Part IV. Synthesis and overall decision Environmental impact assessment deferral deactivation Doel 4 and Tihange 3

1 Synthesis of project impacts

1.1 Assessment of conventional effects

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 that continued attention is paid to monitoring and timely adjustment. Nor does the project jeopardize the achievement of the good ecological potential of both water bodies.

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 may be a (limited) effect because of the intake of cooling water. For disturbance, only changes are to be expected with respect to noise disturbance. The importance of this is rather limited since during the lifetime extension period the disturbance will only come from Doel 4. Moreover, this is an existing noise that is continuous and predictable; a significant impact on the surrounding species is therefore 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, positive effects in terms of nitrogen depositions 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 causes a deterioration of the water quality, which in Doel, however, is limited to the zone within the breakwater. Significant 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 possible importance of this zone for the 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 relativized ecosystems, taking into account the measures taken by the operator of the facility, whether or not under the provisions of its environmental permit (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, as the facility is located in an already highly urbanized region and the operator has also taken measures to reduce the acoustic effects of the facility. Measures have also been taken on the site to enhance local biodiversity.

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

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

The operation of KC Doel and CN Tihange may also have an impact on air quality. The main sources of potential impact are steam boilers and diesel engines, which, however, have limited hours of operation annually. As more combustion plants are taken out of service with the closure of the other reactors at both sites, their impact will continue to 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). Therefore, there is 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 (in part) 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 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 kton (cumulative) over the period of the lifetime extension. 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 $_{CO2eq}$. 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 kton), we can see that the emissions from both reactors over the period covered by the lifetime extension together represent only about 0.12% of the emissions avoided over the same period.

Neither Doel 4 nor Tihange 3 affect the resilience of their environments to the effects of climate change during the reference period. Within the time perspective of lifetime extension, neither site is vulnerable to climate change impacts either, and this situation is independent of whether or not the lifetime of Doel 4 and Tihange 3 is extended.

The project has no significant health impact. 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 period of life extension. As for risk perception regarding 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 extension.

1.2 Radiological assessment

1.2.1 Impact on people and environment under normal operation

Exposure to ionizing 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 further 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 operating licenses 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 period of 10 years) due to the gaseous and liquid discharges 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 (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 for recent years around 0.02 mSv/year for KC Doel and 0.03-0.05 mSv/year for CN Tihange depending on considered period 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 whole site of KC Doel 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 with the extension of Doel 4 and Tihange 3. The monitoring of the gaseous and liquid discharges and the monitoring of the environment in the framework of the surveillance program and a specific program carried out by the operator will continuously monitor the impact on humans and the environment. Since doses and impacts on humans and the environment at site boundaries are trivial, there are also no transboundary impacts during normal operation.

Finally, we wish to note that during the period of the Project, decommissioning of one or more of the other reactors may begin. This could possibly have an impact on the radiological condition, but is not the subject of this environmental impact assessment. This will require a separate environmental impact assessment.

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

Two design basis accidents, namely the Loss Of Coolant Accident (LOCA) and the Fuel Handling Accident (FHA) which can be considered to be overarching for this type of accidents and one expansion design accident, a Complete Station Blackout (CSBO) with core melt which in turn can be considered to be representative for this, were studied for both reactors Doel 4 and Tihange 3. 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 evaluation 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 also provides insight for the design basis accidents (LOCA and FHA) into a wider range of impacts that may be associated with an accident, such as soil contamination.

Despite Doel 4 and Tihange 3 reactors being of the same type and power, a difference can be observed in the effects for the same accident scenario. This is due to the precise design (reactor building volume, leak rate to the outside, etc.) 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 be further noted that conservative estimates are made, both to the discharged amounts of radioactivity to the accidents (under the considered scenarios) and the calculation of the impact. That is, in a real accident that proceeds according to the scenarios considered (including the operation of the safety systems), the impacts will always, or almost always, be smaller.

For Tihange 3, for the 3 accidents considered, 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 stable iodine intake (ingestion of contaminated food is not included, as it can be easily avoided). The effective dose is largest for the design expansion accident (CSBO) and amounts to 4.29 mSv over the duration of the accident (5 mSv in 24h is the reference level for sheltering[141]). 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 permit 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 overlying 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). This is due to the discharge of iodine isotopes. In this accident and also 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 the 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 transboundary impact of all considered accidents for Tihange 3 is very limited due to the distance from neighboring 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 installations, the effective dose is highest for the CSBO accident and amounts to 8.89 mSv, which is thus an excess of the reference level for sheltering (5 mSv in 24 h) but 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 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 greens and meat). Also for the CSBO accident scenario for Doel 4, it is not excluded that the derived level for the soil concentration of 4000 Bq/m2 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). However, again, for all accident scenarios, because of the limited half-life of the major iodine isotopes, this will 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 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 immediate countermeasures such as sheltering, evacuation or the intake of stable iodine for thyroid protection are necessary in neighboring countries. Mainly in the Netherlands, given the

[141] Reference levels should not be considered as limits. In a real situation, sheltering would perhaps be recommended, on the one hand because of the uncertainty that exists in any accident situation, but also because a reduction in exposure (dose optimization) can be weighed against the adverse effects of sheltering within the framework of the precautionary principle.

vicinity of Doel 4, contamination of the food chain with iodine isotopes where countermeasures may be required is possible. In other neighboring 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 requires no countermeasures. Therefore, the lifetime dose due to the considered accident scenarios is very limited in all neighboring countries.

For the impact on fauna and flora, based on the quantities discharged and 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 will both be the only reactor at the respective KC Doel and CN Tihange sites operated for electricity production, the likelihood at both sites decreases for a serious accident. After the final shutdown of the other reactors, 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. Given the physical distance between the sites of both reactors, the probability of a simultaneous accident with Doel 4 and Tihange 3 is even smaller than Multi unit events at the same site.

1.2.3 Impact on waste and spent fuel generation

An extension of the operation of the Doel 4 and Tihange 3 units will give rise to the generation of an additional quantity of low- and medium-level waste, estimated on the basis of long-term averages at a total of 864 ^{m3} for the current projected LTO period of 10 years. This is primarily Category A waste, with only a limited amount of Category B waste, which may include certain resins and filters. 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 approximately 2,161 400L-colli which 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 repository is 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. Since 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 over a 10-year LTO period at Doel 4 and Tihange 3 was also estimated. For both units together, the LTO will result in an additional consumption of about 810 fuel elements (type UOX 14ft). Weighted in relation to the entire Belgian reactor park, this corresponds to a surplus of 7.3% in number of fuel assemblies, or 8.9% in tonne Heavy Metal (tHM).

Given this relatively limited quantity and assuming that 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} storage units under construction at Doel and Tihange, there will be sufficient capacity for safe storage at the sites, pending a decision regarding long-term management.

Large quantities of material streams are generated during decommissioning operations, 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 various components of the tub sample 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. It is expected that this limited activity increase by the LTO will 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.

1.3 Mitigation measures and gaps in knowledge for non-radiological effects

1.3.1 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 Doel's site, the following is involved:

1. Prevent drainage of groundwater and cooling water to the mixed sewer system and disconnection of stormwater (e.g. in new projects or maintenance work) causing dilution of wastewater and frequent overflows;
2. Continued optimization of wastewater treatment is appropriate to permanently resolve former bottlenecks (nitrite, AOX); more consistent measurement of a number of other parameters so that compliance with discharge standards can be verified;
3. Future conversions and renovations must be sufficiently flood- and climate-robust to cope with the effects of more intense rainstorms in the future and not transfer flooding to the surrounding area;
4. The shutdown of Doel 3 (2022) and Doel 1 and 2 (2025) can be used as an opportunity to optimize water treatment and (rain) water management for Doel 4.

The following recommendations apply to both Doel and Tihange:

1. Disconnect stormwater from sanitary wastewater and reuse stormwater as sanitary water, avoid urban water use to the maximum extent;
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 of the temperature of the Zeeschelde and Meuse rivers

1.3.2 Gaps in knowledge and monitoring

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 entering the Scheldt and Meuse.

For the Air theme, the main knowledge gap is in the area of emissions from combustion plants, as measurement values or model characteristics are not known for all plants. 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 as to how the capacity of Doel 4 and Tihange 3 (if the project is not implemented) would be filled. This means that the effects on air quality and nitrogen deposition in the reference situation cannot be estimated precisely.

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

1.4 Mitigation measures and gaps in knowledge regarding radiological effects

1.4.1 Emergency Planning

1.4.1.1 Purpose and Basic Concepts

The purpose of nuclear emergency planning is to ensure that there is sufficient capability within the operational organization and at the local, regional, national and, as appropriate, international levels for an effective response to a nuclear emergency. This capability refers to an integrated set of infrastructural elements that include, but are not limited to: competent authority and responsibilities, organization and personnel, coordination, plans and procedures, tools, equipment and facilities, training, drills and exercises, and a management [systemxcvi].

In a nuclear or radiological emergency, there are the following objectives:

a) regain control of the situation and mitigate the consequences;
b) saving lives;
c) avoid or minimize severe deterministic effects;
d) Provide first aid, critical medical treatment and manage the treatment of radiation injuries;
e) Reduce the risk of stochastic effects;
f) keeping the public informed and maintaining public confidence;
g) minimize non-radiological impacts;
h) protect property and the environment as much as possible;
i) prepare as much as possible for the resumption of normal social and economic activity.

Legal framework

European and international guidelines

Table 101 lists the main European and international guidelines related to nuclear emergency planning.

Table 101: Relevant European and international directives related to nuclear emergency planning.

European and international directive	Relevant content related to nuclear emergency planning
2013/59/Euratom[xcvii]	The Directive requires Member States to develop an emergency response system that provides emergency plans for the different types of identified nuclear and radiological emergencies that may occur. Directive 2013/59/Euratom of December 5, 2013 was partially translated in the Royal Decree of March 1, 2018, establishing the nuclear and radiological emergency plan for the Belgian territory (see Table 102).
IAEA Safety Standards Series No. GS-G-2.1[xcviii]	These guidelines describe appropriate responses to a range of nuclear or radiological emergencies.
IAEA Safety Standards Series No. GSR Part 7[xcviii]	This publication establishes the requirements for an adequate level of preparedness for a nuclear or radiological emergency. The application of these requirements is intended to mitigate the consequences of a nuclear or radiological emergency should such an emergency occur despite all efforts to prevent it.
ICRP Publication 63[xcix]	This publication provides quantitative guidelines for intervention levels. These guidelines cover the introduction of protective measures in the very short term and their continuation over a longer period of time.
ICRP Publication 109[c]	This report provides guidance on preparedness for and response to all radiation exposure situations in nuclear or radiological emergencies.
WENRA Safety Reference Level for Existing Reactors 2020[ci]	This report contains guidelines regarding a harmonized approach around nuclear safety within the various member states.

Belgian law

The following is an overview of Belgian legislation relevant to nuclear emergency planning (Table 102).

Table 102: Belgian legislation relevant to nuclear emergency planning.

Nature	Content
Law of April 15, 1994 on the protection of the population and the environment against the dangers of ionizing radiation and on the FANC[cii]	This law contains provisions for the effective protection of the population, workers and the environment against the danger of ionizing radiation. The law also regulates the creation of a public institution with legal personality: the "Federal Agency for Nuclear Control," abbreviated FANC, which is charged with monitoring compliance with this law and its implementing decrees.
ARBIS (20/07/2001)[ciii]	This regulation applies to all practices that may involve a risk as a result of exposure to ionizing radiations emitted, either by an artificial or natural radiation source, when the natural radionuclides are being or have been processed because of their radioactive properties, their fissile properties or because of their culture properties. Among other things, this RD sets the basic standards for protection from exposure to ionizing radiation.

Ministerial circular NPU-1 on emergency and intervention plans (26/10/2006)[civ]	This circular provides further explanation of the provisions and principles contained in the Feb. 16 RD on emergency and intervention plans.
RD containing safety regulations for nuclear installations (30/11/2011)[cv]	This decision is addressed to the operators of Class 1 nuclear installations and, in particular, nuclear reactors for electricity production. It promulgates a set of safety regulations to be applied by the operator.
RD amending the ARBIS (20/07/2020)[cvi]	This RD amends various provisions of the ARBIS to partially transpose Directive 2013/59/EURATOM. It also inserts some additional provisions.
RD establishing the nuclear and radiological emergency plan for the Belgian territory, *BS* March 6, 20 18)[cvii]	This RD establishes the nuclear and radiological emergency plan for the Belgian territory. This plan aims to ensure the coordination of measures to protect the population and the environment in case of radiological emergencies directly or indirectly threatening the Belgian territory. The plan defines the missions to be carried out and the competencies of all parties involved. Belgium has had a national nuclear and radiological emergency plan since 1991. Many updates have been made since then. After consultation with all relevant (inter)national partners, the nuclear and radiological emergency plan for the Belgian territory was updated in 2018.

1.4.1.2 Internal and external emergency plans for KC Doel and CN Tihange nuclear facilities

The emergency plan of each Belgian nuclear unit is systematically described in the safety report and approved at the time of authorization. In addition, the "internal" emergency plan contains the instructions for all actors.

In the event of an accident in a nuclear unit at KC Doel or CN Tihange, the operations room at the plant in question (i.e., the on-site Technical Center) is activated and manages all technical issues to control the accident and limit its consequences. At the site level, the Emergency Room (NPK - Doel/Tihange) manages the environmental impact and liaises with the NCCN[cviii].

1.4.1.3 Harmonization between neighboring countries for KC Doel and CN Tihange

It is desirable for countries to coordinate with each other in advance their basic principles of how to proceed in the event of a cross-border nuclear accident. This prevents measures on one side of the border from being substantially different from those on the other side. In connection with this, the European cooperation HERCA-WENRA[cx] promotes harmonization in the border areas around nuclear power plants. Harmonization in this approach means that the neighboring country does not take measures that conflict with or go beyond those of the source country.

The Netherlands, France, Belgium and Germany have formulated policies to prepare similar protective measures in the event of a nuclear accident (see Table 103).

Table 103: Intervention guideline values (IRW) and preparation or emergency planning zones (radius of circles in km) (NPZ) established by Belgium, the Netherlands, Germany and France around the Doel and Tihange nuclear power plants for immediate protection measures in the event of a nuclear emergency).

	Policy Belgium		**Policy Netherlands**		**Policy Germany**		**Policy France**	
	IRW	NPZ	IRW	NPZ	IRW	NPZ	IRW	NPZ
Reflex Zone	-	3.5 km(142	-	-	-	5 km(143	-	2 km(142
Evacuate	50 mSv(144	10 km	100 mSv	10 km	100 mSv(144	10 km	50 mSv	(5 km(145))
Hide	5 mSv(146	20 km	10 mSv	20 km	10 mSv(144	100 km	10 mSv	10 km ☎→ 20 km(145)
Iodine prophylaxis - ≤40 years(147	50 mSv(148	20 → 10 0 km(149	100 mSv	20 km	250 mSv(150	100 km	50 mSv	-
-≤18 years and pregnant	10 mSv(148	20 → 100 km(149	50 mSv	100 km	50 mSv(150	Germany	50 mSv	-

Source: https://www.herca.org/download/4719/, https://www.herca.org/download/4735/ https://www.herca.org/download/4720/ and https://www.herca.org/download/4712/

1.4.1.4 Organization of emergency plan exercises for KC Doel and CN Tihange

KC Doel and CN Tihange hold internal exercises several times a year. In addition, the nuclear and radiological emergency plan for the Belgian territory stipulates that an annual emergency plan exercise is organized for KC Doel and CN Tihange by the crisis center. Every 3 years a large-scale exercise, in principle involving all disciplines, must be organized for 1 nuclear site. There are 2 types of exercisescxi:

- theoretical exercises: the different actors sit around the table together and discuss how they would act in reality;
- terrain exercises: the exercise is staged at the site of the (simulated) emergency. In principle, there is a real deployment of troops and resources at that site, but different modalities are possible.

In accordance with the intended objectives, the crisis center involves in these exercises the various disciplines (fire department, medical assistance, police, civil protection, measurement teams, etc.).

Table 104 and Table 105 show the exercises for KC Doel and CN Tihange over the past 10 years. There were 2 exercises for Doel 4 and 5 exercises for Tihange 3.

[142] Immediate sheltering in case of General Emergency - reflex mode.
[143] Immediate evacuation in case of General Emergency - reflex mode.
[144] Total integrated effective dose over 7 days (inhalation and external irradiation).
[145] In preparation.
[146] Total integrated effective dose over 24 hours (inhalation and external irradiation).
[147] 45 years for Germany.
[148] Total integrated equivalent dose for thyroid (inhalation).
[149] Extension Zone.

[150] Total integrated thyroid dose over 7 days (inhalation).

Table 104: Exercises KC Purpose over the past 10 years (Source: NCCN).

Exercise	Date	Installation	Scope of the exercise
Exercise KC Doel 2012	March 29, 2012	Doel 2	Exercise of limited scope without deployment on terrain.
Exercise KC Doel 2013	October 22, 2013	Doel 3	**Methodological guided exercise With deployment on site.**
Exercise KC Doel 2014	October 14, 2014	Doel 2	Exercise of limited scope without deployment on terrain.
Exercise KC Doel 2015	March 26, 2015	Doel 4	Exercise of limited scope without deployment on terrain.
Exercise KC Doel 2016	March 15, 2016	Doel 1	Exercise of limited scope without deployment on terrain.
Exercise KC Doel (Doel Ex) 2017	Nov. 21, 2017	Doel 3	**Methodological guided exercise With deployment on site.**
Exercise KC Doel 2018	May 8, 2018	Doel 4	Exercise of limited scope without deployment on terrain.
Exercise KC Doel 2019	March 21, 2019	Doel 2	Exercise of limited scope without deployment on terrain.
Exercise KC Doel 2020	Sept. 14, 2020	Doel 1	Exercise of limited scope without deployment on terrain.
Exercise KC Doel 2021	Oct. 19, 2021	Doel 2	**Methodologically guided exercise without field deployment.**
Exercise KC Doel 2022	May 17, 2022	Doel 3	Exercise of limited scope without deployment on terrain.

Table 105: Exercises CN Tihange over the past 10 years (Source: NCCN).

Exercise	Date	Installatio n	Scope of the exercise
Projet d'Exercice Grande Ampleur Site Electrabel nv Tihange (PEGASE) 2012	November 20 & 21 2012	Tihange 3	**Methodological guided exercise With deployment on site.**
Exercise Tihange 2013	December 5, 2013	Tihange 1	Exercise of limited scope Without deployment on terrain.
Exercise Tihange 2014	May 26, 2014	Tihange 3	Exercise of limited scope Without deployment on terrain.
Exercise Tihange 2015	November 26, 2015	Tihange 1	Exercise of limited scope Without deployment on terrain.
Exercise Tihange 2016	November 29, 2016	Tihange 3	**Methodological guided exercise With deployment CELMES on site.**
Exercise Tihange 2017	November 24, 2017	Tihange 1	Exercise of limited scope Without deployment on terrain.
Exercise Tihange 2018	November 30, 2018	Tihange 3	Exercise of limited scope Without deployment on terrain.
Exercise Tihange 2019	May 16, 2019	Tihange 2	Exercise of limited scope Without deployment on terrain.
Exercise Tihange (TihEx) 2020 phase 1* Exercise Tihange (TihEx) 2020 phase 2*	March 17, 2021 June 29, 2021	Tihange 3	**Methodological guided exercise With deployment on site.**
Exercise Tihange (TihEx) 2022	Nov. 28, 2022	Tihange 2	Exercise of limited scope Without deployment on terrain.
Exercise Cellmes 2022	Nov. 25 - 26 2022	Tihange?	**Methodological guided exercise With deployment on site.**

1.4.2 Gaps in knowledge

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 extremely 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 (see §9.2.2). Doses are therefore well below these for the occurrence of deterministic effects (deterministic effects must be avoided at all times, even in accident situations (see §2.3.2 and §9.4.1) [and

), but also almost always well below effective doses where epidemiological studies can show stochastic effects of radiation (cancer occurrence and genetic effects (see §2.3.2) [reference to §Basic Concepts radiation protection used in the assessment]. This is because the probability of the occurrence of these effects is very small at such low doses and this on top of a high spontaneous occurrence of the same effects. Although, from the precautionary principle, we attach to every additional exposure (dose), however low, the possibility of the occurrence of stochastic effects, it is not possible to confirm with certainty this occurrence, 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: see §2.3.2).

2 General Decision

The postponement of the deactivation of Doel 4 and Tihange 3 may give rise to the perpetuation, for a period of 10 years, 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 solution of problems specific to the current operation, such as the 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 the temperature of the Scheldt near the Dutch border (about 3.4 km away 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 may be a (limited) effect because of the intake of cooling water. In terms of disturbance, only noise disturbance is potentially relevant, but a significant impact on nearby species is not expected. Also for Tihange, it can be concluded that disturbance to fauna due to noise and lighting is not significant, since the plant is located in an already highly urbanized 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 deposits, positive effects can even be expected rather due to the "avoided emissions" associated with 10 years of additional nuclear production. Indeed, 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 given the potential importance of this zone for the birds of the nearby Birds Directive area, this is an important conclusion. Also 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 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 areas of conservation in the vicinity of the Doel and Tihange sites. The impact 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 threshold values for harmful effects on fauna and flora. The calculated dose rate for discharges to air and water is also well below that threshold. It can thus 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 program 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 have a negative impact on the conservation objectives for the respective special protection areas.

As for the consequences in the event of an accident, 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 of potential impact are steam boilers and diesel engines, which, however, have limited hours of operation each year. As more combustion plants are taken out of service with the closure of the other reactors at both sites, their impact will continue to 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 (in part) 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 **greenhouse gas emissions attributable** to the operation of Doel 4 and Tihange 3 over the lifetime extension period are only a fraction of the avoided greenhouse gas 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 Mton).

Neither Doel 4 nor Tihange 3 affect the resilience of their environments to the effects of climate change during the reference period. Within the time perspective of lifetime extension, neither site is vulnerable to climate change impacts either, and this situation is independent of whether or not the lifetime of Doel 4 and Tihange 3 is extended.

In terms of ***health,*** a (modest) positive impact can be expected as a result of avoiding a quantity of NO_x 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 effect on the avoidance of health and safety effects that may 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 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 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 in the considered period of the project drop to 0.017-0.013 mSv/year for the entire KC Doel site and to 0.020 to 0.015 mSv/year for CN Tihange.

It can be concluded that the lifetime extension of Doel 4 and Tihange 3 will not result in 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 probability 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 **design expansion 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 however exceeded, meaning that in such a case, taking stable iodine for thyroid protection would be recommended. In a design-basis accident, the effective dose appears 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.

An 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 remain within the set limits. This is also true if the analysis is done on the basis of the FANC guidelines for new Class 1 installations In a design expansion accident, the effective dose appears to be of the same order as that of both design basis accidents, but the equivalent thyroid dose is lower.

The project thus entails a limited risk related to an accident (both design basis - and design extension accident). However, for the whole CN Tihange site, the risk will decrease, since 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 immediate countermeasures such as sheltering, evacuation or the intake of stable iodine to protect the thyroid gland are necessary in neighboring 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 other neighboring 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. Therefore, the lifetime dose due to the considered accident scenarios is very limited in all neighboring countries.

Since 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 serious accident at both sites decreases.

An extension of the operation of the Doel 4 and Tihange 3 units will give rise to the generation of an additional quantity of low- and medium-level waste, estimated on the basis of long-term averages at a total of 864 ^{m3} for the current projected LTO period of 10 years. 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 approximately 2,161 400-liter 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 amounts to 34 modules, with an ample 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. Since 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 over a 10-year LTO period at Doel 4 and Tihange 3 was also estimated. For both units together, the LTO will result in an additional consumption of about 810 fuel elements (type UOX 14ft). Weighted in relation to the entire Belgian reactor park, this corresponds to a surplus of 7.3% in number of fuel assemblies, or 8.9% in tonne Heavy Metal (tHM).

Given this relatively limited quantity and assuming that 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 the units at both sites where it would otherwise be very condensed over several years. With SF2 (Spent Fuel Storage Facility) 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.

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