Non-technical summary of the

Environmental Impact Assessment

In the context of postponing the deactivation of the Doel 4 and Tihange 3 nuclear power plants

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

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This document is a translation of the original non-technical summary written in Dutch.

Content

1 Context of environmental impact assessment

Nuclear power has been the main source of electricity in Belgium since the commissioning of the various reactors at the Doel and Tihange sites in the years 1975-1985, with an annual production share between about 40% and 60% over the last 35 years.

The gradual phase-out of the use of nuclear power for electricity production on the Belgian territory was regulated by the law of 31 January 2003 (the nuclear phase-out law). This stipulated that nuclear plants would be deactivated 40 years after the date of their industrial commissioning, and that all individual licences relating to electricity production by those plants would come to an end at the same time. The law also states that no new nuclear power plant for industrial electricity production by fission of nuclear fuels can be established and/or put into operation.

The nuclear phase-out law was first amended on 18 December 2013 to extend the operating period of the industrial electricity production of Tihange 1 by 10 years. The nuclear phase-out law was amended again by the law of 28 June 2015 (law annulled on 5 March 2020 by the Constitutional Court and replaced by the law of 11 October) to ensure energy supply. This gave permission to restart Doel 1 (it had already been shut down in accordance with the 2003 law) and postponed the deactivation of Doel 2 by 10 years. Table 1 lists the current dates for deactivation for each nuclear power plant.

Table 1: Deactivation calendar according to the original Act of 2003 and its subsequent amendments (status 1 January 2023)

Nuclear plant	Date of industrial commissioning	Date of deactivation (after 40 years)	Date of deactivation (amendments to 2003 law, status 1 January 2023)
Doel 1	15 February 1975	15 February 2015	15 February 2025
Doel 2	1 December 1975	1 December 2015	1 December 2025
Doel 3	1 October 1982	1 October 2022	1 October 2022
Doel 4	1 July 1985	1 July 2025	1 July 2025
Tihange 1	1 October 1975	1 October 2015	1 October 2025
Tihange 2	1 February 1983	1 February 2023	1 February 2023
Tihange 3	1 September 1985	1 September 2025	1 September 2025

Late December 2021, the government asked the Federal Agency for Nuclear Control (FANC) and FPS Economy (DG Energy) to analyse by 17 January the actions needed to activate the so-called plan B (keeping Doel 4 and Tihange 3 nuclear reactors open longer than planned) with a view to ensuring Belgium's electricity supply after 2025.

The FANC's analysis showed that an extension of the operating period for the youngest nuclear reactors was possible in terms of nuclear safety, albeit subject to the necessary regulatory adjustments and safety improvements of the installations. An operation extension also requires an environmental impact report.

On 18 March 2022, the federal government then decided to effectively proceed with an extension of the operation period of Doel 4 and Tihange 3, thus maintaining a nuclear production capacity of 2 gigawatts.

On 9 January 2023, the Belgian government and operator ENGIE Electrabel came to an agreement to secure keeping the country's two youngest nuclear reactors, Doel 4 and Tihange 3, open for 10 years beyond their planned 2025 closure date.

2 Project objective: ensuring security of electricity supply

Elia has recently (2021) calculated that by 2025, after the proposed closure of all nuclear power plants, there would be a need for additional flexibly deployable generation capacity of about 3.6 GW to meet security of supply and flexibility standards. By 2032, this need would increase to 4.6 GW, primarily due to the increasing electrification of the economy and society.

Electricity imports are not a sufficient answer to that demand. It is to be expected that in current market conditions, combined with the winding down of fossil plants in Germany, among others, and the partial unavailability of the French nuclear park, there will be little surplus capacity in the North West European market at certain times.

Elia argues that market forces will not fill the shortage of capacity from the year 2025 onwards in the short term and to a sufficient extent. Therefore, the creation of a CRM (Capacity Remuneration Mechanism) mechanism was proposed, which should not only provide sufficient capacity but also be able to use this capacity in a sufficiently flexible way. Expansion of this mechanism and its associated production units is currently underway.

In the current context of uncertainty in energy supply, high prices for energy and geopolitical instability, the Government wishes to focus more on domestic (non-fossil) production capacity and reduce dependence on (foreign) fossil sources.

In that context, the lifetime extension of Doel 4 and Tihange 3 is a logical decision; it allows a guaranteed capacity of 2 GW to be made available to the grid again in a relatively short term (i.e. after the plants are shut down in 2025 and restarted after the necessary modifications and procedures).

3 Initiator and team of experts

The initiator of the environmental impact assessment on the decision and works related to it is the Belgian Federal Public Service Economy, SMEs, Self-Employed and Energy, Vooruitgangstraat 50, 1210 Brussels.

The environmental impact assessment was prepared by a team of recognised radiological and non-radiological EIA experts. The general project management and the radiological/nuclear disciplines were in the hands of SCK CEN. KENTER was responsible for coordinating the non-radiological parts of the EIA and specifically those for Doel 4. SERTIUS was responsible for the non-radiological disciplines for Tihange 3.

4 Object of the environmental impact assessment

The project that is the subject of the environmental impact assessment relates to the strategic decision and works (as known at the time of conducting the assessment) for the lifetime extension of the Doel 4 and Tihange 3 nuclear reactors for a period of 10 years, from the date of the first post-closure industrial electricity production (as provided for in the 2003 Nuclear Generation Act). The latest envisaged date for shutdown when extended by 10 years is 31 December 2037 (see Table 2)[1].

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[1] When we refer to the extension of Doel 4 and Tihange 3 in this report, we always mean the extension as defined here, even if specific dates are mentioned for practical reasons.

Table 2: Extension of the Doel 4 and Tihange 3 nuclear reactors for industrial electricity production as considered in this environmental impact assessment. This timing is in line with the draft law approved at the Council of Ministers on 1 April 2022.

Nuclear plant	Planned closure Nuclear Exit Act 2003	Extension	No later than anticipated date of deactivation upon extension
Doel 4	1 July 2025	Ten-year period from date of first industrial electricity generation after 1 July 2025	31 December 2037
Tihange 3	1 September 2025	Ten-year period from date of first industrial electricity generation after 1 September 2025	31 December 2037

Doel 4 and Tihange 3 are respectively part of the site of the Doel nuclear power plant (Kerncentrale Doel - KC Doel), located along the Scheldt, at Scheldemolenstraat, Haven 1800, 9130 Doel, and of the site of the Tihange nuclear power plant (Centrale Nucléaire de Tihange, CN Tihange), located along the Meuse, at Avenue de l'Industrie 1, 4500 Huy (Figure 1), and are operated by Electrabel SA.

Figure 1: Location of the Doel and Tihange nuclear power plants (orange), the nuclear power plants on Belgium's borders (green) and other Class 1 nuclear facilities in Belgium (blue).

In terms of safety, all nuclear reactors currently comply with the applicable legal safety requirements. These regulations were strengthened in 2020 with additional safety requirements, which apply from 2025. Since Doel 4 and Tihange 3 are among the most modern nuclear reactors in Belgium, and since they have already been the subject of several upgrading projects (in the context of the previous three periodic safety reviews and of the post-Fukushima stress tests), the works required to realise the LTO (Long Term Operations) are not particularly extensive or complex.

The works considered in the EIA include both design improvements and ageing management. Design improvements include managing potential heat waves and associated temperatures, strengthening the habitability of emergency planning centres in case of severe accidents, and additional (mobile) cooling systems for irradiated nuclear fuel, which can be switched on in accident situations. With regard to ageing management, the safety authority (FANC-AFCN) estimates that the large mechanical components (reactor vessel, reactor cover, steam generators) do not need to be replaced; for other components (smaller mechanical components such as pumps or valves, electrical equipment, instrumentation, civil structures), there will only be a complete picture of the possible replacement works once Electrabel SA has completed its studies.

Based on the works as known at the time of the scoping of the potential impacts and the assessment of these impacts[2], the impacts are evaluated as very localised and generally limited to the site for the various non-radiological disciplines. There is no radiological impact within the period when the extension is studied and radioactive waste is assessed for the LTO including the works. A limited amount of low-level radioactive waste is expected for the works, representing only a fraction of the cumulative amount over the considered LTO period.

The latest status of the works that are included in the environmental impact assessment in the present report was available in a note dated 15 March 2023[3]. The description of the works and the scoping of possible impacts contained in this note are not fundamentally different from those that were assumed when assessing the impacts of the works carried out in this EIA. The effective list of works to be carried out in the context of LTO Doel 4 and Tihange 3 may still evolve in consultation between the operator, Electrabel S.A., and the safety authorities.

5 Functioning of the Doel 4 and Tihange 3 nuclear power plants

The goal of extending the Doel 4 and Tihange 3 units at the respective KC Doel and CN Tihange sites is the continued industrial production of electricity.

Doel 4 and Tihange 3 are reactors of the so-called pressurised water type (PWR - Pressurised Water Reactor). Such a reactor is typically composed of three compartments with three separate circuits: the reactor building with primary circuit, the machine room with secondary circuit and the cooling circuit forming the tertiary circuit (Figure 2).

Figure 2: Operation of the nuclear power plant with, from left to right, the reactor building, the machine room and the cooling circuit (Source: Electrabel SA).

[2] Information available up to 31 January 2023 was included for this purpose, information received later was not guaranteed to be included.

[3] PSR LTO KCD4 CNT 3-ELP-Description des travaux du LTO de D4/T3 (ref. CNT-KCD/4NT/0031174/000/02), Tractebel Engineering S.A., 15 March 2023.

The reactor building contains the reactor vessel that holds the nuclear fuel or fissile material. Fission produces fission products and neutrons. The energy released in fission, is transferred to water under high pressure (155 bar) in a PWR such as Doel 4 and Tihange 3. Doel 4 and Tihange 3 both have three circuits, which together form the primary cooling circuit (each with its own pump), pumping water around from the reactor core to the steam generators.

The heated high-pressure water from the primary circuit goes to the steam generator where it gives off its heat to the water on the other side (secondary circuit) where steam is formed. Thus, there is never direct contact between the water from the primary and secondary circuits. The steam drives a turbine in the engine room, and the attached alternator converts the rotation of the turbine into electric current. The steam in the secondary circuit continues to the condenser where the steam is converted back into liquid water, which is pumped back to the steam generator. Cooling of the condenser is done with water from the tertiary cooling circuit, again never in direct contact with the water of the secondary circuit. The tertiary circuit is fed by Scheldt water (Doel) or Maas water (Tihange), which results in this Scheldt or Maas water heating up slightly. Therefore, it first goes to the cooling towers with forced draft before either returning to the condenser or flowing back into the Scheldt or Maas.

During normal operation and maintenance in the nuclear zone, small quantities of radioactive elements may be released. This creates a number of radioactive waste streams in gas, liquid and solid form in addition to the spent fuel elements. For the latter two, treatment systems exist at the KC Doel and CN Tihange sites. For Doel, the treatment system is housed in a central water and waste treatment building (WAB), while for Tihange it is more dispersed among the different facilities; liquid waste is treated for the entire site at Tihange 2.

Since the final shutdown (DSZ) of Doel 3 (23 September 2022) and Tihange 2 (31 January 2023) for the industrial generation of electricity, both sites are in a state where part of the reactors are still producing electricity and another part that is in the phase of final shutdown (also called post-operational phase or POP).

For Doel 4 and Tihange 3, too, the final shutdown and post-operational phase will obviously come up at some point, with or without the realisation of the lifetime extension project. The only difference is when the DSZ will happen: With project realisation, it will be more than 10 years later than without project realisation. However, it does not change the environmental impacts per se.

Target 4 and Tihange 3 will also have to be decommissioned after shutdown and POP. The impact of this phase is not part of the environmental impact assessment of the lifetime extension of Doel 4 and Tihange 3. However, the quantities of radioactive waste and spent fuel from decommissioning are included in the project assessment.

6 Alternatives

An alternative to a plan or project can be defined as 'another way to achieve the objectives of the plan or project'. Therefore, the question is whether there are alternative ways to ensure security of electricity supply beyond 2025.

The decision to extend the lifetime of the Doel 4 and Tihange 3 nuclear reactors by 10 years is driven by unexpected and undesirable developments in the energy market and in the geopolitical situation in Europe. In preparation for making that decision, the government considered whether equivalent alternative options were available and what the advantages and disadvantages of those options were.

In summary, several of the possible alternative energy sources are not real alternatives: renewable energy capacity is not yet sufficiently developed, import possibilities are under pressure and the strategic reserve is not intended to be used structurally. The CRM mechanism is the most obvious alternative, and is therefore being further developed. In this sense, it is not a real alternative but an additional guarantee, in combination with the lifetime extension of Doel 4 and Tihange 3, to ensure security of electricity supply. Incidentally, Elia assumes that even with a lifetime extension of both plants, the capacity provided by the CRM mechanism will continue to be needed. This is also obvious since the shortfall in 2025 was estimated at 3.6 GW, of which only 2 GW will be filled by keeping the plants open longer.

7 Baseline condition

In an environmental impact assessment, to visualise the impact of a plan or project, a clear definition of the baseline condition is important. The baseline condition is the state of the environment that arises if a plan or project is not implemented; it thus forms the basis of comparison for the impact of the plan or project. In this case, the baseline state is the state that would arise if the lifetime of Doel 4 and Tihange 3 were not extended, if, in other words, Doel 4 and Tihange 3 were to be permanently shut down in 2025 according to the calendar of the nuclear phase-out law. The condition that would arise if the plan or project did go ahead (lifetime extension) is compared with that reference condition (no lifetime extension). The difference between the two indicates the impact of the plan or project (in this case, the lifetime extension) (Figure 3).

In principle, the reference state is the state of the environment in the year 2025. Furthermore, the starting point is that this reference state does not fundamentally change (under the influence of evolutions not related to the operation of Doel 4 or Tihange 3) between 2025 and 2037, or at least not in such a way that the assessment of the impact on the environment would be altered.

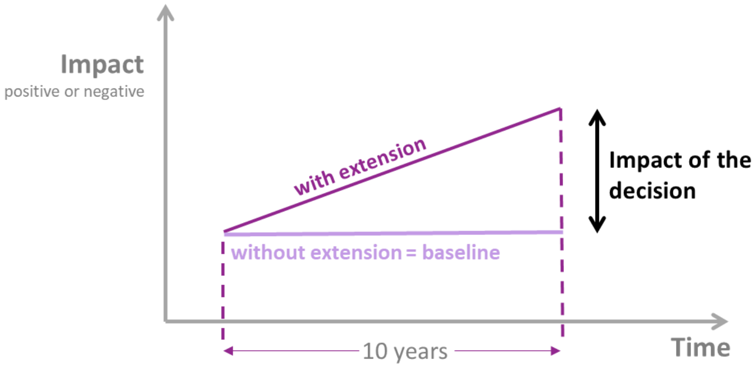

Figure 3: Schematic representation of the baseline state.

Besides the reference condition, the terms 'reference period' and 'reference scenario' are also used in the environmental impact assessment. These terms follow from the particularity of the project, which is that the effects are limited to a time-limited period (10 years), the beginning and end of which are not currently known with certainty (see Table 2). We call this time-limited period the reference period. For impacts that have a clear time dimension (e.g. amount of pollutants emitted per year, amount of waste produced per year, ...), the environmental impact assessment also considers the impacts cumulated over the reference period, either by summing up the amounts per year to a total for the period or by making a similar estimate of the cumulative impacts.

The reference scenario describes the project-related developments during the reference period if the project is not implemented. For the Doel and Tihange sites, this scenario implies that no nuclear reactor remains active at the site. For the Doel 3 and Tihange 2 plants, by 2027 the post-operational phase will be fully or largely over, and decommissioning will have started. For the Doel 1, Doel 2 and Tihange 1 reactors, the post-operational phase will run until around 2030, after which decommissioning will also have started for these reactors.

No information is currently available on the form that decommissioning will take and the associated environmental impacts; therefore, they cannot be taken into account in the environmental impact assessment. However, comprehensive environmental impact assessments at project level will be carried out for the decommissioning of the various reactors in the future.

8 Procedure

The environmental impact assessment is carried out within the framework of the European EIA Directive, the Habitats Directive and the Birds Directive. However, these directives contain few procedural provisions on how the EIA process should proceed.

In summary, the main provisions with procedural scope from the EIA Directive relate to:

1. Consulting with the authorities that 'by virtue of their specific environmental responsibilities may be affected by the project' (Article 6.1);
2. Informing the public, at an early stage of the environmental decision-making procedure, of, inter alia, the procedure, opportunities for public participation and the subject matter of the permit application (Article 6.2);
3. Making available to the public the results of the environmental impact assessment and the opinions issued (Article 6.3);
4. Consulting the 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 carried out by the Belgian government, Federal Public Service Economy and the Minister of Energy.

After completion of the environmental impact assessment, the Federal Public Service Economy organises a consultation among the three Belgian regions, the Belgian provinces, interested municipalities, the Federal Council for Sustainable Development, the National Agency for Radioactive Waste and Enriched Fissile Materials (NIRAS) and the Federal Agency for Nuclear Control (FANC).

In addition, an online public consultation will be organised for 60 calendar days through a website dedicated to the publication of the full environmental assessment file for the deferral of the deactivation of Doel 4 and Tihange 3. The notification for the consultation and public participation is done by the Federal Public Service Economy.

9 Selection of potentially significant impacts

9.1 Impacts of the Project

The environmental impact assessment studies and assesses both the radiological and non-radiological impacts of the 10-year lifetime extension of the Doel 4 and Tihange 3 reactors. When discussing the impact, the focus is on the final receptors of that impact, 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, the other receptors listed in Article 3 and Annex IV of the European EIA Directive were examined for which significant adverse effects could occur.

For the themes of Soil, Groundwater, Noise, Mobility and Landscape, it was considered that no significant (non-radiological) effects are to be expected from life extension at the strategic level. Thus, these do not affect the receptor disciplines either.

In terms of non-radiological effects, the environmental impact assessment therefore covers the effects within the themes of Surface Water, Air, Biodiversity, Health, and Climate. Within the environmental impact assessment, these impacts are assessed in light of the extent to which they do or do not contribute to achieving the policy objectives for these themes.

9.2 Avoided impacts of the Project

These are effects that do not occur if the project is implemented, but do occur if the project is not implemented. They are therefore effects that occur in the reference situation. Since the magnitude of an effect is determined by making the difference between the project situation and the reference situation, these are negative or 'avoided' effects.

Given the ambiguity about the actual filling of the 'avoided' production capacity, we do not study a number of effects that may be related to it (but which strongly depend on the nature and location of the replacement plants). These include, for example, effects on landscape, air quality or water quality.

Specifically, we limit the study of avoided impacts to:

- The avoided emissions of greenhouse gases (with knock-on effects in the Climate discipline);

- NO_x emissions avoided (with knock-on effects for the discipline People and Health).

In addition, we also consider the avoided supply uncertainty. Avoiding this uncertainty is the very objective of the plan, and as such not a side effect of it. Nevertheless, it is good to get a picture of the effects on this aspect if the lifetime of Doel 4 and Tihange 3 were not extended. We consider the effects of supply uncertainty primarily in the context of the "People" theme.

9.3 Effects on the Project

The "effects on the Project" refers specifically to the impact of climate change on the Project. The obligation to include this aspect in the environmental impact assessment follows from the amendments made to the EIA Directive 2011/92/EU by Directive 2014/52/EU. Indeed, Annex IV to that Directive states that an environmental impact assessment must include, inter alia, a description of the project's impact on climate (e.g. the nature and extent of greenhouse gas emissions) and the project's vulnerability to climate change.

10 Overview of environmental impacts

10.1 Non-radiological impacts

Extending the lifetime of Doel 4 and Tihange 3 means that for an additional period of 10 years (treated) sanitary wastewater, treated industrial wastewater and (heated) cooling water will be discharged into the Zeeschelde and Meuse rivers respectively. Since the discharge standards are respected at both sites and the contribution of the discharges to the concentration of the various pollutants in the surface water is limited, this will not lead to a deterioration of the ecological status of the Zeeschelde (Doel) or the Meuse (Tihange), provided continued attention is paid to monitoring and timely adjustment. Nor does the project jeopardise the achievement of the good ecological potential of both water bodies.

From the biodiversity theme, effects of the project were studied for the Doel site in terms of surface water quality, barrier effect, mortality, disturbance, direct land take, and eutrophication and acidification. For barrier effect and direct land take, it was found that no effects are to be expected. For mortality, there might be a (limited) effect because of the intake of cooling water. For disturbance, only changes are to be expected for noise disturbance. The significance of this is rather limited, as during the lifetime period the disturbance will only come from Doel 4. Moreover, this is an existing noise that is continuous and predictable; therefore, a significant impact on nearby species is not expected.

The effects of the operation of Doel 4 in terms of acidifying and eutrophying depositions are negligible. Moreover, other factors such as the quality of the Scheldt water are much more decisive for the trophic state at that site. However, in terms of nitrogen depositions, positive effects can be expected from the 'avoided emissions' associated with 10 years of additional nuclear production.

The discharge of cooling water, sanitary water and industrial water will cause a deterioration of water quality, which in Doel is however limited to the zone within the breakwater. Meaningful effects on the ecosystem of the Scheldt as a whole are therefore avoided. Also locally, there are no indications that the effects would be detrimental to the organisms present. Given the designation of the Scheldt itself as a Habitats Directive area and the potential importance of this zone for birds of the Birds Directive area, this is an important conclusion.

For Tihange, it follows from the analysis that the effects of the project on the aquatic environment are not such that they would hypothecate the conservation strategies for the related ecosystems, taking into account the measures that were taken by the operator of the facility, whether under the provisions of its environmental permit or not (discharge control, disposal system, etc.). Given that the Meuse near the Tihange power plant does not have a high ecological value (mainly ubiquitous species) and that only one reactor of the three is destined to remain in operation for the next few years, no negative evolution of the aquatic environment is expected.

Disturbance to fauna attributable to human presence (noise, lighting, etc.) is not considered significant for Tihange 3, as the plant is located in an already highly urbanised region and the operator has taken measures to reduce the acoustic effects of the plant. Measures have also been taken at the site to enhance local biodiversity.

The contribution of the lifetime operation of Tihange 3 to acid depositions will not be significant. As in the case of Doel 4, a positive impact can even be assumed, as the electricity that will be produced by the reactor will not have to be generated by CCGT plants, which emit significantly more flue gases responsible for acidification and nitrogen deposition.

Taking all the above elements into account, it can be argued that the lifetime operation of Tihange 3 is not incompatible with the conservation objectives set out in Walloon legislation.

The operation of KC Doel and CN Tihange may also have an impact on air quality. The main sources with a potential impact are steam boilers and diesel engines, which, however, only have a limited number of operating hours each year. As more combustion plants are taken out of service upon closure of the other reactors at both sites, their impact will further decrease.

The impact calculations for KC Doel show that the impact on ambient air quality is negligible (less than 1% of the limit or test values used). There is therefore no need for mitigation measures.

If the lifetime of Doel 4 and Tihange 3 are not extended, electricity will have to be generated instead using (partly) fossil fuels. The emissions generated in this process (which can be considered 'avoided' in the case of lifetime extension of Doel 4 and Tihange 3) are much higher than those generated in the operation of Doel 4 and Tihange 3, and the impact on air quality will therefore be greater.

GHG emissions attributable to the operation of Doel 4 and Tihange 3 add up to about 31 ktonnes (cumulative) over the lifetime extension period. The avoided greenhouse gas emissions from keeping Doel 4 and Tihange 3 open longer are of a different order. Over the entire period, delaying the deactivation of both reactors results in avoiding emissions of about 24,830 ktonnes CO_2eq. This is equivalent to an annual saving equivalent to almost 20% of emissions in the "production of electricity and heat" sector in Belgium in the year 2021 (12.8 Mton). If we compare with the emissions released from the operation of Doel 4 and Tihange 3 over the same period (together 31 ktonnes), we can see that the emissions from both reactors over the period covered by the lifetime grant together account for only about 0.12% of the emissions avoided over the same period.

Neither Doel 4 nor Tihange 3 have an impact on the resilience of their environments to the effects of climate change during the reference period. Within the time perspective of lifetime extension, both sites are also not vulnerable to climate change impacts, and this situation is independent of whether the lifetime of Doel 4 and Tihange 3 is extended or not.

The project has no meaningful health impacts. Legionella has never posed a problem in the past as a result of the measures taken and, in the case of Doel, also of the specific conditions (brackish feedwater), and there is no reason to believe that this would be different during the lifetime extension period. Regarding risk perception in relation to nuclear accidents, it can be stated that such risk perception does exist, but there is no demonstrable link to psychosomatic effects. Finally, it can be confirmed that the lifetime extension of Doel 4 and Tihange 3 significantly reduces the chances of a blackout (especially in the first years of the lifetime extension), thus having a positive effect on the avoidance of the health and safety effects that can be associated with power outages. Finally, it can be indicated that in terms of external safety, no meaningful increase in risk is expected as a result of the lifetime grant.

10.2 Radiological impacts

10.2.1 Impact on people and the environment in normal operation

Exposure to ionising radiation in normal operation and the associated impact on humans and the environment results, on the one hand, from direct radiation from the sites and the radioactive gaseous and liquid discharges. The dose due to direct radiation exposure at the boundary with and outside the sites is very small and undetectable. It is indistinguishable from natural variations in background radiation. External radiation also decreases sharply with distance (inverse square law).

If Doel 4 and Tihange 3 are extended for another 10 years beyond 2025, liquid and gaseous discharges under normal operation will be of the same level as those resulting from the operation of Doel 4 and Tihange 3 currently and in recent years. Gaseous and liquid discharges are a fraction of the discharge limits established in the operation licences of KC Doel and CN Tihange, and the dose is mainly determined by the gaseous discharges of carbon 14 (C-14). This radionuclide, also naturally occurring, is produced during reactor operation by the neutrons released during nuclear fission.

The effective dose resulting from the Project (the extension of Doel 4 and Tihange 3 for a 10-year period) due to the gaseous and liquid discharges is estimated to be 0.010 mSv/year for the most exposed person (critical individual) and this for the 10-year period of continued operation. This is a trivial dose, well below the legal limit of 1 mSv/year. The exposure in Belgium to natural radiation is 2.4 mSv. An effective dose of 0.010 mSv/year corresponds to the extra dose you would receive from cosmic radiation during a 2-week holiday in the mountains. Moreover, this dose is a very conservative estimate (critical individual: most sensitive age group, at location of maximum exposure, food from location with highest concentrations of radionuclides ...).

Given the final shutdown, according to the current calendar, of the other reactors at both sites, exposure due to activities at the KC Doel and CN Tihange sites is expected to decrease after 2025, even with the extension of Doel 4 and Tihange 3, compared to the situation in recent years. The typical effective dose for the critical individual of gaseous and liquid discharges was estimated to be around 0.02 mSv/year for KC Doel and 0.03-0.05 mSv/year for CN Tihange in recent years depending on period considered and assumptions. After 2025, and with the extension of Doel 4 and Tihange 3, the effective dose will decrease from 0.017-0.013 mSv/year for the entire KC Doel site and from 0.020 to 0.015 mSv/year for CN Tihange during the considered period of the Project. This decrease is due to the fact that a decrease as a function of time is expected in discharges after the shutdown of Doel 1, 2 and 3 for KC Doel and Tihange 1 and 2 for CN Tihange. The impact on the environment is also negligible and will continue to decrease for the entire KC Doel and CN Tihange sites, even if Doel 4 and Tihange 3 are extended. The monitoring of the gaseous and liquid discharges and the monitoring of the environment in the framework of the radiological surveillance programme and a specific programme carried out by the operator will continuously monitor the impact on humans and the environment. Given that doses and impacts on humans and the environment at the site boundary are trivial, there are also no transboundary effects under normal operation.

Finally, we would like to note that during the period of the Project, the decommissioning of one or more of the other reactors may be started. This could possibly have an impact on the radiological situation, but is not the subject of this environmental impact assessment. A separate environmental impact assessment is required for this.

10.2.2 Impact on people and the environment in the event of an accident

Two design-basis accidents were studied for the Doel 4 and Tihange 3 reactors, namely the Loss Of Coolant Accident (LOCA) and the Fuel Handling Accident (FHA). These accidents can be considered overarching for this type of accident. In addition, one beyond-design basis accident, a Complete Station Blackout (CSBO) with core melt, was considered (which in turn may be considered representative of this type of accidents). The effects of the two design-basis accidents fall within the limits of the general data under Article 37 of the Euratom Treaty. However, assessments under the FANC-AFCN/Bel-V guidelines for new Class 1 installations were also used for the impact assessment. The results of this analysis also fall within the limits of the general data under Article 37 of the Euratom Treaty. Strictly speaking, the latter assessment is not applicable here as Doel 4 and Tihange 3 are already existing Class 1 installations. However, it is the unique analysis that was used to assess the impacts for the CSBO accident, and this analysis provides insight into a wider range of impacts that may be associated with an accident, such as contamination levels, for the design-basis accidents (LOCA and FHA).

Despite the fact that Doel 4 and Tihange 3 reactors are of the same type and power, a difference can be observed in the effects for the same accident scenario. This is due to the exact design (reactor building volume, leakage rate to the outside, ...) and safety systems in terms of the amounts of radioactivity discharged to the environment, but also to the height of the discharge (chimney height) for the accidents at both sites. It should further be noted that conservative estimates are made, both towards the discharged quantities of radioactivity in the accidents (under the scenarios considered) and the impact calculation. This means that in a real accident following the considered scenarios (including the operation of the safety systems), the impacts will always, or almost always, be smaller.

For Tihange 3, for the 3 accidents considered (LOCA, FHA and CSBO), according to the guidelines for new Class 1 installations, there are no exceedances of the effective dose and equivalent thyroid dose during the accident with respect to the specific reference levels for immediate, urgent protective measures such as sheltering, evacuation or intake of stable iodine (ingestion of contaminated food is not included, as it can be easily avoided). The effective dose is highest for the beyond design-basis accident (CSBO) and amounts to 4.29 mSv over the duration of the accident (5 mSv in 24h is the reference level for sheltering[4]). This dose is comparable to the dose an average Belgian receives per year from both natural radiation and that from medical diagnostic applications. The thyroid dose was limited in this accident because of the Containment Filter Venting System (CFVS), which according to the operating licence must be used in such an accident. This system filters the iodine and aerosols present (including the long-lived Cs-137) to a significant extent and, consequently, the effective dose is largely due to the radiation from the radioactive noble gases in the overriding cloud.

Of the accidents considered, the FHA accident gives the highest thyroid dose (4.95 mSv for Tihange for the age group 1-2 years old). It results from the discharge of iodine isotopes. In this accident and in the LOCA accident, there is a possibility that the food chain will be contaminated, with the radioactive iodine and countermeasures will be necessary. Given the limited half-life of iodine isotopes, contamination will be limited in time. Contamination with long-lived radionuclides such as Cs-137 is very limited (LOCA only) and therefore no impact on the food chain is expected for this in the accident scenarios. The lifetime effective dose (over 50 years for adults and up to 70 years for other age groups) due to the accidents is limited and well below 1 Sv. The cross-border impact of all considered accidents for Tihange 3 is very limited due to its distance from neighbouring countries. Doses are limited and radioactive iodine contamination is possible, but will be conservatively estimated at the edge for countermeasures to be taken.

For the considered Doel 4 accidents, equivalent to Tihange 3, according to the analysis of the new Class 1 plants, the effective dose is the highest for the CSBO accident. It amounts to 8.89 mSv, which thus exceeds the reference level for sheltering (5 mSv in 24 h) but is still significantly lower compared to the reference level for evacuation (50 mSv in 1 week). Equivalent thyroid doses are similar for the LOCA and FHA accident for Doel 4 and amount to

[4] Reference levels should not be considered as limits. In a real situation, sheltering would perhaps be recommended, partly because of the uncertainty that exists in any accident situation but also because exposure limitation (dose optimisation) can be weighed against the adverse effects of sheltering under the precautionary principle.

around 35 mSv (age group 1-2 years old). These values are higher than the reference level for stable iodine intake for children and pregnant women (10 mSv equivalent thyroid dose). Also for the considered design-basis accidents for Doel 4, based on the conservative estimates of iodine isotope deposition, the derived food chain values will be exceeded and consequently food chain countermeasures may be necessary (typically milk, leafy vegetables and meat). Also for the CSBO accident scenario for Doel 4, it cannot be ruled out that the derived level for the soil concentration of 4000 Bq/m^2 is exceeded and therefore food chain countermeasures are necessary. However, in this accident, the deposition of iodine is smaller than in the design-basis accidents (LOCA and FHA). For all accident scenarios, due to the limited half-life of the main iodine isotopes, this will again be limited in time (half-life of 8.02 days for I-131). Contamination with long-lived radionuclides such as Cs-137 will be very limited and will not require countermeasures in the scenarios considered. Consequently, one year after the accident, no countermeasures are to be expected. In addition, the lifetime effective doses are also much lower than 1 Sv for the Doel 4 accident scenarios.

The cross-border impact of the accidents remains limited, for all considered accident scenarios for both Doel 4 and Tihange 3 no direct countermeasures such as sheltering, evacuation or the intake of stable iodine for thyroid protection are necessary in neighbouring countries. Mainly in the Netherlands, given the proximity of Doel 4, contamination of the food chain with iodine isotopes where countermeasures may be required is possible. In the other neighbouring countries, this is very unlikely for both Doel 4 and Tihange 3, but also not entirely excluded for some countries. However, contamination with iodine isotopes is short-lived, given the limited half-life. Contamination with long-lived radionuclides such as Cs-137 is very limited and does not require countermeasures. The lifetime dose due to the considered accident scenarios is therefore very limited in all neighbouring countries.

For the impact on fauna and flora, based on the amounts discharged and the associated depositions in the different accident scenarios, a very moderate to negligible impact can be expected for Doel 4 and a negligible impact for Tihange 3. Again, these are conservative estimates.

Given that after 2025, according to the current calendar, Doel 4 and Tihange 3 are both the only reactors at the respective KC Doel and CN Tihange sites operated for electricity generation, the likelihood at both sites decreases for a severe accident. After the final shutdown of the other reactors, the radioactivity drops rapidly, an accident remains possible (due to e.g. the loss of cooling), but the potential radioactive discharges and thus the potential impact will decrease rapidly as a function of time. The impact of possible multi-unit events at both sites (accidents involving more installations, as in the Fukushima Dai-ichi accident) will therefore also be smaller after 2025. The probability of a simultaneous accident with Doel 4 and Tihange 3 is even lower than multi-unit events at the same site, given the physical distance between the sites of both reactors.

10.2.3 Impact on the generation of radioactive waste and spent fuel

In Belgium, ONDRAF/NIRAS (the National Agency for Radioactive Waste and Enriched Fissile Materials) classifies radioactive waste into three categories. Category A refers to the low- and intermediate-level short-lived waste, Category B groups low- and intermediate-level long-lived waste and Category C contains the high-level long-lived radioactive waste mainly arising from spent fuel.

A 10-year extension of the operation of the Doel 4 and Tihange 3 units will give rise to an additional amount of low- and intermediate-level waste, estimated at a total of 864 m^3 based on long-term averages. This is mainly category A waste, with only a limited amount of category B waste, which may include certain resins and filters. Compared to the ~50,000 m^3 of category A waste currently included as a source term in the surface disposal safety file, this represents a marginal increase (~1.7%).

Assuming that the quantity of category B waste is negligible, the additional volume of waste corresponds to about 2,161 400-litre drums that will be packaged in 540 disposal units (monoliths) destined for surface disposal in the facility planned for that purpose at Dessel, for which the licensing procedure is ongoing. The (volumetric) capacity of the disposal amounts to 34 modules, with a large reserve of 20% or 5.4 modules, to take into account uncertainties about future production of category A waste. The additional waste that would be produced by the 10-year extension of Doel 4 and Tihange 3 will occupy 0.6 modules of this. As this is the extension of an existing activity, resulting in waste families with known characteristics, no further effects are expected for both short- and long-term waste management.

The cumulative number of fuel elements that will be consumed during an additional 10-year period at Doel 4 and Tihange 3 was also estimated. For both units combined, the extension will result in an additional consumption of about 810 fuel elements (type UOX 14ft). Weighted against the entire Belgian reactor park, this corresponds to a surplus of 7.3% in number of fuel bundles, or 8.9% in tonne Heavy Metal (tHM).

Given this relatively limited quantity and assuming they will be similar in properties to the existing fuel assemblies, no effects on their continued management are expected. The postponement of deactivation of Doel 4 and Tihange 3 will spread the disconnection from the grid of units at both sites where this would otherwise be very condensed over several years. With SF2 facilities under construction and licensed at Doel and Tihange, there will be sufficient capacity for storage at the sites, pending a decision regarding long-term management.

During decommissioning operations, large quantities of material streams are generated, most of which can be released and recycled. However, the heart of the plant, i.e. the reactor vessel and internal parts, can be considered radioactive waste. Waste classification (category A or B) is based on the radioactivity concentration of safety-relevant radionuclides and therefore depends on neutron flux during reactor operation and irradiation duration. Activation calculations of the different tub sample components showed that the overall activity hardly increases, and that the small fraction of long-lived isotopes (which are important for long-term management) will increase by about 25%, proportional to the duration of the 10-year operation extension. This limited activity increase due to the extension is expected to have little or no impact on the delineation of the transition zone between category A and category B waste. Therefore, no significant shifts in volumes of waste are expected.

11 Cross-border impacts

11.1 Doel 4

Most of the non-radiological effects attributable to the lifetime operation of Doel 4 are confined to the immediate vicinity of the nuclear power plant and are limited in magnitude; thus, they do not give rise to transboundary effects. Only for the Water theme could there be (limited) transboundary effects. Based on monitoring the temperature of the Scheldt near the Dutch border (at a distance of about 3.4 km from the discharge point), the impact of the cooling water discharge can at most be considered as limited negative, meaning that the temperature increase due to the discharge will be less than 1°C. This temperature increase will continue to decrease downstream on Dutch territory.

If the lifetime of Doel 4 is not extended, other means of production will obviously have to be used to replace the lost production capacity. Cross-border effects cannot be excluded a priori in such a case. However, the importance and nature of those cross-border effects will depend strongly on the sites where the (theoretical) replacement capacity is envisaged, on the technical characteristics of those plants and on their licensing characteristics.

As seen, the gaseous and liquid radiological discharges from the operation of all KC Doel units have a negligible and unobservable impact (order 0.02 mSv/year) for the hypothetical most exposed person located just outside the KC Doel site. The dose that could come from direct radiation from the site remains within the ranges of natural variations. Bearing in mind that the impact can only decrease with distance (dilution for discharges and inverse square law for any direct radiation), it can be said that under normal operation of KC Doel, and thus also in the case of extending the lifetime of Doel 4, no transboundary effects on humans and the environment are to be expected.

Calculations of the cross-border radiological impact of various accident scenarios show that the doses in the Netherlands, as well as other neighbouring countries, fall below typical guideline values for direct countermeasures (such as sheltering or taking iodine tablets). Food chain countermeasures may be necessary in the Netherlands for iodine isotopes, similar given the proximity, to those in Belgium. In the other neighbouring countries, depositions where countermeasures for the food chain are necessary are very unlikely but in very unfavourable meteorological conditions also cannot be completely ruled out for the LOCA accident. However, if there is an impact on the food chain, including in the Netherlands, it will be short in duration (no significant deposition of long-lived radionuclides such as Cs-137). Consequently, the radiological impact in neighbouring countries will be limited.

11.2 Tihange 3

CN Tihange is located at shortest distances of 38 km and 58 km from the Dutch and German borders, respectively.

Most non-radiological effects resulting from the postponement of the deactivation of Tihange 3 are limited to the immediate vicinity of the nuclear power plant. They are of limited magnitude and therefore do not lead to cross-border effects.

Only the release of cooling water, which affects the temperature of the Meuse, could have effects over a longer distance. However, given the temperature data of the Meuse at the last monitoring station for the Netherlands, the impact of the cooling water release can be considered negligible (fewer exceedances of 25°C and no exceedances of 28°C per day on average in the last 3 years).

It should be noted that several transboundary impacts in the baseline cannot be excluded if deactivation is not postponed. The significance and nature of these transboundary effects will depend to a large extent on the sites where (theoretical) replacement capacity is planned, the technical characteristics of these plants and their licensing characteristics.

As seen, the gaseous and liquid radiological discharges from the operation of all units of CN Tihange have a negligible and unobservable impact (order 0.044 mSv/year) for the hypothetical most exposed person located just outside the CN Tihange site. The dose that could come from direct radiation from the site remains within the ranges of natural variations. Bearing in mind that the impact can only decrease with distance (dilution for discharges and inverse square law for any direct radiation), it can be said that under normal operation of CN Tihange, and thus also in the case of extending the lifetime of Tihange 3, no transboundary effects on humans and the environment are to be expected.

The doses calculated for the considered accidents for Tihange 3 for neighbouring countries are such that no immediate countermeasures such as sheltering or administration of stable iodine are required. The need for very limited and short-term measures related to the food chain cannot be completely ruled out. The deposition of long-lived radionuclides is very limited and thus the radiological impact of these accidents also remains limited.

12 Mitigating measures

Given the (very) limited non-radiological effects of the project, mitigation measures are not an issue. However, some recommendations can be formulated for the Water theme.

For the Doel site, these include the following:

1. Preventing drainage of groundwater and cooling water to the mixed sewerage system and disconnecting rainwater (e.g. in new projects or maintenance works) resulting in dilution of wastewater and frequent overflows;
2. Continued optimisation of wastewater treatment is recommended to permanently solve former bottlenecks (nitrite, AOX); more consistent measurement of a number of other parameters to check compliance with discharge standards;
3. Future conversions and renovations should be sufficiently flood- and climate-robust to cope with the consequences of more intense rainfall in the future and not pass on water nuisance to the surrounding area;
4. The shutdown of Doel 3 (2022) and Doel 1 and 2 (2025) can be used as an opportunity to optimise water treatment and (rain) water management for Doel 4.

The following recommendations apply to both Doel and Tihange:

1. Disconnect rainwater from sanitary wastewater and reuse rainwater as sanitary water, avoid urban water use to the maximum;
2. Softening (infiltration), constructing green roofs or water features (buffering) on the site to reduce the heat island effect, retain and store (rain) water more locally and prevent desiccation;
3. Anticipatory fine-tuning of cooling capacity based on monitoring the temperature of the Zeeschelde and Maas rivers

Regarding radiological effects, reference can be made to emergency planning, which aims to deal with the consequences of any accidental effects. Radiological effects in normal operation are trivial, and so no mitigation measures are required for this. Monitoring of carbon-14 discharges to the atmosphere can be recommended.

13 Knowledge gaps

13.1 Non-radiological impacts

Knowledge gaps in terms of non-radiological impacts are limited. For the Water theme, there is a gap in the understanding of the exact proportion of wastewater from Doel 4 and Tihange 3, and thus of the exact contribution of the operation of Doel 4 and Tihange 3, respectively, to the residual pollution released into the Scheldt and Meuse.

For the Air theme, the main knowledge gap is in the area of emissions from the incinerators, as no measured values or model characteristics are known for all installations. By using emission factors from the literature and assumptions, these gaps were filled. This leads to an increased uncertainty regarding the results of the impact calculations, but even when this is taken into account, it can be said that the impact is negligible.

Finally, there is the uncertainty regarding how any lost capacity of Doel 4 and Tihange 3 (if the project is not implemented) would be filled in. This means that the effects on air quality and nitrogen deposition, among other things, cannot be estimated precisely in the reference situation.

For Tihange, it is proposed to verify the Seveso status of the site after the shutdown of Tihange 1 and 2. Even if, in such a case, the plant would no longer be classified as a Seveso facility, attention should be paid to accident prevention to control potential safety risks to the population.

13.2 Radiological impacts

When calculating the radiological impact of discharges, several uncertainties may play a role, such as the amount and characteristics of the radionuclides discharged (the so-called source term), meteorological conditions, location and age of individuals and local living habits (e.g. diet). For calculations of impacts under normal operation, discharges are well known and meteorological conditions are considered for a full (reference) year. Furthermore, the most exposed person is considered with very conservative living habits regarding radiological impact. This leads to a conservative estimate of radiological impact. Accident scenarios also make conservative assumptions, but the real exposure during an accident depends on the exact amounts of radionuclides discharged, the exact meteorological conditions (e.g. local showers) and the location and habits of people. This could possibly be supplemented in an accident by countermeasures such as sheltering, taking stable iodine and evacuation. Notwithstanding the uncertainties described above, in case of normal operation the doses to which people are exposed are very low (much smaller than 1 mSv/year) but even in accident situations, in most cases for all or most of the exposed population the dose incurred will be limited. Doses are therefore well below these for the occurrence of deterministic effects (deterministic effects must be avoided at all times, even in accident situations), but also almost always well below effective doses where epidemiological studies can show stochastic effects of radiation (occurrence of cancer and genetic effects). This is because the probability of the occurrence of these effects is very low at such low doses, and this on top of a high spontaneous occurrence of the same effects. Although, based on the precautionary principle, we link the possibility of the occurrence of stochastic effects to every additional exposure (dose), however low, it is not possible to confirm this occurrence with certainty, we only know with certainty that the probability of this occurrence is very small or even non-existent (<0.57% at 100 mSv effective dose).

14 General conclusion

The postponement of the deactivation of Doel 4 and Tihange 3 may give rise to the perpetuation, over a 10-year period, of a number of environmental impacts. The environmental impact assessment assessed for the receptor groups "humans" and "biodiversity" whether these (radiological and non-radiological) effects could be considered significant. An impact analysis was also carried out for a number of other topics for which there are policy objectives that may be affected by the project, or which determine the impact on humans and biodiversity. Furthermore, the 'avoided impacts' of the project, in terms of greenhouse gas and nitrogen oxide emissions, and their knock-on effects within the health and climate themes, were also studied. The (avoided) health effects attributable to the (avoided) supply uncertainty were also addressed.

The analysis shows that the effects on the water system are not such as to affect the ecological status of the Zeeschelde or the Meuse, or that they would hypothecate the achievement of the good ecological potential of these water bodies. In both cases, the contribution of the discharges to the quality of the water bodies is negligible. For Doel, there is only an effect on water quality in the zone within the breakwater; there is no impact on the objectives of the Zeeschelde IV water body. For the Doel site, the environmental impact assessment does call for attention to the resolution of problems specific to the current operation, such as frequent overflow events and the state of the sewage system. For the Water theme, there may also be (limited) transboundary effects for the Doel site. Based on monitoring of the temperature of the Scheldt near the Dutch border (at a distance of about 3.4 km from the discharge point), the impact of the discharge of the cooling water can at most be considered as limited negative, meaning that the temperature increase due to the discharge will be less than 1°C. This temperature increase will further slowly decrease downstream on Dutch territory.

From the biodiversity theme, for the site Doel effects of the project were studied in terms of surface water quality, barrier effect, mortality, disturbance, direct land take, and eutrophication and acidification. For barrier effect and direct land take, it was found that no effects are to be expected. For mortality, there might be a (limited) effect because of the intake of cooling water. In terms of disturbance, only noise disturbance is potentially relevant, but no significant impact on nearby species is expected. Also for Tihange, it can be concluded that disturbance to fauna due to noise and lighting is not significant, as the plant is located in an already highly urbanised region, and the operator has also taken measures to reduce the acoustic effects of the plant.

The negative effects of the operation of Doel 4 and Tihange 3 in terms of acidifying and eutrophying depositions are negligible. In terms of nitrogen depositions, rather positive effects can even be expected due to the 'avoided emissions' associated with 10 years of additional nuclear production. After all, the electricity that will be produced by both reactors will not have to be produced by CCGT plants, which would give rise to significantly more acidification and nitrogen deposition.

The discharge of cooling water, sanitary water and industrial water does not lead to ecological effects at the level of the Scheldt, nor locally. Given the designation of the Scheldt as a Habitats Directive area and the potential importance of this zone for the birds of the nearby Birds Directive area, this is an important conclusion. Also for Tihange, the analysis shows that the effects of the project on the aquatic environment are not such that they would hypothecate the conservation objectives for the related ecosystems, taking into account the measures taken by the operator of the facility.

The project causes no avoidable and irreparable damage to nature, and has no significant impact on the conservation status of habitats and species in special protection areas in the vicinity of the Doel and Tihange sites.

The effect of avoided emissions on the conservation objectives of Natura 2000 sites elsewhere in Belgium is likely to be positive, but its significance is difficult to estimate.

The measured radiation levels in the vicinity of Doel and Tihange remain well below the thresholds for adverse effects on fauna and flora. The calculated dose rate for discharges to air and water is also well below that threshold. It can therefore be concluded that the current discharge limits for the considered Belgian nuclear power plants do not lead to harmful effects on fauna and flora, which is also confirmed by the measurement results of the monitoring programme of FANC-AFCN and the operator. If only Doel 4 and Tihange 3 respectively are still in operation, the radiological impact on natural values will obviously be even smaller. It is thus clear that the radiological effects of keeping both plants open longer will not negatively affect the conservation objectives for the respective SPAs.

As far as the consequences in the event of an accident are concerned, for the different accident scenarios studied (and under conservative assumptions), it can be said on the basis of the quantities discharged and the associated depositions that the impact on fauna and flora has a very moderate to negligible effect in the vicinity of Doel 4, and a negligible effect in the vicinity of Tihange 3.

The operation of Doel 4 and Tihange 3 may also have an impact on air quality. The main sources with a potential impact are steam boilers and diesel engines, which, however, have limited annual operating hours. As more combustion plants are taken out of service upon closure of the other reactors at both sites, their impact will further decrease. The impact calculations for KC Doel show that the impact on ambient air quality is negligible (less than 1% of the limit or test values used).

If the lifetime of Doel 4 and Tihange 3 are not extended, electricity will have to be generated instead using (partly) fossil fuels. The emissions generated in this process (which can be considered 'avoided' in the case of lifetime extension of Doel 4 and Tihange 3) are much higher than the emissions from operation of Doel 4 and Tihange 3, and the impact on air quality will therefore be greater.

The GHG emissions attributable to the operation of Doel 4 and Tihange 3 over the lifetime grant period are only a fraction of the avoided GHG emissions over the same period. The annual avoided emissions from keeping Doel 4 and Tihange 3 open longer are equivalent to almost 20% of emissions in the "production of electricity and heat" sector in Belgium in the year 2021 (12.8 Mtonnes).

Neither Doel 4 nor Tihange 3 have an impact on the resilience of their environment to the effects of climate change during the reference period. Within the time perspective of lifetime extension, both sites are also not vulnerable to climate change impacts, and this situation is independent of whether the lifetime of Doel 4 and Tihange 3 is extended or not.

In terms of health, a (modest) positive impact can be expected as a result of avoiding an amount of NOx emissions over the period that Doel 4 and Tihange 3 remain open longer. No demonstrable link was found between risk perception regarding potential nuclear accidents and the occurrence of psychosomatic effects in the population. The lifetime extension of Doel 4 and Tihange 3 significantly reduces the chances of a blackout, with thus a positive impact on avoiding the health and safety effects that can be associated with power outages. In terms of external safety, no meaningful increase in risk is expected as a result of the lifetime extension.

The effective dose due to the gaseous and liquid discharges associated with the lifetime extension of Doel 4 and Tihange 3 is estimated at 0.010 mSv/year for the most exposed person (critical individual) and this for the 10-year period of continued operation. This is a trivial dose, well below the legal limit of 1 mSv/year. Moreover, this dose is a very conservative estimate. Given the final shutdown, according to the current calendar, of the other reactors at both sites, exposure due to operations at the KC Doel and CN Tihange sites is expected to decrease after 2025, even with the extension of Doel 4 and Tihange 3, compared to the situation in recent years. The typical effective dose for the critical individual of gaseous and liquid discharges was estimated to be around 0.02 mSv/year for KC Doel and 0.03-0.05 mSv/year for CN Tihange for recent years and for the entire site, depending on considered period and assumptions. After 2025, and with the extension of Doel 4 and Tihange 3, the effective dose will decrease to 0.017-0.013 mSv/year for the entire KC Doel site and to 0.020-0.015 mSv/year for CN Tihange during the considered period of the project.

It can be concluded that the lifetime extension of Doel 4 and Tihange 3 will not cause any negative health effects in normal operation, either due to radiological effects or non-radiological effects. On the contrary, the effects in terms of avoided emissions of nitrogen oxides and of reduced likelihood of power outages may give rise to positive health effects.

The environmental impact assessment also studied the effects of the project on the dose that would result from two design-basis accidents and from a beyond design-basis accident. An analysis based on the Doel 4 safety file shows that the effective doses and equivalent thyroid doses resulting from both design-basis accidents for Doel 4 are within the set limits. If the analysis is done based on the FANC guidelines for new class 1 plants, the criterion for equivalent thyroid doses is exceeded though, meaning that taking stable iodine to protect the thyroid would be recommended in such a case. In a design-basis accident, the effective dose is found to be of the same order as that of both design-basis accidents, but the equivalent thyroid dose is lower. In all three accident scenarios, contamination of the food chain could also occur, with typically exceedances of activity levels in milk, leafy vegetables and meat, with radioactive iodine isotopes. Given the relatively short half-life of these isotopes (8.02 days for I-131), this contamination would be limited in time.

Analysis based on the Tihange 3 safety file shows that the effective doses and equivalent thyroid doses resulting from both design-basis accidents for Tihange 3 are within the set limits. This is also true if the analysis is done on the basis of FANC guidelines for new class 1 installations In a beyond design-basis accident, the effective dose is found to be of the same order as that of both design-basis accidents, but the equivalent thyroid dose is lower.

Thus, the project poses a limited risk related to accident (both design-base and beyond design-basis accident). However, for the whole CN Tihange site, the risk will decrease, as during the 10-year life extension period only Tihange 3 will still be operated on the site.

The cross-border impact of the accidents remains limited, for all considered accident scenarios for both Doel 4 and Tihange 3 no direct countermeasures such as sheltering, evacuation or the intake of stable iodine to protect the thyroid gland are necessary in neighbouring countries. Mainly in the Netherlands, given the proximity of Doel 4, contamination of the food chain with iodine isotopes where countermeasures may be required is possible. In the other neighbouring countries, this is very unlikely for both Doel 4 and Tihange 3, but also not entirely excluded for some countries. However, contamination with iodine isotopes is short-lived, given the limited half-life. Contamination with long-lived radionuclides such as Cs-137 is very limited and does not require countermeasures. The lifetime dose due to the considered accident scenarios is therefore very limited in all neighbouring countries.

Given that after 2025, according to the current calendar, Doel 4 and Tihange 3 will be the only reactor at the respective KC Doel and CN Tihange sites operated for electricity generation, the probability for a severe accident at both sites decreases.

An extension of the operation of Doel 4 and Tihange 3 units will give rise to the generation of an additional quantity of low- and medium-level radioactive waste, estimated at a total of 864 m3 based on long-term averages for the current projected 10-year LTO period. This is mainly category A waste, with only a limited amount of category B waste. Compared to the ~50,000 m3 of category A waste currently included as a source term in the surface disposal safety file, this represents a marginal increase (~1.7%).

Assuming that the quantity of category B waste is negligible, the additional volume of waste corresponds to about 2,161 400-litre drums that will be packaged in 540 disposal units (monoliths) destined for surface disposal at the facility planned for that purpose at Dessel. The (volumetric) capacity of the disposal will be 34 modules, with a large reserve of 20% or 5.4 modules, to take into account uncertainties surrounding future production of category A waste. The additional waste that would be produced by the LTO of Doel 4 and Tihange 3 will occupy 0.6 modules of this. As this is the extension of an existing activity, resulting in waste families with known characteristics, no further effects are expected for both short- and long-term waste management.

The cumulative number of fuel elements that will be consumed during a 10-year LTO period at Doel 4 and Tihange 3 was also estimated. For both units combined, the LTO will result in an additional consumption of about 810 fuel elements (type UOX 14ft). Weighted against the entire Belgian reactor park, this corresponds to a surplus of 7.3% in number of fuel bundles, or 8.9% in tonne Heavy Metal (tHM).

Given this relatively limited quantity and assuming they will be similar in properties to the existing fuel assemblies, no effects on their continued management are expected. The postponement of deactivation of Doel 4 and Tihange 3 will spread the disconnection from the grid of units at both sites where this would otherwise be very condensed over several years. With SF^2 (Spent Fuel Storage Facility) installations under construction and licensed at Doel and Tihange, there will be sufficient capacity for storage at the sites, pending a decision regarding long-term management.