuclear power plant.

Unit	Type/design	Thermal capacity	Electrical capacity	Date of first criticality	Containment	Fuel storage capacity
Doel 1	PWR (2 primary cooling circuits) Westinghouse	1312	445	18/07/1974	Double (steel + reinforced concrete)	Together for Doel 1 and 2: 664 positions
Doel 2	PWR (2 primary cooling circuits) Westinghouse	1312	445	04/08/1975	Double (steel + reinforced concrete)	
Doel 3	PWR (3 primary cooling circuits) Westinghouse	3064	1006	14/06/1982	Double with internal liner	672 positions
Doel 4	PWR (3 primary cooling circuits) Westinghouse	3000	1036	31/03/1985	Double with internal liner	628 positions

A PWR is typically composed of 3 compartments with 3 separate circuits: the reactor building with primary circuit, the machine room with secondary circuit and the cooling circuit which forms the tertiary circuit. We describe here the typical operation of a PWR with specific data for Doel 1 and 2.

Figure 3: Operation of the nuclear power plant with, from left to right, the reactor building, the machine room and the cooling circuit (Source: Electrabel NV).

The reactor building contains the reactor vessel that contains the nuclear fuel or fissile material. The fissile material is enriched uranium in the form of sintered uranium dioxide (UO_2) with an enrichment percentage of uranium-235 (U-235) of about 4% (natural uranium contains about 0.7% U-235). Pellets of fissile material are stacked in zirconium alloy tubes. They ensure the containment of the fission products. The pins thus formed are bundled into fissile material elements and held in a network by grids.

Fission produces fission products and neutrons; the latter can cause new fission, setting off a chain reaction. To keep this chain reaction under control and monitor the reactivity of the nuclear reactor, absorbent beams (control rods) and boron[7] (an element that easily captures neutrons) are used. The control rods are divided into two groups:

- the control rods (21 pieces) that ensure the rapid control of the reactivity;
- the stop rods or the switch-off system (also called SCRAM, 12 pcs) with which, together with the control rods, an emergency stop can be performed.

The control rods have the property of significantly absorbing neutrons and will, in the event of an automatic stop or emergency stop, fall between the fuel elements by themselves under the effect of gravity, thereby stopping the fission reactions (passive safety). However, due to radioactive decay of the fission products, the reactor core remains hot after shutdown and must be further cooled.

In a PWR such as Doel 1 and 2, the energy released during fission, from the energy and radioactive decay of the fission products, and from the energy of the neutrons, is transferred to water at high pressure (155 bar). The high pressure ensures that the water does not boil. The water is also used to slow down the neutrons created during fission, to increase the chances of them generating another fission. In Doel 1 and 2, this water is pumped from the reactor core to the steam generator via two circuits, which together form the primary cooling circuit (each with its own pump). A pressure vessel regulates the pressure.

The reactor buildings consist of a steel shell on the inside, while the cylindrical exterior consists of reinforced concrete with a semi-circular dome resting on top. The space between the steel shell and the reinforced concrete is always kept under pressure. The Doel 1 and 2 reactor buildings are symmetrically located on either side of the nuclear emergency response building (GNH in Dutch), which is shared by both reactors. It contains the main safety systems for the two units (cooling and spray systems), the external storage for the fresh nuclear fuel elements, the

[7] Present in the water of the primary circuit in the form of boric acid.

pools for the spent fissile material (in which the water is continuously purified and cooled) and the storage tanks for the liquid and gaseous effluents. A detailed description of the safety systems can be found in a national safety report of the Federal Agency for Nuclear Control (FANC).

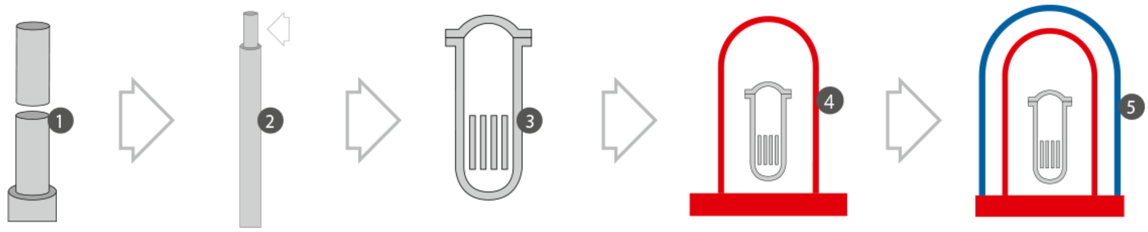

Figure 4: The successive barriers shielding the uranium and the fission products from the outside world, i.e. the compressed uranium dioxide in tablets (1) is stacked in the fuel rods that are welded shut (2), located in the reactor vessel (closed during operation, opened for loading and unloading of nuclear fuel), a 25 cm-thick steel vessel (3) placed in the primary steel shell of the reactor building (4) successively surrounded by the secondary wall of the reactor building in reinforced concrete (5).

The heated water under high pressure from the primary circuit goes to the steam generator where, via thousands of tubes, it transfers its heat to the water on the other side (secondary circuit), where steam is created at a pressure of 60 bar. There is therefore never direct contact between the water in the primary and secondary circuit. The steam drives a turbine in the machine room, and the alternator connected to the turbine converts the rotation of the latter into electrical current. The steam in the secondary circuit continues to the condenser where it is converted back into liquid water which is pumped back to the steam generator. The condenser is cooled with water from the tertiary circuit in the cooling circuit, again never in direct contact with the water from the secondary circuit. The tertiary circuit is supplied with water from the Scheldt. The steam from the secondary circuit transfers its heat to the water from the Scheldt from the tertiary circuit, causing this water to heat up slightly. That is why it first goes to the forced draught cooling towers before it either goes to the condenser again or flows back into the Scheldt.

Radioactivity and radiation are present in a nuclear reactor or originate from:

- the nuclear fuel: this consists of uranium dioxide and contains various uranium isotopes, all of which are spontaneously radioactive but have long half-lives and decay primarily by alpha decay;
- nuclear fission during the operation of the reactor: this generates fission products, many of which are radioactive (with half-lives of milliseconds to millions of years) and decay primarily by emitting beta and gamma radiation; the neutrons released during fission are themselves a form of ionising radiation;
- activation of various materials, primary water, etc.: radioactive and non-radioactive nuclei can capture a neutron and make new radionuclides, we call these activation products (activation of the reactor vessel steel is an example, also the formation of tritium);
- successive neutron absorption and beta decay starting from the uranium in the nuclear fuel. This creates various isotopes of neptunium, plutonium, americium and curium, all radioactive, and including several with very long half-lives.

As in all industrial processes, small quantities of these radioactive elements may be released into the nuclear zone during normal operation and maintenance. This creates various radioactive waste streams in gas, liquid and solid form, in addition to the spent fissile material elements. At the DoelNPP site, treatment systems for solid and liquid effluents are housed in the water and waste treatment building (WAB in Dutch).

Besides the components described above, there are a number of auxiliary buildings, some of which are safety-related, outside the nuclear part of the plant:

- Diesel Generators Building (5 diesel generators);
- Electric Emergency Services Building, where the control room is situated; there is only one control room for the two units Doel 1 and Doel 2;
- Mechanical Emergency Services Building;
- The water-steam building houses the isolation valves of the steam generator feed-water systems, of the steam pipes, the safety valves, the valves for release of steam to the atmosphere and the feed-water systems;
- the emergency system building (2nd level of protection). This building was added following the first safety review. The building houses an emergency feed-water system, an emergency injection system for the primary pump seals, an emergency control room and a number of support systems;
- forced draft cooling towers to cool the component cooling system.

Other buildings are not specifically safety related:

- The machine room (mentioned above);
- The pumping stations for the supply of water from the Scheldt, the associated inlet tunnel and the untreated water discharge channel;
- Basements for the neutralisation tank and related pumps.

The operation of the nuclear power plant as a whole and Doel 1 and 2 specifically for the generation of electricity requires, like any industrial process, raw materials, and will also produce various waste streams. The main raw materials and waste streams are summarised in Table 4.

Table 4: Main raw materials and waste streams.

Main raw materials	Waste flows
Enriched uranium (nuclear fuel)	Radioactive waste streams: atmospheric and liquid discharges, radioactive waste including spent nuclear fuel
Fuel oil	Non-radioactive hazardous waste (recycling)
Oils	Non-radioactive non-hazardous waste
Surface water for the production of demineralised water	Non-radioactive air emissions
Water from the Scheldt (cooling water)	Sanitary and industrial waste water
City water	Return of cooling water
Use of land	

4.3 Alternatives

An alternative for a project can be defined as '*another way of achieving the objectives of the project*'. The first question is therefore what the objective of the present Project is (postponing the deactivation of Doel 1 and 2), and then whether there are (or have been) alternative ways of achieving that objective.

As stated above, the policy objective pursued with postponing the deactivation is to *guarantee security of supply* as regards electricity. By keeping the Doel 1 and 2 reactors open longer (until 2025 instead of 2015) and therefore postponing the previously decided deactivation, this objective is indeed achieved (for the period until 2025).

The question is then whether, at the time the law of 28 June 2015 was adopted, there were alternative ways of achieving the objective (guaranteeing security of supply for the period 2015 - 2025). It is not enough in this regard to come up with theoretical replacement alternatives in the form of alternative energy mixes. These alternatives must also pass the test of reasonableness. This means, among other things, that they must be realistic and promising, i.e. that realising these alternatives in the short term was a plausible option at the time the decision was made.

The answer to this question is that in 2015 there were no valid, operational alternatives that could sustainably guarantee security of supply by replacing the (significant) lost capacity (15% of total nuclear capacity). The capacity for renewable energy was not yet sufficiently developed and could not be developed in the short term. The same goes for (new) gas power plants that could be used as a possible transitional solution between the nuclear and renewable phase; most of these plants still had to be built in 2015.

As regards the *import* of electricity from abroad, the explanatory memorandum to the Law of 28 June 2015 states that (translated) "the integration of foreign generating capacity into the Belgian grid is not possible in the short term". For its part, the GEMIX study (2009) stated that a structural dependence on imports higher than 10% makes the electricity system vulnerable in the event of an outage. Moreover, an expected decrease in French electricity exports and a growing demand for structural imports from Germany also had to be taken into consideration[8]. Finally, the GEMIX study also noted that the chronic shortage of generation capacity in Belgium (before the economic crisis) had already reached the limits of import capacity, and that this capacity was not expected to increase by 2020. In summary, it can be stated that electricity imports were not a structural solution to the loss of nuclear capacity in 2015.

The conclusion is thus that there were no valid alternatives to the specific policy objective which the postponement of deactivation was intended to address.

Of course, the foregoing does not mean that there are no alternative mixes of inputs, each with their own advantages and disadvantages in terms of environmental impact[9]. However, it is not the purpose of the present analysis to compare such scenarios.

In the present analysis, we limit ourselves to understanding the environmental impact of extending the working life of the Doel 1 and 2 nuclear reactors, over the period 2015-2025. We do not therefore make the comparison with the impact of alternative (hypothetical) solutions[10]. We do compare the impact with the situation where the Project would not have been carried out and the deactivation would not have been postponed. This situation, which we call the baseline scenario, is discussed in §4.4.

For the sake of completeness, it can also be stated that the extent to which electricity supply can be guaranteed has evolved since 2015, and will continue to evolve in the future. For the period 2022-2025 (and taking into account unexpected events in neighbouring countries, which could put a brake on imports), Elia assumes a capacity requirement of more than 1 GW. For the period 2025-2040, security of supply is guaranteed as a result of the construction of new gas-fired power plants[11] and a further increase in the generation capacity of renewable energy.

4.4 Baseline scenario

[8] This aspect is confirmed in a recent study by Elia (*Adequacy and flexibility study for Belgium 2020 - 2030. ELIA, 2019*). This study states, inter alia: "In the coming decade, 100 GW of coal and nuclear capacity is to be phased out in Europe (of which the major part is in Western Europe) (...) The accelerated phase-out of coal in our neighbouring countries in particular (the Netherlands, UK, Italy, France but especially Germany) have a negative impact on our import possibilities during the winter months".

[9] The feasibility of several such alternatives was studied, among others, in the "Studie over de perspectieven van elektriciteitsbevoorrading tegen 2030" (Study on the perspectives of electricity supply by 2030) of the Federal Public Service Economy (2015) and in the GEMIX study (2009). A plan EIA was also drawn up for the first study (Arcadis, 2015).

[10] Except for the so-called "avoided emissions", see below.

[11] These plants still need to be built. The so-called CRM mechanism, whereby initiators are paid for providing additional capacity, should ensure that this is indeed done on time.

In an environmental impact assessment, a clear definition of the baseline scenario is important in order to visualise the impact of a plan or project. By definition, the baseline scenario is the situation of the environment that would ensue if a plan or project were not carried out; it is therefore the basis for comparison of the effects of the plan or project. In the case of the present project, the baseline scenario is the situation that would arise if the deactivation is not postponed, in other words if Doel 1 and 2 were to be shut down in 2015 according to the timetable of the Law on the Nuclear Phase-out. The situation that would arise if the plan or project were to be implemented (postponement of deactivation) is compared with the baseline scenario (deactivation). The difference between the two indicates the effect of the Project (in this case the decision to deactivate). Figure 5 illustrates this principle.

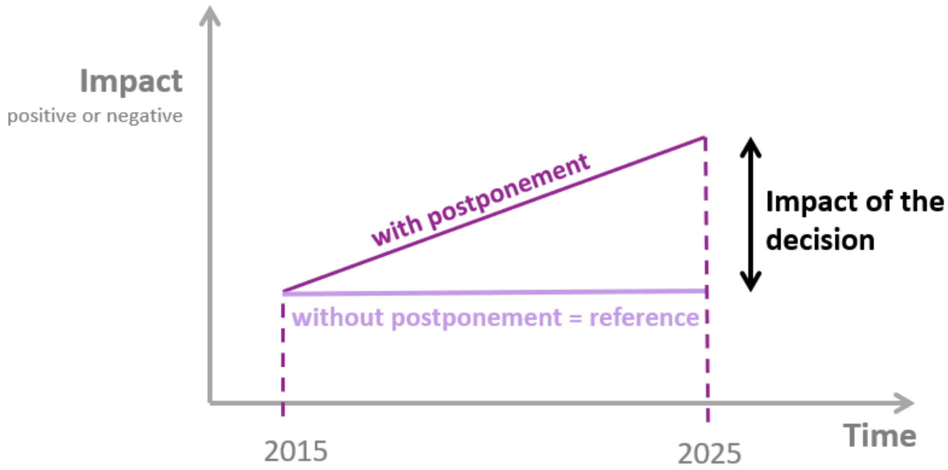

Figure 5: Illustration of the baseline scenario.

In principle, the baseline scenario is the situation of the environment in 2015. Furthermore, the starting point is that this baseline scenario will not fundamentally change (under the influence of developments unrelated to the operation of Doel 1 or 2) between 2015 and 2025, or at least not in such a way as to alter the environmental impact assessment. If this were to be the case, the (altered) baseline scenario in the year 2025 must be taken into account. This is discussed in more detail in §4.5

In addition to the baseline scenario, we also use the terms 'reference period' and 'reference scenario' in this EIA. These terms result from the specific nature of the Project, which is that the impact is limited to a time period, the beginning and end of which are fixed. This time-limited period is called the *reference period*. For impacts that have a clear time dimension (e.g. the quantity of pollutants emitted per year, quantity of waste produced per year, ...) the environmental impact assessment also looks at the cumulative impact over the reference period, by adding up the quantities per year to a total for the period or by making a comparable estimate of the cumulative impact over the period 2015-2025.

The *reference scenario* describes the project-related developments during the reference period if the Project is not implemented, i.e. if the deactivation of Doel 1 and 2 would have taken place in 2015. Specifically, this means:

- No more electricity generation at Doel 1 and 2 after 15 February and 1 December 2015 respectively;
- The other reactors at the Doel site close according to the timetable provided for in the Law on the Nuclear Phase-out (see §1.1**Error! Reference source not found.**).

This scenario is the basis for comparison for the subject of this environmental impact assessment. Figure 6 makes the difference clear.

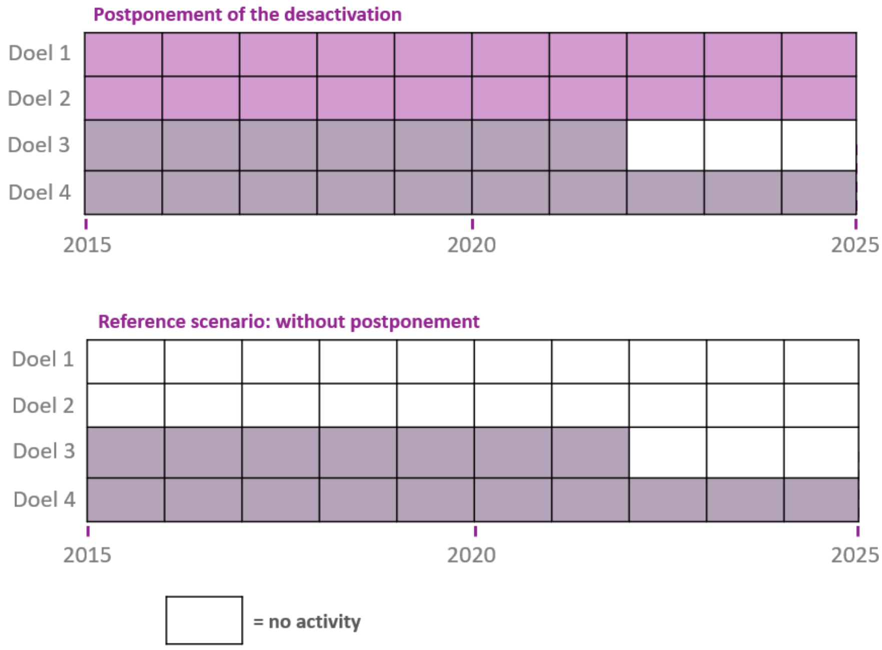

Figure 6: Operation of the four nuclear generation units at Doel NPP, in a situation with (top) and without (bottom) postponement.

4.5 Potentially relevant autonomous and controlled developments

As stated above, the starting point for this EIA is that the baseline scenario (the situation in which there is no postponement of the deactivation in 2015) itself does not undergo any changes over the reference period that are significant for the environmental impact assessment.

Below, an overview is given of various autonomous and controlled developments (in the study area or in its surroundings) that may be relevant:

1. Complex project extra container capacity Antwerp (CP ECA): this project involves construction of a new tidal dock in the port of Antwerp, east of the village of Doel, adjoining the existing Deurganck dock.
2. For the village of Doel, which does not have to make way for the ECA, a separate research project is ongoing, aimed inter alia at setting out sustainable future prospects for the village.
3. On the opposite bank of the Scheldt, between the Scheldelaan and Kanaaldok B2, INEOS is planning 'Project ONE', a propane dehydrogenation plant where propane gas is converted into propylene, and an ethane cracker, in which ethane gas is converted into ethylene.
4. Nature development: as part of the development of the port of Antwerp and the Sigma plan, nature development projects are being planned and implemented in the immediate vicinity of the DoelNPP.

The above developments are taken into account in the EIA, and in particular the extent to which they may increase the scale of the impacts, for example, because the surrounding area has become more vulnerable or because the projects considered cause impacts of their own which are cumulative with the impacts described in this EIA.

5 Procedure

The environmental impact assessment of the Project is performed in the context of the European EIA Directive, the Habitats Directive and the Birds Directive. However, these directives contain few procedural provisions on how the environmental impact assessment process must be performed.

In summary, the main provisions as regards procedures contained in the EIA Directive relate to:

1. Consulting the authorities "likely to be concerned by the project by reason of their specific environmental responsibilities" (Article 6.1);
2. Informing the public, at an early stage in the environmental decision-making procedure, of the procedure, the possibilities for public participation and the subject of the permit application (Article 6.2);
3. Making available to the public the results of the environmental impact assessment and the opinions expressed (Article 6.3);
4. Consultation of competent authorities in other Member States (Article 7);
5. Informing the public of, inter alia, the content of the decision on the permit and the considerations on which the decision is based (Article 9);
6. Appeal procedures (Article 11).

The required notifications under the Espoo Convention, the Aarhus Convention and the EIA Directive (cross-border and within Belgium) are made by the Belgian authorities, the Belgian Federal Public Service Economy and the Minister of Energy.

On 13 August 2020, in the framework of the new law on the postponement of the deactivation of Doel 1 and 2, the Federal Public Service Economy informed the authorities of the countries situated in a 1000 km radius around Doel 1 and 2 of the proposed Project. This notification and consultation were made by the Federal Public Service Economy according to article 7.1 of the EIA Directive. The countries interested in taking part in the cross-border consultation will have the opportunity to submit the opinions of their public and the relevant authorities on the environmental impact assessment to the Directorate-General for Energy of the Federal Public Service Economy, SMEs, Self-employed and Energy, the coordinator of the efforts relating to the environmental impact assessment.

Once the environmental impact assessments have been completed, the Federal Public Service for the Economy will launch a consultation with the three Belgian regions, the Belgian provinces, the relevant local authorities, the Federal Council for Sustainable Development, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS) and the Federal Agency for Nuclear Control (FANC).

In addition, an online public consultation on the environmental impact assessment dossier will also be organised. The notification of this consultation and the communication of the possibilities for public participation is done by the Federal Public Service Economy.

6 Discussion and assessment of the impacts

6.1 Selection of potentially significant impacts

6.1.1 Impacts of the Project

In this EIA, both radiological and non-radiological impacts of postponing (over the period 2015-2025) the deactivation of Doel 1 and 2 were studied and assessed. The emphasis was on the impacts for which there is at least a theoretical possibility that a significant negative impact would occur. The following elements were used to determine for which impacts this might be the case:

- Analysis of the components of the Project (i.e. of the Doel 1 and 2 reactor units) and of the environmental impact that they might cause;
- Analysis of the vulnerability of the environment;

- Consultation on previous environmental impact assessments and the scoping therein[12];
- A workshop organised with the various EIA experts (radiological and non-radiological).

The conclusion of this exercise was that the discussion of impacts needed to focus on the final receptors of these impacts, namely human health on the one hand and biodiversity on the other. This applies to both radiological and non-radiological impacts.

For the non-radiological impacts, other receptors listed in Article 3 and Annex IV of the European EIA Directive were also identified for which significant adverse impacts could occur.

For the themes Soil, Groundwater, Noise, Mobility and Landscape, it was judged that no significant (non-radiological) impacts should be expected at the strategic level by postponing the deactivation. These therefore do not affect the receptor disciplines either. Table 5 summarises the main considerations that led to this decision.

Table 5: Overview of the themes that are not studied in the strategic section of the environmental impact assessment for the Project, and the corresponding justification.

Theme	**Justification for not considering this theme in the environmental impact assessment at strategic level**
Soil	The storage and handling of hazardous substances in large quantities (diesel, neutralisation products, etc.) potentially involve certain soil and groundwater contamination risks. Part of this storage is also directly related to Doel 1 and 2 (e.g. part of the diesel storage needed to keep the pumps running in the event of a power cut). Keeping Doel 1 and 2 open longer therefore theoretically increases the risk of additional soil pollution as a result of diffuse leaks or accidents. Considering the measures taken in accordance with the Vlarem conditions (e.g. containment, leakage detection, etc.) it can be stated that the chance of significant new soil pollution occurring during the additional 10-year period of operation is very low. The operation of Doel 1 and 2 requires that the part of the site taken up by the installations is paved. Postponing the deactivation means that this ground cover also lasts another 10 years. However, it can be assumed that even if the plants had been shut down in 2015, the paving would not have been removed during the subsequent 10 years, given the long time needed for decommissioning. The LTO project includes the construction of several new buildings (pump station and tank for extinguishing water) but this does not involve a significant increase in paving on the soil.
Landscape	The landscape impact of the Doel nuclear power plant is primarily determined by the 170 m high cooling towers and their characteristic water vapour plumes, and to a lesser extent by the installations of Doel 3 and 4. The high voltage lines also have a visual impact. In comparison, the Doel 1 and 2 installations are relatively modest in height and size. Their presence for an additional 10 years would have no substantial effect on the overall visual impact of the plant. The same applies to the impact of the few additional installations set up under the LTO project.
Groundwater	The Doel power plant does not use groundwater. Therefore, postponing the deactivation of Doel 1 and 2 or not has no consequences in this respect. Various existing buildings with foundations and piles that reach down to the depth of the tertiary sediments (-15m) and of diaphragm walls around different parts of the power plant may however disrupt the natural groundwater flow. However, this situation would not fundamentally change if Doel 1 and 2 were deactivated, and certainly not in the short term. With regard to potential groundwater pollution, reference can be made in the first place to the considerations regarding the theme Soil (see above), from which it appears that the likelihood of additional soil (and therefore groundwater) pollution as a result of the storage of polluting substances is very small, given the measures taken in accordance with the regulations in force. An impact on the groundwater balance is not expected either, since within the reference period no significant differences in paved surface area are expected between the situation with and without postponing the deactivation.
Mobility	Traffic movements in connection with the operation of the DoelNPP are primarily caused by the vehicles of staff and subcontractors to and from the site. In addition, there is vehicle traffic to supply and maintain the installations. The traffic in connection with the daily operation of the plant is via road. The (heavy) traffic

[12] EIA Doel Nuclear Power Plant (2010), LTO - screening of environmental aspects for Doel 1 and Doel 2 (2015), EIA Electrabel (2021), EIA SF[2], EIA Perspectives of electricity supply by 2030 (2015).

Theme	Justification for not considering this theme in the environmental impact assessment at strategic level
	to and from the nuclear power plant passes through the Waasland harbour, more specifically around the Deurganck dock and from there to the junction with the R2. On average, around 1,700 people are present on the site (during the day) equating to around 1,300 vehicles, approximately broken down into 900 passenger cars, 300 delivery vans and 100 trucks. There is more vehicle traffic during major works/reviews. During peak periods, passenger traffic amounts to up to 600 passenger car equivalents/h supplemented by a truck density of 25 passenger car equivalents/h. At the most congested times (between 7.00am and 9.00am in the morning and between 4.00pm and 6.00pm in the evening) this gives 625 passenger car equivalents/h. There is no saturation of the local road network around the DoelNPP. However, heavy traffic in the morning and evening rush hour is possible. Postponing the deactivation of Doel 1 and 2 does not increase the amount of vehicle traffic compared to the period before 2015. Compared to a situation with deactivation in 2015, no significant decrease in vehicle traffic is expected, as a large part of this traffic relates to the plant as a whole and cannot be specifically attributed to the operation of Doel 1 and 2. On the contrary, the decommissioning of both reactors could generate a lot of additional traffic, possibly even more if deactivated in 2015 compared to postponing the deactivation until 2025. As previously stated, the difference may be relevant in places, but not on a larger spatial scale.
Noise	At the DoelNPP site, various noise sources can be identified which together account for the total noise emission of the operation in the open air. A distinction must be made between the sources which are in continuous operation and the sources which are only actually in operation a limited part of the time (< 1%), such as emergency units and emergency cooling banks. The temporary sources are only operated in emergency situations, but are also tested every month for safety and maintenance reasons. The 2010 EIA showed that the two cooling towers are responsible for 55% of the noise (primarily the sound of falling water). The auxiliary cooling towers (ventilators) account for 20% and the openings and walls of machine rooms and reactor buildings another 15%. The 2015 screening note for the LTO works showed that the new installations envisaged in the context of the LTO will not cause any additional noise pollution. Conversely, it can also be stated that the deactivation of Doel 1 and 2 will only have a limited (positive) impact on the noise pollution, since this is to a large extent due to the cooling towers connected to Doel 3 and 4, which will continue to operate after the closure of Doel 1 and 2

As regards the non-radiological impact, the environmental impact assessment therefore relates to the impact within the themes Surface water, Air, Biodiversity, Humans and Health, and Climate. Within the environmental impact assessment, these impacts are evaluated with respect to the extent to which they help achieve the policy objectives for these themes or not. As stated above, the focus is on the receptor disciplines Biodiversity and Humans and Health; the other disciplines provide the information necessary to correctly describe the impact in the context of these receptor disciplines.

6.1.2 Avoided impacts of the Project

For most of the impacts studied in the EIA for the Project, it is clear that they would not have occurred in the baseline scenario (the situation where the 2015 deactivation would not have been postponed), and that no negative impacts would have been associated with the deactivation per se. In some cases, however, it must be taken into account that not postponing the deactivation over the period 2015-2025 could have led to (possibly significant) impacts. In the first instance, these are the emissions that would have been caused by the (theoretical) generation capacity that would have had to replace the decommissioned nuclear capacity over that period[13].

[13] This theoretical generation capacity may of course have had other impacts, in terms of e.g. water quality, biodiversity, landscape, etc. However, these impacts are mainly relevant in places, and therefore difficult to budget for, as the locations of theoretical replacement capacity are not known.

In order to say anything with certainty regarding the scale of these avoided impacts, it is necessary to further define the baseline scenario in terms of how the decommissioned generation capacity would be made up for over the period 2015-2025. This is, of course, a theoretical exercise, and the intention is not to compare the impacts of different (non-realised) energy mixes[14].

In order to simplify this exercise, it was decided in this environmental impact assessment, for the purpose of determining the avoided impacts, that the replacement of the theoretically decommissioned capacity should be in the same proportion as the current share of non-nuclear capacity.

It is clear that this should not be seen as a fully-fledged and reasonable alternative to postponing the deactivation, since this alternative was not available in practice at the time the postponement was decided upon[15]. For this reason, we do not study all aspects of this alternative. It makes no sense, for example, to compare the landscape impacts of a theoretical capacity of wind farms with the landscape impacts of Doel 1 and 2, or the cooling water impacts of a theoretical capacity of gas-fired power plants with the actual impact of the cooling water discharges of Doel 1 and 2.

The most relevant (and budgeted) impacts of the baseline scenario relate to emissions of nitrogen oxides (NO_x), with possible impacts on human health, and emissions of greenhouse gases, with possible impacts on the theme Climate. Since these emissions did not occur during the implementation of the Project (postponing the deactivation), they are referred to in this EIA by the term "avoided emissions".

In addition, we also consider the avoided supply uncertainty. Avoiding this uncertainty is the very purpose of the Project, and as such is not a secondary consequence. Nevertheless, it is good to get an idea of the impacts on this aspect if the deactivation of Doel 1 and 2 had not been postponed, whereby, as stated above, there was in fact no reasonable alternative to make up for the capacity lost in the event of the deactivation.

6.1.3 Impacts on the Project

The "Impacts on the Project" specifically refer to the effects of climate change on the Project. The obligation to include this aspect in the environmental impact assessment comes from the amendments made to the EIA Directive 2011/92/EU by Directive 2014/52/EU. Annex IV to that Directive states that an environmental impact assessment must include a description of *the impact of the project on climate* (e.g. the nature and level of greenhouse gas emissions) and the *vulnerability of the project to climate change*.

This may relate both the integrity and the functioning of the Project. The very rationale for a project may also change as a result of climate change and the impacts of a project described in an EIA may become more or less important as the climate changes[16].

6.2 Structure of this non-technical summary

The summary of the environmental impact assessment on the following pages is structured as follows:

1. First, the non-radiological impact on the so-called "intermediate receptors" are discussed (see §6.3). These are components of the environment that can influence impacts in the final receptors (humans and biodiversity). In concrete terms, these are the aspects water, air and climate. Changes in water quality, for example, can have an impact on biodiversity, so it is important to identify what these possible changes in

[14] This was actually addressed in the "Studie over de perspectieven van elektriciteitsbevoorrading tegen 2030" (Study on the perspectives of electricity supply by 2030) of the Federal Public Service Economy (2015)" and the accompanying plan EIA.

[15] Various alternative energy supply scenarios have been elaborated in recent years that take into account a full or partial nuclear phase-out, but as mentioned above, it was not possible to implement these in 2015, and they cannot therefore be considered reasonable alternatives for the present Project.

[16] A classic example of this is the extent to which the impact of a discharge on a watercourse would become more significant if climate-related drought changed the average discharge of that watercourse.

quality consist of. It was already indicated above for which of these receptors no significant impact is expected; as such, they will not be discussed further.

2. The radiological baseline scenario is then described (see §6.4). Knowledge of this baseline scenario is necessary to be able to interpret the significance of any additional impacts of the Project. The non-radiological elements of the baseline scenario are discussed in the impact assessment of the various themes.
3. The effects on humans (§0) and on biodiversity (§6.6) are then discussed. These are the "final" receptors that determine the impact of the Project. For both themes, the non-radiological effects are discussed first, followed by the radiological effects.
4. The impact of the Project on the production of nuclear waste is discussed in §6.7.
5. Finally, a summary of the cross-border impacts is provided (§7)

The EIA (and the present summary), concludes with a decision in which the main findings are summarised.

6.3 Non-radiological effects on water, air and climate

6.3.1 Impact on the water system

The Doel nuclear power plant is highly dependent on the surface water system for its operation, as the tertiary cooling circuits are supplied with water from the Scheldt. Surface water is also sometimes used to produce process water (demineralization water) which after being used and treated is discharged back into the Scheldt.

The tertiary cooling circuits of the Doel 1 and 2 units are direct circuits with single use of the cooling water. The result is that a large quantity of surface water is pumped up, is heated and partially evaporates, and is then discharged back into the Scheldt at a slightly higher temperature. Besides the temperature impact, the cooling water also has a higher chloride content due to the addition of products to prevent microbial growth and foaming. One positive impact of using water from the Scheldt, which is especially beneficial in summer, is that due to the operation of the cooling towers, the discharged cooling water has a higher oxygen content than the water in the Scheldt.

As a result of the discharged cooling water, a considerable temperature rise (over 3°C) can be observed within the area of the breakwater in the Scheldt, up to a maximum of ca. 1050 m from the point of discharge. Relevant but acceptable temperature rises of between 1 and 3°C occur at low tide and at the low tide turnaround up to a maximum of 1,300 m from the point of discharge, an area still within the breakwater. At high tide, a relevant temperature rise of between 1 and 3°C occurs outside the breakwater to a maximum of 500 m downstream and a maximum of 800 m upstream of the point of discharge. For the area within the breakwater, the environmental quality standards regarding temperature for the Scheldt are not met.

Figure 7 shows the amount of cooling water discharged over a 10-year period (2015-2025) for the Project (with postponement) versus the baseline scenario (no postponement). In the baseline scenario, Doel 1 and 2 are no longer in use after 2015, which will reduce the need for cooling water. The figures up to and including 2019 are based on actual discharged flows. The average volume of withdrawn water from the Scheldt for the period 2013-2019 was approximately 1,145 million m³, and the average volume of discharged cooling water approximately 1,128 million m³ (around 1.5% of the cooling water evaporates). The fluctuations in volumes shown on the graph are due to some of the installations being idle (e.g. in 2015 and 2018). A forecast by Electrabel was used for the period 2020-2025, which assumes that Doel 1 and 2 consumes approximately 469 million m³ per year over this period. In the baseline scenario, this flow is no longer discharged, and the volume of cooling water discharged is therefore only 60% of the volume if the deactivation is postponed. The pollutant load discharged via the cooling water is proportionally reduced.

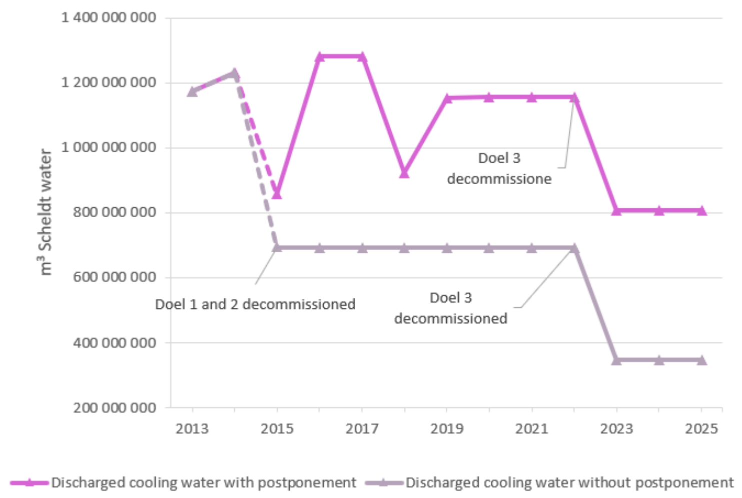

Figure 7: Volume of cooling water discharged if the deactivation is postponed, compared to the baseline scenario (no postponement).

The nuclear power plant also consumes urban water (drinking water) as a source for the process water, sanitary installations and replenishment of the cooling ponds (for the Doel 3 and 4 units). Excess process water is discharged back into the Scheldt following physico-chemical treatment. The sanitary wastewater, together with rainwater runoff from roofs and pavements, is treated in five biorotors and discharged into the Scheldt. Each biorotor for the treatment of sanitary wastewater has a discharge point. The industrial wastewater and the cooling water are discharged at the same point into the Scheldt. The sanitary and industrial wastewater and cooling water must meet the discharge standards laid down in the environmental permit.

Table 6 summarises the differences between the two scenarios in terms of volumes of cooling water and wastewater (sanitary and industrial). The differences between the alternatives in terms of urban water consumption, and hence the discharge of sanitary and industrial wastewater, are small and have not been budgeted for separately.

Table 6: Volume of water discharged with and without postponing the deactivation.

Discharge		**10 year postponement of deactivation**	**Baseline scenario (no postponement)**
Cooling water	Total quantity	11.4 billion m^3	6.7 billion m^3
	Average per year	1.14 billion m^3	0.67 billion m^3
Sanitary facilities	Total quantity	600,000 m^3	<600,000 m^3
	Average per year	60,000 m^3	<60,000 m^3
Industrial	Total quantity	3 million m^3	<3 million m^3
	Average per year	300,000 m^3	<300,000 m^3

In general, the nuclear power plant complies with the discharge standards imposed for sanitary wastewater, industrial wastewater and cooling water, but the discharge standards are not always met for certain parameters (e.g. nitrite, AOX). Efforts are still needed to adapt the remediation facilities for these parameters as well, or to take source-oriented measures to resolve these bottlenecks.

Although in normal circumstances the discharge standards can be met for most parameters and the calculated contribution to the increase in concentrations is limited or negligible, keeping Doel 1 and 2 open longer will result in some residual pollution entering the Zeescheldt for 10 years. The part of the Zeescheldt where the discharges are made currently still has 'inadequate' ecological status and does not comply with all environmental quality standards.

However, there is no reason to fear a deterioration of the ecological status of the Zeescheldt, or that the targets for this body of water will be comprised as a result of keeping Doel 1 and 2 open for a further 10 years.

Besides the discharges, the high level of paving around the site needs to be taken into account (around 52%, which equates to approx. 56 ha of paving), as does the fact that the run-off rainwater, together with the sanitary wastewater, ends up in a mixed sewerage system; in the event of (heavy) rain this causes frequent overflows from the collection pits into the Scheldt, whereby the water that is discharged has not been treated. This has a negative impact on water quality, and it should be recalled that the Scheldt does not yet meet the environmental quality standards for nitrogen, phosphorus and organic pollution. In this respect, however, there is no difference between the situation with and without a postponement of deactivation, since the paved surface area is the same in both cases.

6.3.2 Impact on air quality

The non-radiological emissions due to the operation of Doel 1 and 2 are primarily caused by the (limited) use of various combustion plants and emergency power facilities. The calculated results of these emissions are summarised in Table 7.

Table 7: Emissions from combustion plants (2014) (source: Electrabel, 2020).

	CO emissions in kg/year	NO_x emissions in kg/year	SO_x emissions in kg/year	PM_{10} emissions in kg/year	$PM_{2.5}$ emissions in kg/year
Total	2,495	9,397	299	145	141

This shows that the *direct emissions* caused by the operation of Doel 1 and 2 are negligible compared to the emission reductions that need to be achieved within Belgium and the regions. The largest emission appears to be NO_x, with an annual load of almost 10 tonnes. This only accounts for 20% of the threshold of 50 tonnes/year used in the Integrated Annual Environmental Report (IMVJ in Dutch). Compared with NO_x emissions in the Antwerp conurbation (over 5,000 tonnes in 2015) or with the NO_x emissions for the Antwerp port area (20,000 tonnes) calculated by Flanders Environment Agency (VMM) for 2014, these emissions are clearly negligible. As such, no relevant impact on air quality is expected if Doel 1 and 2 are kept open longer, nor any relevant change in the deposition of acidifying and eutrophying substances.

These direct emissions can be compared with the so-called *"avoided" emissions* that would be achieved from the decommissioning of the Doel 1 and 2 plants, and from replacing the lost capacity by non-nuclear electricity generation. For a number of parameters for which national emission ceilings (NEC) have been defined, these emissions are shown in Table 8.

Table 8: Avoided emissions if the deactivation of Doel 1 and 2 is postponed.

	SOx (SO_2)		NOx (NO_2)		NH_3		TSP[17]	
	Avoided emission	Share in NEC-2030 target (48,500 tonnes)	Avoided emission	Share in NEC-2030 target (124,800 tonnes)	Avoided emission	Share in NEC-2030 target (68,400 tonnes)	Avoided emission	Share in NEC-2030 target (22,200 tonnes)
Year	ton	%	ton	%	ton	%	ton	%
2015	125	0.26	540	0.43	0.6	0.0008	13.6	0.061
2016	169	0.35	752	0.6	1.6	0.0023	27.6	0.124
2017	144	0.3	814	0.65	1.6	0.0023	14.2	0.064

[17] TSP = Total Suspended Particles

2018	37	0.08	294	0.24	0.7	0.001	3.5	0.016
2019	48	0.1	461	0.37	1.4	0.0021	4.4	0.02
2020	32	0.07	396	0.32	1.4	0.002	2.6	0.012
2021	37	0.08	595	0.48	2.3	0.0034	2.8	0.013
2022	27	0.05	558	0.45	2.4	0.0035	1.8	0.008
2023	20	0.04	539	0.43	2.5	0.0037	1.2	0.006
2024	14	0.03	515	0.41	2.6	0.0038	0.8	0.004
2025	6	0.01	266	0.21	1.4	0.0021	0.3	0.001

The emissions can be compared with the so-called national emission ceilings (NEC). The share of these emissions compared to the national and regional emission ceilings is small or very small for most parameters. The (avoided) NO_x emissions appear to account for the largest share with regard to the emission ceilings. On average over the period 2015-2025, this amounts to 0.4% of the national NO_x ceiling for 2030, which can be regarded as significant.

It is clear that if Doel 1 and 2 are kept open longer, the emissions that would be generated over the period 2015-2025 by the combustion plants linked to both reactor units would be many times smaller than the emissions that would be generated over the same period if Doel 1 and 2 were to be deactivated in 2015. For SO_x and NO_x, under the assumptions as regards the composition of the generation capacity in the baseline scenario, this is 0.5% and 1.8% respectively. The emissions attributable to keeping the power plants open longer are therefore very small compared to the avoided emissions.

Of course, this also applies to the resulting impacts on air quality and on acidifying and eutrophying depositions. However, the actual scale of these "avoided" derivative impacts is not known, as it depends to a significant extent on any permit conditions and source characteristics of the (hypothetical) replacement plants, and on the vulnerability of the environment in which they are situated.

6.3.3 Impact on the Climate theme

The greenhouse gas emissions of the DoelNPP come from several operational diesel engines (which power emergency pumps and emergency generators) and from steam boilers and standard boilers. The greenhouse gas emissions inventory of the DoelNPP identifies 13 diesel engines for Doel 1 and 2, with a total installed thermal capacity of 80 MW. Together, these installations were only in operation for approximately 189 hours in 2019.

Table 9 shows the greenhouse gas emissions for the site and for Doel 1 and 2 for the period 2015-2019, as derived from the site's emissions inventory and ETS[18] reporting. The share of Doel 1 and 2 varies from year to year, with a maximum share of 30% of the total emissions from the site. If we simplify and assume a maximum of around 500 tons per year, and that this maximum value is emitted each year, we obtain cumulative greenhouse gas emissions of around 5500 tons maximum over the period 2015-2025, as a direct impact of postponing the deactivation of Doel 1 and 2.

Table 9: Greenhouse gas emissions (tonnes CO_2eq/year) for the Doel nuclear power plant (DoelNPP) and the Doel 1 and 2 units for the period 2015-2019.

	2015	**2016**	**2017**	**2018**	**2019**
Greenhouse gas emissions DoelNPP (tonnes CO_2eq)	1,887	1,420	1,414	1,675	1,272
Greenhouse gas emissions Doel 1 and 2 (tonnes CO_2eq)	487.30	421.81	358.49	395.68	164.40
Share of greenhouse gas emissions Doel 1 and 2 in DoelNPP	26%	30%	25%	24%	13%

[18] ETS = Emission Trading System

Generation Doel 1 and 2 (GWh)	3,340	6,040	6,830	2,610	
Relative greenhouse gas emissions Doel 1 and 2 (gCO_2eq/kWh)	0.146	0.070	0.052	0.15	

For the calculation of the *avoided* emissions, we make the simplifying assumption, as explained above, that the (theoretical) generation capacity that should make up for the lost nuclear capacity during the period 2015-2025 has the same relative composition as the non-nuclear part of the generation capacity at that time.

The calculations are summarised below.

Table 10: Calculation of avoided greenhouse gas emissions if deactivation of Doel 1 and 2 is postponed, over the period 2015-2025, assuming a mixed non-nuclear energy mix.

		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Emissions from electricity generation	kton CO_{2eq}	12,725	11,340	11,567	11,201							
Non-nuclear generation in Flanders	GWh	28,619	27,094	28,105	29,175							
Generation Doel 1 and 2 plus forecasts	GWh	3,340	6,040	6,830	2,610	4,560	4,180	6,660	6,590	6,690	6,700	3,620
Relative emission non-nuclear	kton CO_{2eq} /GWh	0.445	0.419	0.412	0.384	0.382	0.375	0.369	0.363	0.359	0.354	0.350
Avoided greenhouse gas emissions	kton CO_{2eq}	1,485	2,528	2,811	1,002	1,742	1,566	2,455	2,394	2,398	2,374	1,269

As a result of the fluctuations in the (observed or predicted) generation of Doel 1 and 2, the avoided emissions also vary quite widely, with a minimum of around 1000 kton CO_2eq in 2018 and a maximum of around 2800 kton in 2017. Over the entire period, postponing the deactivation of Doel 1 and 2 results in avoided emissions of around 22,000 kton CO_2eq. This equates to a saving of around 2.8% of the total greenhouse gas emissions in Flanders for 2018 (77,700 kton), or almost 17% of the emissions in the subsector "electricity and heat" for Flanders in the same year.

If we compare the emissions generated from the operation of Doel 1 and 2 over the same period (5,500 tonnes), we see that the emissions from Doel 1 and 2 over the period in which the deactivation is postponed represent only 0.025% of the emissions avoided over the same period. The emissions attributable to keeping the power plants open longer are therefore negligible compared to the avoided emissions.

Over the baseline period 2015-2020, the Project will have no additional impact on the resilience of the environment to climate change impacts. Potentially relevant impacts in terms of increased flooding or heat waves will not increase if the deactivation is postponed, firstly due to the short time horizon (2025) in which climate change manifests itself, and secondly due to the fact that the Doel 1 and 2 site will remain paved over the baseline period even if deactivated in 2015.

As regards the vulnerability of the Project to the effects of climate change, a possible increase in the risk of flooding is potentially relevant, firstly from the Scheldt (as a result of rising sea levels) and secondly as a result of higher peak rainfall intensity. The analysis in the EIA clearly demonstrates that the site is resilient to the effects of climate change (in terms of flooding, water damage, extreme weather, etc.) well beyond what is expected in 2025. For example, the site is protected from flooding from the Scheldt, which on average only occurs once every 10,000 years. Failure at the most critical point of the dike could already occur with a return period of 1,700 years. In such a situation, water levels of 20 cm on average could occur on the site, with water depths up to 60 cm in places. Wave overtopping at the dike can occur with a return period of 200 to 300 years. With a return period of 10,000 years, this may result in an average of around 10 cm of water on the site, with higher or lower levels in places; the safe operation of the site is not however compromised. Whether or not Doel 1 and 2 are in operation over the baseline period 2015-2025 does not change the above considerations.

6.4 Description of the radiological baseline scenario

6.4.1 Basic concepts

Radioactivity is a property of certain atoms whereby they spontaneously emit energy in the form of radiation, changing through radioactive decay to a more stable form, until they eventually become stable atoms. The emitted radiation contains large amounts of energy and can ionise atoms in interaction with the matter through which it moves, and is therefore also called *ionising radiation*.

Various forms of radioactive decay exist that also emit specific radiation. For example, the most important are *alpha, beta and gamma decay*, which emit alpha, beta and gamma radiation respectively. A less common form of decay is spontaneous fission, in which the nucleus splits into two fission products and also releases a number of neutrons. These neutrons are also a form of ionising radiation. This process also takes place in a nuclear reactor, and this is referred to as induced fission. When certain atoms decay, a combination of these different forms of radioactive decay can also occur, in which case a combination of the different types of radiation is also emitted.

A *radioactive source* is a collection of radioactive atoms, these can all be the same radionuclides (e.g. Cs-137) or a combination of radionuclides (e.g. Cs-137 and Cs-134).

The *activity* of a radioactive source is the number of radioactive atoms that decay per second. The unit is the becquerel (Bq). 1 Becquerel corresponds to 1 radioactive atom that decays per second. The becquerel is a small unit. Weak radioactive sources, e.g. for testing a detector, usually have an activity of a few thousand becquerels (a few kBq). An overview of the activity of various radioactive sources can be found in Table 11.

Table 11: Examples of the activity of various radioactive sources.

Radioactivity in sea water	12 Bq/litre
Radioactivity in potatoes	160 Bq/kg
K-40 present in the human body	3 kBq
Total activity in the human body (K-40, H-3, C-14, Ra-226, etc.)	8.5 kBq
Discharge of radioactive aerosols to air, including Cs-137, DoelNPP site per year - average (2015-2019)	61.5 MBq
Tc-99m used in bone scintigraphy for diagnosis per patient	740 MBq
I-131 used for thyroid cancer treatment per patient	2 GBq
1 million tonnes of uranium ore	720 TBq
Cs-137 released at Chernobyl accident	89 PBq
Cs-137 released from above ground nuclear bomb tests	948 PBq

Radioactive atoms can also be mixed with non-radioactive material, e.g. when radioactivity is discharged into water, that water will contain a certain activity per litre of water (Bq/l). Similarly, radioactivity can be present in e.g. food (Bq/kg), in the air (Bq/m^3) or deposited on the ground (Bq/m^2).

The activity of a source of a specific radionuclide is proportional to the number of radioactive atoms it contains; the proportionality constant is specific to each radionuclide. This implies that the activity of a source of a specific radionuclide decreases exponentially as a function of time. The time at which the activity is halved is called the *half-life* and this is radionuclide-specific and can range from less than a millisecond to billions of years.

Radioactivity is a natural phenomenon and everything around us is radioactive to a greater or lesser extent. We therefore distinguish between *natural radioactivity* and *artificial radioactivity*.

Exposure to ionising radiation from radioactive sources can occur in various ways: via external irradiation or via external or internal contamination with radioactive particles. These different exposure pathways have a different radiological impact and are always taken into account in a radiological impact analysis.

The effect or impact of ionising radiation is described with the concept of *dose*:

- Absorbed dose is the amount of energy absorbed per amount of mass and is expressed in gray (Gy), which is 1 joule (unit of energy) per kilogram.
- Equivalent dose is the absorbed dose weighted for the type of radiation, to account for the biological effect of the type of radiation. At the same absorbed dose, alpha radiation will cause much more damage than beta or gamma radiation. Neutrons also generally produce a greater biological effect. The equivalent dose is expressed in sievert (Sv).
- Effective dose is the equivalent dose weighted for the sensitivity of the different organs and is also expressed in sievert (Sv).

Deterministic effects (tissue reactions) are effects that occur once a certain threshold dose is exceeded. The threshold dose is different for different radiation effects, but for the occurrence of clinical effects it is typically above 1 Gy, these are doses that should be avoided in any case and that are only exceeded in very serious radiation accidents.

In addition, there are *stochastic effects*, namely the risk of cancer and genetic effects, which can already occur at lower doses. Epidemiological studies have shown that the incidence increases linearly with the effective dose. At low doses, the occurrence of stochastic effects is therefore limited and indistinguishable from spontaneous occurrence (without radiation exposure).

The effective dose makes it possible to compare different exposures and thus their risk. Table 12 shows the effective dose per year for an average Belgian (for 2015), where the contribution from various forms of exposure is given.

Table 12: Dose load of average Belgian in 2015 (source: FANC).

Dose load per capita in 2015	**mSv/year**
Cosmos (cosmic radiation, cosmogenic radionuclides, flying, being at high altitude)	0.35
Earth radiation (external radiation natural radioactivity in soil)	0.40
Inhalation of natural radionuclides (radon, thoron and decay products)	1.40
Ingestion of natural radionuclides (all natural radioactivity in food and drinking water)	0.29
Industrial applications (discharges, etc.)	<0.01
Medical applications (X-ray, CT, SPECT, PET, etc.)	1.53
Total (average)	3.98

For the public, a threshold value for the effective dose of 1 mSv/year is applicable, understood as the additional dose due to human activities on top of the dose due to natural exposure and doses received in the context of medical diagnosis or treatment. However, the average Belgian receives only less than 1% of this dose limit (<0.01 mSv/year) due to industrial nuclear and radiological applications, including nuclear power plants for energy generation.

The criterion for evaluating the radiological impact on fauna and flora is the absorbed dose rate (energy absorbed per unit of time), for fauna and flora usually expressed in microgray per hour (μGy h^{-1}). In these impact calculations, the radionuclide concentrations in the environment are converted into the effective dose rate, multiplied by a weighting factor that takes into account the various forms of radiation and the possible exposure pathways of the species in question.

In the case of the normal operation of the DoelNPP, limited amounts of radioactivity are discharged in a controlled manner:

- into the atmosphere in the form of gaseous discharges;
- into the surface water, in the form of liquid discharges.

The discharge limits of the operational nuclear power plant are based on the regulatory annual limit of 1 mSv for the most exposed population, so that the discharges cannot result in exceeding the dose limit. In addition to the maximum quantities that may be discharged annually, the discharge permit also states the characteristics of the radioactive substances discharged.

6.4.2 Atmospheric discharges

The gaseous discharges to the atmosphere contain radioactive substances in gaseous form (gas and vapour), or in the form of aerosols when these are solid or liquid particles in suspension in the discharged air. These effluents originate from processes which, for example, occur in the nuclear power plants to ensure the degassing of the primary cooling water. These can first be collected in storage tanks where the short-lived radionuclides decay and their activity is therefore greatly reduced before being discharged. The gaseous effluents also come from the general ventilation of the nuclear buildings. In all nuclear plants, safety regulations require that the air inside the buildings be continuously renewed by forced ventilation. The air emitted to the exterior, which depends on the volume of the buildings and the ventilation flow rates, are specific to each plant.

Figure 8 shows the proportion of the different atmospheric discharges to the discharge limits according to the operating permit for DoelNPP, for the period from 2014-2019. As shown in this figure, the actual atmospheric discharges represent only a fraction (in all cases less than 4%) of the discharge limits for the different groups of discharges.

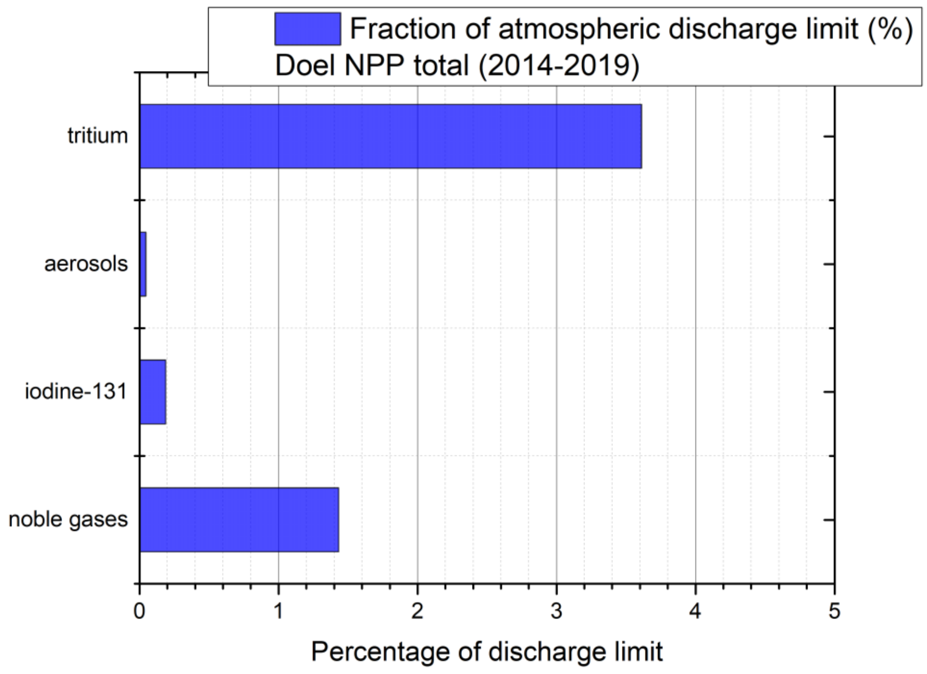

Figure 8: Actual discharges for the period 2014-2019 expressed as a percentage of the discharge limits for the different groups of radionuclides.

6.4.2.1 Liquid discharges

The liquid radioactive effluents primarily come from process circuits, for example those used to treat primary cooling water in nuclear power plants. They are also formed by the wastewater produced when tools, the sanitary wastewater and the water used for cleaning the floors in the nuclear zones, such as the fuel storage docks, are decontaminated, water leaks, etc. These wastewaters can contain dissolved and solid radioactive particles in suspension, as well as non-radioactive substances. To ensure that the quantities of radioactivity released into the environment are as low as possible, the wastewaters are treated before being discharged. The pre-treated wastewaters from the Doel nuclear power plant that contain limited quantities of radionuclides are discharged into the Scheldt.

The nuclear power plant primarily discharges tritium into the Scheldt. Due to the current and the flow of the water from the Scheldt, the discharged radioactivity is dispersed and diluted. The possible impact of the discharges on humans and the environment is evaluated by the FANC, which regularly takes samples of water, sediment, aquatic plants, fish and crustaceans, and which measures the levels of radioactivity. Complementary to the monitoring programme of the FANC, the Doel nuclear power plant has also had a limited monitoring programme since 2014 with a focus on bio-indicators such as aquatic plants.

Figure 9 shows the liquid discharge volumes from 2004 to 2019. The quantities are much lower than the discharge limits and have remained virtually constant over the past 15 years. Over the last 5 years, an average of 33% of the discharge limit for tritium and 3% of the discharge limit for the other radionuclides was discharged.

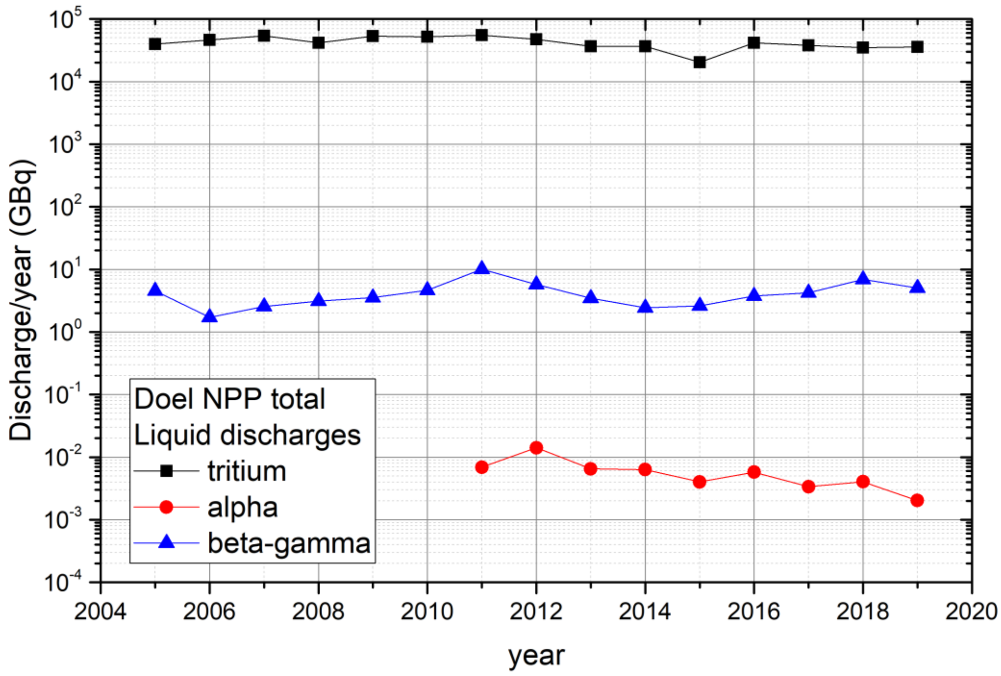

Figure 9: Evolution of the liquid discharges into the Scheldt over the period 2005-2019.

6.4.3 Monitoring of radioactivity at the site and in the environment

The radiological situation at the DoelNPP site and in the surrounding area is continuously monitored by measurements taken in the context of a monitoring programme carried out by the competent authority (FANC) on the one hand, and by the operator of the nuclear power station on the other. The measurements always highlight a combination of natural radioactivity and artificial radioactivity. Specifically in the vicinity of DoelNPP, traces of artificial radioactivity can originate from the operation of DoelNPP itself (as a result of discharges: see previous section) but also from other nuclear activities in the past (above-ground nuclear bomb tests, Chernobyl accident) or radiological effects of other nuclear and non-nuclear activities.

The average external radiation exposure per year in the vicinity of the DoelNPP site is around 0.70 to 0.75 mSv/year, and is caused by radiation from natural radioactivity in soil and cosmic radiation (0.4 to 0.45 mSv/year external radiation soil and about 0.3 mSv/year cosmic radiation). This value is stable over the years.

The discontinuous measurements (sampling and analysis in laboratories) around Doel determine the radioactivity levels of the particulate matter in the air, deposition in deposition containers (dry and wet deposition), soil and grass, water and sediments near DoelNPP (downstream), and finally shrimps, mussels and algae (in the Scheldt estuary downstream of Doel and in the North Sea).

The results of this discontinuous program, which has a higher sensitivity for detecting potential artificial radionuclides, first of all demonstrates the prevalence of natural radioactivity. The traces of artificial radioactivity in the soil are almost entirely due to the Chernobyl accident and to the fallout from the nuclear tests in the atmosphere, which peaked in the 1960s. The concentrations measured in the vicinity of Doel are average for those in Belgium.

In conclusion, in the baseline scenario, the Doel nuclear power station has no significant measurable radiological impact on the environment through atmospheric discharges, nor does it have a significant measurable radiological impact on the Scheldt. An analysis of measurement results in the vicinity of DoelNPP is always representative of all activities on the site. The conclusions therefore apply in particular for the impacts of Doel 1 and 2 in the baseline scenario.

6.4.4 Dose calculations for the baseline scenario

Calculations can be used to determine the contribution of DoelNPP to the total exposure based on the discharges.

To calculate the impact of the discharges to the *atmosphere*, atmospheric dispersion models are used to calculate the activity concentration of the various radionuclides discharged into the air (in Bq/m^3) and by deposition on the ground (in Bq/m^2).

A simple river model that takes into account the dilution of the discharged volumes is used to calculate the concentrations of the discharged radionuclides in the *Scheldt water*.

These different calculations show, starting from the actual discharges, a maximum impact (i.e. an effective dose to the most exposed critical person) of 0.02 mSv/year. These calculations also show that this exposure is stable over the years, as shown in Figure 10. This conservatively calculated effective dose to the most exposed person is 50 times lower than the dose limit for the public which is 1 mSv/year.

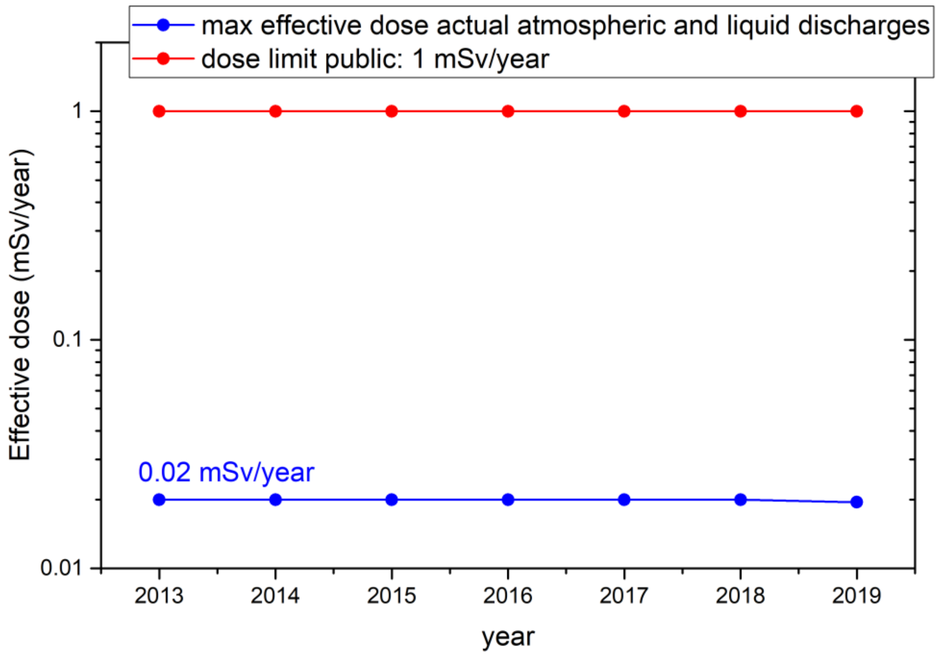

Figure 10: Effective dose for most critical individual in the vicinity of DoelNPP calculated from reported actual discharges. The dose limit for the public is shown, by way of comparison.

The radiological impact of the <u>permitted</u> discharge limits for DoelNPP as a whole (4 units) for the gaseous and liquid discharges is given in

Table 13. This is the actual dose per year for the most exposed person. Since these calculations are performed for different age groups and the most exposed person for gaseous discharges and liquid discharges belongs to a different age group, the total is not the sum but the value for the most exposed person for the combined type of discharges. As the permitted discharge limit is (much) higher than what is actually discharged, the total dose calculated on the basis of these limits is naturally also higher than the dose calculated on the basis of the actual discharges, but at 0.37 mSv it is still lower than the standard of 1 mSv/year. This confirms that as long as the discharge limits are not exceeded, there is no risk that the actual dose will exceed the standard.

Table 13: Actual dose per year to the most exposed individual from gaseous, liquid and total discharges corresponding to the discharge limits for the total DoelNPP.

	Gaseous discharges	Liquid discharges	Total
DoelNPP (4 units)	180 µSv/year	230 µSv/year	370 µSv/year

6.4.5 Radioactive waste and spent fissile material

6.4.5.1 General

Radioactive waste is described as low-level, medium-level or high-level, depending on the amount of radiation it emits. Radioactive waste can also be considered short-lived or long-lived, depending on how long it remains radioactive.

In Belgium, ONDRAF/NIRAS (the Belgian Agency for Radioactive Waste and Enriched Fissile Materials) classifies radioactive waste into three categories. Category A refers to low-level and medium-level short-lived waste, category B groups low and medium-level long-lived waste, and category C contains high-level long-lived waste.

Low-level and medium-level waste (categories A and B) comprises more than 95% of the total volume but less than 10% of the radioactivity of all radioactive waste.

The aim of waste treatment and conditioning is to convert radioactive waste into a solid and stable end product that meets specifications for storage and final disposal.

The processes for processing and conditioning of the radioactive waste are either applied in the nuclear power plants themselves (for part of their own waste), or are centralised at the Belgoprocess site in Dessel. The residue remaining after processing is encapsulated in cement to capture the radioactive particles. Everything is then packed in steel drums. Once the radioactive waste is processed and sealed in a drum, it is referred to as 'conditioned'. In Belgium, conditioned radioactive waste is temporarily stored in suitably protected storage buildings on the Belgoprocess site. Most of the spent fuel elements are temporarily stored on the sites of the Doel and Tihange nuclear power plants.

Disposal of radioactive waste, as defined in Belgian legislation, refers to transferring it to a facility with no intention of retrieving it, but without prejudice to the possibility, as the case may be, of recovering the waste.

6.4.5.2 Low-level and medium-level waste (A and B)

After treatment of the various waste flows, operational waste from DoelNPP is transported to Belgoprocess for further processing and/or storage.

An approximate figure of 120 m^3/year of conditioned waste can be assumed for the Doel nuclear power plant. This is low and medium-level waste, with no distinction between category A and B waste.

6.4.5.3 Fissile material (C)

Electricity is generated in the nuclear power plant using the energy released by fission of the uranium-235 present in the fissile material. After three to four years in the reactor core, the fissile material is spent, which means that all usable energy is gone. This spent fissile material is cooled under water (usually for 5 to 10 years) and then transported to the spent fuel storage building (located on the nuclear power plant site), pending a decision on how it will be managed long-term.

The quantity of high-level waste generated by a nuclear power plant depends to a significant extent on the amount of electricity generated and the recharging cycle of the unit.

6.5 Impacts on human health

6.5.1 Non-radiological impacts

Postponing the deactivation of Doel 1 and 2 does not lead to health impacts due to *chemical or physical stressors.* The nitrogen oxide emissions of the plant are in fact very limited, and in any case lower than those that would occur under the baseline scenario, and are therefore avoided by postponing the deactivation of Doel 1 and 2. There is therefore a positive impact in this respect. The Project also has no relevant impact on the noise levels in the vicinity of the power plant.

As regards *biological stressors*, Legionella is potentially relevant. Indeed, the bacteria could be present in the cooling water system and could be spread to the surrounding area via atomisation, and subsequently inhaled. The auxiliary cooling towers of Doel 1 and 2 are topped up with urban water. The growth of Legionella is prevented or limited in this circuit by adding biocides. The management plan stipulates that these auxiliary cooling towers must be sampled and analysed for the presence of Legionella at least twice a year. If the limit values are exceeded, the necessary measures must be taken (cleaning, more biocides) and new checks are made. As far as is known, Legionella infections have never occurred as a result of the cooling towers operating at DoelNPP. It can therefore be concluded that, provided the management plan is applied, the risk of Legionella contamination from the cooling towers is negligible.

Psychosomatic and psychosocial aspects, related to the operation of the Doel nuclear power plant on the one hand and the nuclear sector in general on the other, can also be considered as stressors that may lead to complaints.

A study conducted in November 2011 (by IPSOS on behalf of Greenpeace) showed that 76% of respondents agreed with the decision to invest in renewable energy sources as an alternative to extending the life of nuclear power plants. In this study, 31% of respondents also expressed concern about a possible blackout if nuclear reactors were phased out between 2016 and 2026; however, a majority (55%) did not share this concern.

Furthermore, the SCK CEN Barometer (2018) showed that 54% of the population consider the potential abuse of nuclear technologies by terrorists to be a high to very high risk, and half of the population consider a potential nuclear accident and radioactive waste to be high to very high risks to their health in the next 20 years. The majority of the population considers reducing the amount of nuclear power plants in Belgium to be a good thing (71% agree or strongly agree) and thinks that nuclear power plants are a danger to the future of their children (64%). On the other hand, more than half of the population (55%) thinks that renewable energy does not meet current energy needs. In 2018, one in four Belgians believed that nuclear power was a climate-friendly technology, but half of them held the opposite opinion; 49% of the population was willing to pay more to promote the use of renewable energy; 40% were not.

In 2018, around 33% favoured not replacing the existing nuclear power plants at the end of their working lives; around 30% believe that all nuclear power plants should be closed as soon as possible without being replaced, while 11% believe that Belgium should close its nuclear power plants and build new ones, and 19% indicated that Belgium should continue to operate the current nuclear power plants and build new ones to replace the old ones.

Around half of the Belgian population considers the risks of nuclear accidents to be high to very high and a large part of the population (75%) thinks that even a low dose following a nuclear accident is harmful for the public health. Opinions on the use of nuclear power for electricity generation were evenly split between favourable and unfavourable in 2018.

The above-mentioned observations present a mixed picture; it cannot be determined whether the use of nuclear energy or the existence of nuclear power plants gives rise to specific psychosomatic or psychosocial complaints. However, it can be assumed that such complaints, if there were any, would mainly be due to nuclear electricity generation in general, rather than to the operation, or not, of the specific Doel 1 and 2 reactor units.

Large-scale blackouts are also likely to lead to health impacts. Given that postponing the deactivation of Doel 1 and 2 was intended to ensure security of supply and therefore avoiding large-scale blackouts, we can assume a positive health impact of the Project. The factors that determine the importance of the health impact of a power outage include direct parameters such as duration and frequency, and on the other hand contextual parameters such as outdoor temperature and scale. Safety issues also arise in the event of a power outage, but these are not the subject of the theme health within an environmental impact assessment. A recent study (Dominianni 2018) reported the health impacts of a power outage based on three occurrences. In two of the three power outages, the context was also a decisive factor: the power outages occurred during a heat wave. The impacts based on this study included respiratory problems and probably increased mortality. Power outages during heat waves can lead to kidney failure. In extreme cold, power outages lead to more common causes of death and heart disease.

The boxed section on p. 10 briefly discusses the economic impacts of power outages. Among other things, this shows that much depends on the duration of a power outage: if it lasts more than 8 hours, the damage will increase exponentially.

6.5.2 Radiological impacts

As regards the radiological impact on health, both the effects of the Project during normal operation (including production of radioactive waste and spent fissile material) and the impacts during accidental situations were studied.

Members of the public who live, or regularly stay, in the vicinity of nuclear sites may be exposed to some degree to the radioactive substances emanating from atmospheric or liquid discharges from the plant. The exposure pathways include external irradiation by radionuclides present in the air or deposited on soil and other surfaces, and internal exposure through ingestion of radioactivity in the body, through the inhalation of radioactive substances or through the ingestion of plant or animal foodstuffs that have themselves ingested radioactivity. The public can also be exposed to radioactivity by using river water, by spending time on the water or river banks, or by consuming fish from the Scheldt.

Exposure models are used to calculate the impact of these discharges to the atmosphere. The dose calculations take into account all exposure pathways and assume a critical person permanently present at the site of maximum dose exposure who gets 10% of their food from an area where deposition of the discharged radionuclides is maximum.

As indicated above, the (conservative) model calculations, starting from the discharges in the current situation, show a maximum impact for the most exposed critical person of 0.02 mSv/year, i.e. 50 times lower than the dose limit for the public. These calculations also show that most of the annual dose is due to atmospheric discharges. Less than 10% of the calculated dose, or 0.002 mSv/year, is due to the liquid discharges in the Scheldt.

If the deactivation of Doel 1 and 2 is postponed, gaseous and liquid discharges from the normal operation of these two units will continue until 2025. The discharges depend entirely on the operation of the units and are related to the thermal capacity and treatment of the liquid and gaseous effluents. Given that no fundamental changes have been made to the operation of the plant in the context of the integrated action plan for operation after 2015, it can be assumed that both the atmospheric and the liquid radioactive effluents will be discharged in the period 2015-2025 under the same conditions as in 2015.

The radiological impact of both atmospheric and liquid discharges for the DoelNPP site as a whole will therefore remain comparable if Doel 1 and 2 is deactivated, and amount to around 0.02 mSv/year (2% of the dose limit) for the most exposed person.

The operation of nuclear power plants over their working lives also allows certain radionuclides with sufficiently long half-lives to accumulate in the soil. In theory, if the deactivation is postponed, this accumulation will continue for another 10 years, before a drop in soil concentrations due to radioactive decay is observed. However, an analysis made in the context of this EIA shows that the effect of accumulation in the soil, and therefore the difference between deactivation or postponing the deactivation, is not observable in 2015. For short-lived nuclides, no accumulation will occur over a long period of time, as equilibrium is reached very quickly between deposition and decay. No significant accumulation will occur for the long-lived C-14 either, as the consensus is that there is an equilibrium between air and soil concentrations.

The EIA Works also show that the radiological impact of *accidents* in DoelNPP (Doel 1 and 2) on human health is limited. This analysis is based on the study of two design basis accident scenarios and one design expansion accident scenario. The calculations made show that in each of these situations the impact at the company boundaries of DoelNPP remains below the limit values in the permit. The analysis of the impact of an accident is a statistical analysis in which it can never be ruled out that the impact is greater and that the intervention guideline values as stated in the federal nuclear and radiological emergency plan are exceeded. In such a case, the emergency plan will be activated to protect the population and the environment.

6.6 Impacts on biodiversity and natural values

6.6.1 Non-radiological impacts

The biodiversity theme merits due attention in the environmental impact assessment, given the location of the project site in the immediate vicinity of several Natura 2000 sites (Special Protection Areas or SPAs) and of sub-areas of the Flemish Ecological Network (VEN in Dutch). Specifically, these are parts of the Special Protection Area of the Habitats Directive (SPA-H) 'Scheldt and Durme estuary from the Dutch border to Ghent' (BE2300006), the Special Protection Area of the Birds Directive (SPA-V) 'Schorren en Polders van de

Beneden-Schelde' (BE2301336) and the Dutch protected area Westerschelde & Saeftinghe which is both SPA-H (NL9803061) and SPA-V (NL9802026). The VEN areas in the vicinity lie within this delineation. The various relevant protection zones are shown in Figure 11.

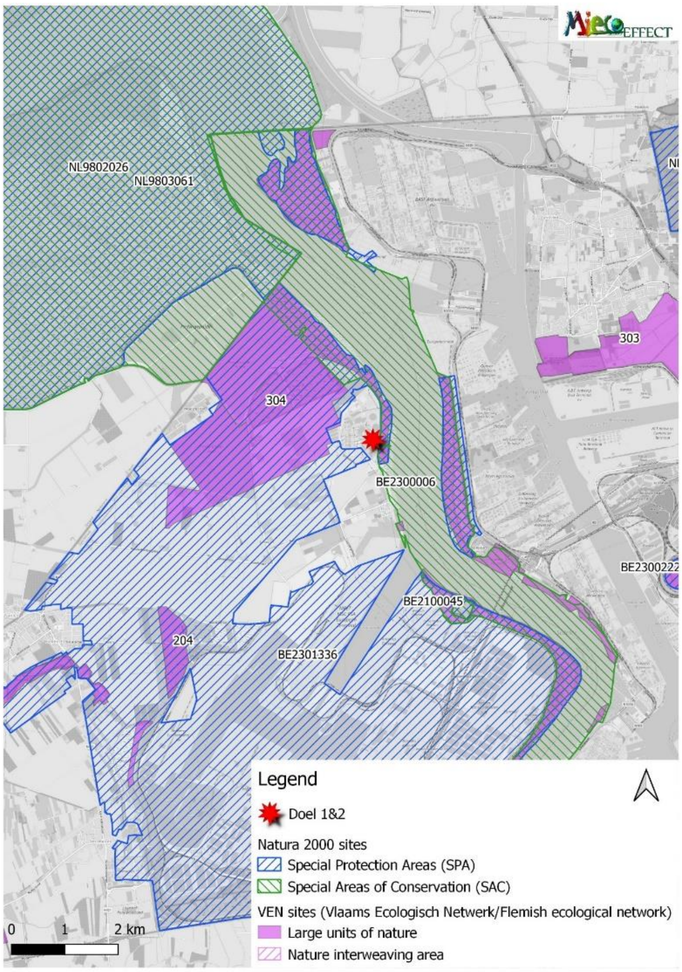

Figure 11: Protection zones for nature.

Many of the potential impacts on biodiversity are due to the discharge of wastewater and cooling water into the Scheldt, which may have an impact on *surface water quality*. This may include chemical quality but also biological quality; both are used to assess the "state" of the water body according to the provisions of the Water Framework Directive. The biological quality elements relevant for the water body Zeescheldt IV are macrophytes (plants), macroinvertebrates (invertebrates) and fish.

In principle, the higher nutrient load and the discharge of AOX (see theme Water) can have an impact on biodiversity, particularly in the zone within the breakwater. At higher nutrient levels, shifts within species communities may occur as fast-growing species are favoured. However, this is not clear from the available monitoring results, which show that the area near the nuclear power plants is actually rich in species. Due to the complexity of the factors which have an impact on populations within the breakwater, it is impossible to know if the discharges have a significant impact here locally. A direct toxic influence of increased nitrite concentrations can be ruled out. For the water body as a whole, little impact from discharges is expected.

The discharge of cooling water is also a point for attention. Changes in thermal conditions can impact the ecosystem in various ways. One direct consequence may be mortality due to lethal temperatures. At the regional level, a temperature rise also affects the ecology by causing shifts in the ecosystem: the life cycles of organisms are disrupted, creating a mismatch in the timing of life stages. For a number of fish species, a water temperature of <10°C is necessary during the spawning period (winter/early spring). If this temperature is not reached, reproduction stagnates. Another effect, important both locally and regionally, is the occurrence of exotic species, which can survive the winter in the warmer parts (especially locally) and then influence the natural community of life in the summer (also regionally). Finally, less oxygen can dissolve in warmer water, causing oxygen shortages to occur more quickly and critical species to disappear.

In 2012 and 2013, the fish stock within the breakwater and beyond was surveyed by the Research Institute for Nature and Forest (INBO). The study revealed no difference in the presence of exotic species, but there was a greater abundance of warmth-loving indigenous species (sea bass and sole) within the breakwater.

As regards macroinvertebrate populations, there is no direct evidence that the discharge of cooling water has caused shifts in the communities, favouring less sensitive or warmth-loving species over other, possibly more typical species. If these effects occur, they will in any case only be localised. There are also no clear indications that cooling water discharge in the vicinity of the nuclear power plant will lead to an increase in the number of exotic species in the macroinvertebrate populations. Although such species have been observed, their presence is not necessarily linked to the presence of the nuclear power plant, but the discharge of ballast water from ships in the port and the presence of artificial hard bank substrates may also play a role. Moreover, there will still be a thermal effect if Doel 1 and 2 is deactivated, due to the cooling water of Doel 3 and 4. In the environmental impact assessment for the works carried out by Electrabel, the discharge of cooling water if Doel 1 and 2 is deactivated is estimated at 60% of the current volume. In the baseline scenario there will still be a zone with higher temperatures, only smaller in size.

The impact of the discharges could potentially also cause indirect effects on the birds of the Birds Directive area. Many of these species forage on the mudflats of the Scheldt. A significant impact on macroinvertebrates or fish at the Scheldt or the mudflats behind the breakwater can therefore have consequences for the availability of food for birds.

The monitoring of the thermal impact shows that this is largely confined to the area within the breakwater. Moreover, the flow only extends downstream of the point of discharge when the tide goes out. At that point, the mud is dry and there is little influence on the communities living in the mud. For fish, which can be important as food for certain bird species, there could potentially be a more significant impact, but the results of the monitoring by the INBO indicate that there are actually more fish inside the breakwater than outside. It can therefore be concluded that any impact of the cooling water discharges on food availability for birds will be limited.

A possible rise in the temperature of the Scheldt water can potentially also give rise to *barrier effects*, if the cooling water flow extends over the entire width of the Scheldt, thereby limiting upstream or downstream movements of certain sensitive species. However, in practice the cooling water flow of the power plant is limited to the area within the breakwater, so that no barrier effect is to be expected.

The *capture of cooling water* is also important, as it can cause mortality for fish, shellfish, crustaceans or other invertebrates that are sucked along. For the capture point for cooling water from Doel 1 and 2, mechanical purification takes place outside the dike, at the water intake, via grids on the intake. It is therefore impossible for fish and crustaceans to end up in the cooling water circuit. As such, no fish or crustacean mortality is observed at this capture point. It can therefore be concluded that the extended operation of Doel 1 and 2 will not lead to a significant increase in mortality of fish and crustaceans in the Scheldt.

Besides the impacts on the Scheldt, the operation of the power plants can potentially also have an impact in terms of *disturbance*. This may involve noise or light disturbance, or disturbance on account of human presence. Many of these factors are difficult to attribute solely to the operation of Doel 1 and 2. Even if both power plants were no longer in operation, there would still be people present for the operation of Doel 3 and 4. The same can be said about the presence of lighting.

Noise modelling carried out in the context of the environmental impact assessment of the works by the operator (Electrabel NV) showed that the noise contours of DoelNPP mainly extend in an easterly direction (towards the Scheldt). The zone in which serious noise disturbance can be expected (55 dB(A) and above) overlaps with the mudflats and salt marshes located along the power plant itself. The zone within which noise disturbance can still have a limited negative effect (45 dB(A) and more) overlaps with the Scheldt itself, with a limited part of Doelpolder Noord and with part of the future nature area Doelpolder Midden. However, this is a continuous noise which is therefore very predictable and is in a clearly remote area. It can therefore be expected that birds will not really be scared away and, moreover, they have already gotten used to it to a significant degree. Passing cars, hikers and, for the Scheldt, boats will probably have a greater impact. Moreover, only part of the noise comes from Doel 1 and 2. It can therefore be expected that the impact of the Project in terms of disturbance will be negligible.

Theoretically, due to atmospheric emissions caused by the combustion plant, emergency generators and pumps and traffic, the Project may also contribute to effects of acidification and eutrophication of ecosystems. As stated in the discussion of the air theme, the operation of Doel 1 and 2 does not give rise to relevant depositions of acidifying or eutrophying substances, especially not in comparison with emissions from other sources in the vicinity (mainly in the port). As such, no negative impact on ecosystems in the vicinity of the plant is expected. Such an impact, although not spatially attributable, could be expected in the baseline scenario, where the lost capacity of Doel 1 and 2 would be at least partly made up for by fossil fuel based generation units. The impact of the deactivation of Doel 1 and 2 for this criterion over the period 2015-2025 would therefore probably be more significant than the impact of postponing the deactivation.

As shown in the discussion of the Water theme, no effects are expected on the groundwater system, nor on natural values that have a relationship with the groundwater. A *change in the hydrology* of the Scheldt is not expected either, as the captured cooling water is almost completely discharged again and, in any case, it is only a very limited share of the total flow into the Scheldt at the power plant. There is no impact on the structural quality of the Scheldt either, as the Project does not involve any direct interventions in the Scheldt or its banks.

Based on the above assessment, it can be stated that the Project *will not cause any avoidable damage* to nature and that *no avoidable and irreparable damage* will occur *within the VEN areas* in the vicinity of the power plant. Furthermore, the analysis shows not only that no impact is expected on current habitats and species within the Natura 2000 sites, but also that achieving the nature objectives of these areas would not be compromised by the Project. In other words, the Project will *not have a significant impact* on the conservation status of habitats and species in the context of the appropriate assessment.

6.6.2 Radiological impacts

Until the 1990s, it was assumed that if humans are protected, the environment is also protected from ionising radiation. This view has been challenged in recent decades, partly because of the growing global interest in environmental sustainability and partly because of the fact that there may be situations where the environment is more exposed to radiation than humans.

Table 14 summarises the main differences between the methodology used to determine the impact on humans and that used to determine the impact on fauna and flora.

Table 14: Main differences between the methodology for determining the radiological impact on humans and on the environment.

Humans	Environment (fauna and flora)
Protection at the level of the individual	Protection at the level of populations/ecosystems
Deterministic and stochastic effects of radioactivity are taken into account	In general, only the deterministic effects are considered
Internal doses are calculated using biokinetic models which simulate the uptake of radionuclides in the human body	Internal doses are calculated using transfer factors, based on activity in the environment
Reference person (biokinetic model)	Reference organisms (represented as simple ellipsoids)
Different age classes	No age classes
Accumulation of radionuclides in the organs is considered	Radionuclides are uniformly distributed throughout the animal tissue
Effective dose (Sv)	Absorbed dose rate (Gy s^{-1})

Data on the effects of radiation or exposure to radionuclides on fauna and flora have been collected and evaluated by various (inter)national organisations and expert groups, with the aim of deriving threshold values. Most numerical threshold values are intended to protect populations. The recommended threshold values vary widely: from 4 to 4000 µGy h^{-1}.

The risk to fauna and flora from radiological exposure is assessed in quantitative terms most effectively by comparing the estimated dose rate with a threshold value. However, for most of the scenarios to be evaluated, we do not have sufficient information to allow a quantitative estimation of the radiological exposure. As such, the evaluation in this EIS is based on the probability of significant exposure being absent, according to dose rate. The significance framework used is shown in Table 15.

Table 15: Significance framework for radiological effects on fauna and flora.

Dose rate	Probability of significant exposure being absent
<10 µGy h^{-1}	Very High
10-100 µGy h^{-1}	High
100-400 µGy h^{-1}	Fairly high
400-4000 µGy h^{-1}	Moderate
>4000 µGy h^{-1}	Low

As the radiological impact on an ecosystem is difficult to evaluate due to its complexity, different categories of reference organisms are used to determine the radiological impact on the environment. These reference organisms are assumed to be representative of the habitats in which they live. All the reference organisms combined refers to an ecosystem. As such, when selecting specific reference organisms, extra attention is given to the "value" of an organism within the ecosystem under study.

In the period 2010-2011, studies were carried out by the Belgian Nuclear Research Centre, on behalf of Electrabel, to assess the radiological impact of atmospheric and liquid *routine discharges* on the environment. The ERICA tool (Environmental Risk from Ionising Contaminants Assessment and Management tool), the reference tool for biota, was used for the calculations. The potential impact is estimated using a risk quotient (*RQ*), defined as the ratio of the calculated predicted exposure dose rate (PEDR) and an estimated no-effect dose rate. The guide value of 10 μGy h^{-1} suggested by ERICA was used as a reference level; at this dose rate, ecosystems are assumed to be protected.

The impact analyses were conducted for the atmospheric and liquid discharge limits of DoelNPP. The calculations showed that the screening value of 10 μGy h^{-1} was never exceeded, despite additional conservative assumptions relating to, for example, the dispersion of radionuclides. Given that the actual discharges were less than 1% of the dose limits, the resulting dose rates were several orders of magnitude lower than the guide value.

Based on the fact that the discharges from the Doel 1 and 2 reactor units amount to only 50-60% of those from the DoelNPP site as a whole, it can be concluded that it is highly unlikely that the routine discharges from Doel 1 and 2 will have an impact on the biodiversity of nearby Habitat Directive areas or other (protected) natural areas and ecosystems. Given that the discharges have remained fairly stable over the last two decades, it can be assumed that this trend will continue if the operation of Doel 1 and 2 is extended from 2015 to 2025, and therefore that the future risk of impacts on fauna and flora from routine discharges is non-existent.

As regards the *accidental* scenarios, a dose rate higher than 45 μG h^{-1} is never calculated, despite highly conservative assumptions. This dose rate is in the range of 10-100 μGy h^{-1} where the probability of the ecosystem being protected is estimated to be very high. For most organisms, after 4 days of exposure and for all organisms after 30 days, the dose rate decreased to < 10 μG h^{-1}.

As there is no effect on fauna and flora of the routine radioactive discharges nor of the accidental scenarios that have been considered, it can be concluded that postponing the deactivation of Doel 1 and 2 has no negative impact on biodiversity as a consequence of radioactive discharges.

6.7 Impact on the production of waste and spent fissile material

Postponing the deactivation of the Doel 1 and 2 nuclear reactors will result in the production of additional low and medium-level radioactive waste. Of the average production of 120 m^3 of conditioned waste per year for DoelNPP, about 1/3 is attributable to Doel 1 and 2, or 40 m^3/year. This corresponds approximately to the ratio of the share of both reactors to the total capacity, or to the total quantity of electricity generated. However, it should be noted that much of the waste is not related to the amount of electricity generated. It is produced when work is done on installations, cleaning or washing work clothes. For this fraction, it is also assumed that 1/3 is a good approximation for the share of Doel 1 and 2.

On this basis, a cumulative additional generation of 400 m^3 of low- and medium-level waste that needs to be disposed of is expected during the reference period 2015-2025. This is primarily category A waste, with only a limited amount of category B waste.

Assuming that the quantity of category B waste is negligible, the additional volume of waste corresponds to approximately 250 monoliths or a quarter of a module in the disposal facility for category A waste. The (volumetric) capacity of the repository is 34 modules. Given that it is an extension of existing activity, resulting in waste families with known characteristics, no further impacts are expected on waste management in either the short or long term.

In the same way as for radioactive waste, an estimate was made of the cumulative amount of fissile material that will be consumed during the reference period 2015-2025. Based on an average discharge of 55 fissile elements per year for Doel 1 and 2, the cumulative additional consumption resulting from postponing deactivation is estimated at 550 fissile elements. ONDRAF/NIRAS takes into account an additional number of fissile elements of about the same order of magnitude (609 units) resulting from extending the operation of Doel 1 and 2. Weighted in relation to the complete Belgian reactor capacity, this corresponds to an additional 5.8% consumption of fissile bundles.

Given this relatively limited quantity and assuming that they will be similar in terms of properties to existing fissile material, no impact is expected on their further management. In DoelNPP, nuclear fissile material is temporarily stored in dry containers in the Fissile material Container Building (SCG in Dutch). Due to the postponement of the deactivation of Doel 1 and 2, the decoupling of the 4 units will be condensed into a few years (2022-2025), whereas this would otherwise be spread out more evenly. Electrabel NV guarantees that there will be sufficient storage capacity for fissile material, thanks to the planned construction of the SF^2 storage facility, for which the permit procedure is ongoing.

When power plants are decommissioned, radioactive components are removed and there are therefore large quantities of radioactive waste. Part of this waste is due to the neutron activation of large (structural) components. Since the waste classification (category A or B) depends on the total amount of safety-relevant nuclides, it is expected that prolonged exposure to neutrons could possibly lead to a reclassification of waste category (e.g. from category A to category B).

Based on model calculations, it can be concluded that extending the lifetime of 40 to 50 years will have little or no impact on the total radioactivity caused by the activation of elements present in the structural components of the plant, since most of these activation isotopes have only a short lifetime. However, there is a significant increase in the number of long-lived isotopes in these structural components. The impact on the total amount of waste from different categories is difficult to estimate at present. In general, however, a slight reclassification towards "heavier" waste categories can be expected, nonetheless without posing any problems for the long-term management of these categories.

7 Cross-border impacts

7.1 Non-radiological impacts

Most of the non-radiological impacts attributable to the postponement of the deactivation of Doel 1 and 2 are limited to the immediate surroundings of the power plant, and they are of limited magnitude and therefore do not give rise to cross-border impacts. There is only the possibility of a (limited) cross-border impact for the theme Water.

Based on monitoring (2012) of the influence of the cooling water of DoelNPP on the temperature of the Scheldt near the Dutch border (at approx. 3.4 km distance from the point of discharge), the influence of the discharge of the cooling water can at most be considered as limited negative (i.e. the temperature rise due to the discharge will be less than 1°C). This temperature rise will steadily decrease downstream on Dutch territory.

It should be noted that various cross-border impacts cannot be ruled out in the benchmark scenario if the deactivation is not postponed. It is therefore possible that the cross-border impacts are more important with deactivation than with postponed deactivation. However, the scale and characteristics of these cross-border impacts will depend to a significant extent on the locations where (theoretical) replacement capacity is built, on the technical characteristics of these installations and on their permit characteristics.

7.2 Radiological impacts

7.2.1 Normal operation

The border with the Netherlands is about 3.15 km from the DoelNPP site, at the closest point. However, given the negligible and unobservable radiological impact (0.02 mSv/year), if all units of DoelNPP are operated, for the most exposed person on Belgian territory (just outside the DoelNPP site), and the fact that the impact only decreases with distance, it can be considered that if the deactivation of Doel 1 and 2 is postponed, there would be no cross-border impacts during normal operation.

7.2.2 Accidents

The radiological impact at the border with the Netherlands (at about 3.15 km from DoelNPP) of the design accidents considered in the EIA Works translates into an effective dose incurred by the population of about 0.5 mSv or less. This value is below the Belgian guideline values for protecting the population. The analysis of the impact of accidents is a statistical analysis in which it cannot be ruled out that accidents with a higher impact may occur, albeit with a lower probability.

An example of the geographical distribution of the risk of serious accidents in nuclear plants in Europe was examined in a study financed by the Austrian government (FlexRisk). Doel 1 and 2 were considered for this study with a containment bypass accident, with an assigned probability of occurrence lower than those considered in the EIA Works. The resulting impact, besides the source term itself, depends on the release parameters and on the weather conditions at the time of the accident, and could exceed the intervention guideline values for nuclear and radiological emergencies. In such cases, the national nuclear and radiological emergency plans will be activated to protect the population and the environment.

8 General conclusion

Postponing the deactivation of Doel 1 and 2 may lead to the continuation, for a period of 10 years, of a number of impacts which already occurred in the preceding period. The question is whether this should be considered a significant impact. The answer to this question was studied in the present EIA for the receptor groups "humans" and "biodiversity", both in terms of non-radiological and radiological impacts. An impact analysis was also carried out for a number of other themes for which there are policy objectives that could be impacted by the Project and/or that determine the effect on humans and biodiversity. Furthermore, the "avoided impacts" of the Project, in terms of greenhouse gas emissions and nitrogen oxides, and their impact on the themes of health and climate, were also studied.

The analysis shows that the impacts on the ***water system*** are not such as to affect the ecological status of the Zeescheldt or to jeopardise the good ecological potential of this water body. However, there needs to be a focus on resolving problems specific to the current operation, such as frequent overflows, the condition of the sewerage system and the fact that not all discharge standards are always met.

Within the theme ***biodiversity***, the *non-radiological impacts* were assessed in terms of surface water quality, barrier effects, mortality, disturbance, acidification and eutrophication from the air, and direct land take. No impacts were to be expected for barrier effect, mortality and direct land take. For disturbance, there is potentially a limited impact from noise disturbance, but given the continuous and predictable nature of the noise, no real damage is expected. As regards acidification and eutrophication from the air, the contribution of the Project itself is negligible and, due to the avoided impacts, this even makes a (limited) positive contribution. The impact of discharges of wastewater, industrial water and cooling water on the ecological quality of the Zeescheldt is negligible.

These findings apply mutatis mutandis to the effects on the VEN areas. As regards the impact on the special protection areas in the vicinity, it can be concluded that there is no negative impact on the conservation objectives, nor does the Project obstruct the achievement of these objectives. The impact of the avoided emissions on the conservation objectives of Natura 2000 sites elsewhere in Belgium is likely to be positive, but the significance is difficult to estimate.

The analysis of the radiological impacts also makes clear that neither the routine radioactive discharges nor the accidental scenarios considered should have an adverse impact on biodiversity in general or on the conservation status of the Natura 2000 sites surrounding the plant.

The non-radiological ***atmospheric emissions*** from the plant, and their impact on air quality, are negligible. Over the reference period, the avoided emissions of nitrogen oxides are low compared to the emission targets. However, in places around the (hypothetical) replacement capacity, these may have a limited impact on air quality. Nonetheless, the emissions avoided by postponing the deactivation over the period 2015-2025 are much larger than the non-nuclear emissions related to both reactor units during the same period.

Also in terms of greenhouse gases, the emissions avoided by postponing the deactivation are much more significant than the emissions associated with the operation of Doel 1 and 2 over the period 2015-2025. The Project would not otherwise affect the resilience of the surrounding area to the effects of climate change, nor would it itself be vulnerable to those changes.

In terms of ***health***, a very modest positive impact can be expected due to the avoidance of a quantity of NO_x emissions over the period that Doel 1 and 2 remain operational for longer. The fact that major power outages are also avoided by the Project can be considered positive in terms of health.

The radiological impacts of the plant on human health are up to 50 times lower than the standard, and this will continue to be the case with the extended operation of Doel 1 and 2 over the period 2015-2025. The radiological health impacts of the DoelNPP are therefore negligible, with or without implementation of the Project. This applies not only to the impacts in normal operation, but also to the impacts of any accidents.