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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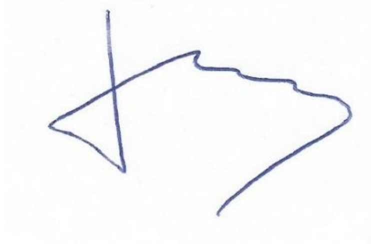
Koen Couderé (KENTER) Coordinateur RIE certifié Agrément n° LNE/ERK/MERCO/2019/00033 Expert certifié en RIE Sol, disciplines Géologie et Pédologie Expert RIE certifié Eau, sous-domaines hydrogéologie, eaux marines et eaux de surface et eaux usées Expert RIE certifié Climat Agréation n° EDA-222	
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1 Environmental impact assessment - Doel 4

1.1 Transboundary impacts of non-radiological aspects

Most of the non-radiological impacts attributable to the life extension of Doel 4 are confined to the immediate vicinity of the nuclear power plant, are of limited magnitude and therefore do not lead to transboundary effects. Only for the Water discipline can there be a question of (limited) transboundary effects.

Based on the monitoring (2012) of the temperature influence of the KC Doel cooling water on the Scheldt at the height of the Dutch border (about 3.4 km from the discharge point), the influence of the cooling water discharge can at most be considered as limited negative (ie the temperature increase due to the discharge will be less than 1°C). This temperature increase will continue to decrease slowly downstream in the Dutch territory.

It should be noted that various cross-border effects cannot be excluded in the baseline situation, if no lifetime extension takes place and therefore other means of generation must be used to deploy the Doel 4 capacity. The magnitude and nature of these transboundary effects will depend to a large extent on where the (theoretical) replacement capacity is planned, on the technical characteristics of these installations and on their permit conditions.

1.2 Transboundary impacts of radiological aspects

1.2.1 Normal operation

The border with the Netherlands is the nearest, approximately 3.15 km from the KC Doel site. However, given the trivial radiological impact (approximately 0.02 mSv/year due to gaseous and liquid releases and possibly a limited dose of direct radiation, but within the limits of local variations in natural radiation) during operation of all KC Doel units for the most exposed person on Belgian territory just outside the KC Doel site and the fact that the impact only decreases with distance (dilution for releases and the inverse square law for any direct radiation from KC Doel), it can be stated that there are no transboundary effects on people and the environment during the normal operation of KC Doel, in other words also not if Doel 4 is extended for a period of 10 years.

1.2.2 Accidents

To assess the cross-border impacts under the two overarching design basis accident scenarios (LOCA and FHA) and the beyond design basis accident scenario, we use on the one hand the calculations of Tractebel which follow the methodology based on the new FANC-AFCN/BEL V guidelines for new Class 1 installations for the impact on the Netherlands (given the short distance, the atmospheric modeling used is suitable for this purpose) and for other neighboring countries at a greater distance the Flexpart methodology, both discussed in the methodology section § 2.3.4.

Both methodologies make a conservative estimate for the critical individual. For the Flexpart calculations, we have for example considered the source term for the LOCA (duration 720 hours) to be a release of 6 hours (this causes less dispsersion), for the FHA of 2 hours (actual duration of release) and for CSBO also 6 hours (releases during different vents and continuous release over 10 days). We also consider all iodine in the elemental form (I_2) in the Flexpart calculation.

The quantities released to the environment that are assumed in these scenarios are given in Table 64.

Tabel 1 : Released activity of different groups of radionuclides important for the impact.

	Design basis scenarios		Beyond design basis scenario
	LOCA	FHA	CSBO
Noble gases	2,5 PBq	8,89 PBq	13,7 PBq
Iodine	64,5 TBq (74,4 % I-131)	7,23 TBq (43 % I-131)	0,49 TBq (14,6 % I-131)

Aerosols (Cs-137 + Cs-134)*	1,88 GBq	-	58.3 GBq

*Cs-134 only applicable for CSBO accident

The calculated radiological impact, namely the total effective dose, the equivalent dose to the thyroid and the level of I-131 deposition, are given in Table 65. These were determined for the Netherlands at a distance of approximately 3 kilometers from the Doel site, in accordance with the new FANC-AFCN/Bel V guidelines (Tractebel studies, applicable to short distances), for other countries (and deposition in the Netherlands) with the Flexpart method (longer distances: see methodology § 2.3.4.3). Both methods use the same total source term. In the Flexpart method, the maximum air concentrations and deposition levels in the countries concerned determined for a series of simulations with the start of the release at each hour of a full year are used (ECMWF 2020 meteorological data for the duration of the release, 6 hours or 2 hours, depending on the scenario) and the groups of radionuclides considered. The maximum values at sea were also determined. On the basis of these concentrations in the air and of the deposits, the total effective dose, the equivalent dose to the thyroid and the deposition levels were then determined. For the dose quantities, the maximum of all age categories was tabulated (critical individual).

Table 2 : The total effective dose (TED), the equivalent dose to the thyroid (both for the critical individual) and the maximum deposition of I-131 for the various neighboring countries and for the various accident scenarios considered were determined using the Flexpart methodology. Two values are given for the Netherlands. The first value was determined with the local impact methodology, the value in brackets with the Flexpart methodology (see text). For the evaluation we use the local method for the Netherlands (for the doses) and the Flexpart method for the other countries.

Doel 4	**LOCA**			**FHA**			**CSBO**		
	DET (mSv)	Dose à la thyroïde (mSv)	Dep. I131 (Bq/m^2)	DET (mSv)	Dose à la thyroïde (mSv)	Dep. I131 (Bq/m^2)	DET (mSv)	Dose à la thyroïde (mSv)	Dep. I131 (Bq/m^2)
Netherlands	0,22 (0,55)	4,05 (16.0)	(3.4 10^5)	0,44 (0,14)	4,79 (1,46)	(33202)	0,44 (12,5)	0,011 (0,51)	(5980)
Germany	0,01	0,26	8400	0,01	0,04	992	0,99	0,009	190
Luxembourg	0,00	0,05	4970	0,00	0,01	380	0,12	0,002	61
France	0,03	0,90	12700	0,02	0,15	1600	1,11	0,032	289
United Kingdom	0,01	0,29	5330	0,01	0,03	410	0,56	0,009	70
Sea	0,37	10.62	-	0,10	1,03	-	8,57	0,340	-

We find that doses in the Netherlands, given proximity, are the highest, but below typical guideline values for direct countermeasures such as sheltering or administration of stable iodine tablets to avoid the accumulation of radioactive iodine in the thyroid (see Emergency planning section §9.4.1). The radiological impact in neighboring countries will therefore remain very limited. The deposition of aerosols (Cs-137 and also Cs-134 for the CSBO accident) is lower than the value for which an impact on the food chain can be expected for all the neighboring countries and for all the scenarios. For iodine isotopes and in particular I-131, the lowest derived value for soil concentration (4000 Bq/m^2 I-131) having a possible impact on the food chain (e.g. contamination of milk) can be exceeded in all neighboring countries for the LOCA accident. This is, with the exception of the Netherlands becausevery limited. The calculated deposition values are, in accordance with the methodology used, for the most unfavorable moment at which the accident can occur (with regard to the weather conditions of the year 2020), for each neighboring country. Moreover, given the half-life of I-131 (8.02 days), this contamination will have no long-term consequences.

1.3 Mitigation Measures: Contingency Planning

This is described collectively for Doel 4 and Tihange 3: see § 9.4.1

1.4 Knowledge gaps

This is described collectively for Doel 4 and Tihange 3: see § 9.4.2

1.5 Recommendations

As part of the assessment of radiological impacts, we would like to make a number of recommendations for the implementation of the Project:

1. The dose resulting from gaseous and liquid releases during the operation of Doel 4 is largely determined by the gaseous releases of carbon-14, a radionuclide also naturally present. The release is based on calculations and has only been verified by measurements for Tihange 2. It has been found that the actual carbon-14 releases at Tihange 2 are lower than those calculated in a (conservative) manner. In this context, if Doel 4 is extended, it would be appropriate to quantify the carbon-14 releases by monitoring, using a method similar to that used for Tihange 2, in order to obtain a better and more realistic estimate of the doses in normal operation;
2. If Doel 4 is extended for 10 years, operation will coincide with the post-operational phases and possibly the dismantling of the other reactors and certain auxiliary buildings on the KC Doel site. It seems recommended to distinguish, as far as possible, between the radiological exposures which potentially result from the dismantling and those resulting from the operation for the continued production of electricity from Doel 4 and to report them separately to the public so that the impact of operation for industrial power generation of Doel 4 can be analyzed separately from any potential decommissioning activity.

2 Synthesis and conslusion site Doel – Doel 4

2.1 Summary of impacts

2.1.1 Non-radiological impacts

The life extension of Doel 4 means that for an additional period of 10 years sanitary wastewater (purified), treated industrial wastewater and cooling water (heated) will be discharged. During this period, the overflow problems, inherent to the site's mixed sewer network, will also persist. However, this will not lead to a deterioration of the ecological status of the Sea Scheldt, provided that continued attention is paid to monitoring and timely adjustment. Nor does the project compromise the realization of the good ecological potential of the water body. However, it is recommended that the thermal discharges be more closely aligned with the evolution of the temperature gradient between the Dutch border and Antwerp.

The Biodiversity discipline studied the impacts of the plan in terms of surface water quality, barrier effect, mortality, nuisance, land use, eutrophication and acidification. No effects were to be expected with regard to the barrier effect and direct land occupation. For mortality, there may be a (limited) effect due to the suction of cooling water. In terms of disturbances, only changes with regard to noise pollution are to be expected. The significance of these changes is rather limited, because during the lifetime of the installation, the nuisance will only come from Doel 4. Furthermore, this is an existing noise which is continuous and predictable, one does therefore not expect a significant impact on surrounding species.

The impacts of the operation of the nuclear power plant in terms of acidifying and eutrophicating fallout are negligible. In addition, other factors such as the water quality of the Scheldt are much more decisive for the trophic state there. On the other hand, 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 leads to a local deterioration of the water quality, which however remains limited to the area inside the longitudinal dike. Significant effects on the entire Scheldt ecosystem are avoided in this way. Locally, there is no indication that the effects are detrimental to the organisms present. Given the designation of the Scheldt itself as a Habitats Directive area and the potential importance of this area for birds in the Birds Directive area, this is an important finding.

The operation of KC Doel can also have an impact on air quality. The main sources likely to have an impact are steam boilers and diesel engines, which however only have a limited number of operating hours each year. If only Doel 4 is used, the number of operating hours of the steam boilers will almost double, but even then the total number of effective operating hours will remain limited. Emissions from the installations are therefore very limited and will decrease further as other combustion installations are taken out of service.

The highest calculated emissions (for 2026) were used as model input to calculate the impact on air quality. As model specifications were not available for all facilities, a number of assumptions were used in these calculations. Impact calculations show that the impact on ambient air quality is negligible (less than 1% of the limit values or tests used). No exceedance of the limit values is identified either, given the expected background concentrations. It is therefore not necessary to take mitigating measures.

If the life of Doel 4 is not extended, electricity will instead have to be generated from (partially) fossil fuels. The emissions that occur (and which can be considered “avoided” when the life of Doel 4 is extended) are much higher than the emissions generated by the operation of Doel 4.

The greenhouse gas emissions that can be attributed to Doel 4 over the lifetime extension period are in the order of 14 ktonnes (cumulative). The greenhouse gas emissions avoided by keeping Doel 4 open longer are of another order. Over the whole period, the postponement of the deactivation of Doel 4 makes it possible to avoid emissions of around 12 417 ktonnes of CO_2eq. This represents an annual saving equivalent to nearly 10% of emissions from the "electricity and heat production" sector in Belgium in 2021 (12.8 Mtonnes). If we compare with the emissions released by the operation of Doel 4 over the same period (14 ktonnes), it can be concluded that the emissions of

Doel 4 over the period covered by the lifetime extension represent only 0.11% of the avoided emissions over the same period.

Doel 4 do not affect the resilience of the environment to the effects of climate change during the reference period, given that both in the reference situation and during the implementation of the Project, the site remains asphalted. From the time perspective of life extension, the Doel site itself is also not vulnerable to the consequences of climate change, and this is independent of whether or not Doel 4 is extended.

The project has no significant health consequences. Based on a preliminary review, only legionella-related effects, psychosomatic aspects (associated with risk perception) and avoided health effects of a power outage were considered potentially relevant. The analysis carried out in this EIA reveals that legionella cannot pose a problem given the brackish water used to supply the cooling towers of Doel 4. With regard to the perception of the risk in terms of nuclear accidents, it can be said that it exists, but that there is no demonstrable link with the psychosomatic effects. Finally, it can be confirmed that the life extension of Doel 4 significantly reduces the risk of power cuts (especially in the first years of the life extension), which has a positive effect on the prevention of health effects that may be associated with power outages.

2.1.2 Radiological impacts

Potential radiation exposure for humans and the environment during normal operation is linked to direct radiation from the radioactivity present on the site and from gaseous and liquid releases containing certain concentrations of radioactivity.

Readings from the TELERAD network operated by the FANC-AFCN show that the dose of external radiation near KC Doel is well below the legal limit of 1 mSv/year and cannot be distinguished from local variations in the natural background.

The Doel nuclear power plant has, in the current situation, no significant measurable radiological impact on the environment through atmospheric emissions or on the Scheldt. This conclusion of course also applies if only the operation of Doel 4 is taken into account.

A calculation based on current release limits shows that even for the “most exposed person” (hypothetically), the dose resulting from atmospheric and liquid releases will be much lower than the effective dose limit for the public of 1 mSv per year . Since, in practice, the actual releases are only a fraction of the permitted limits, the actual dose (for the entire KC Doel site) is obviously even lower; it is (at most) only about 2.2% of the dose limit.

A comprehensive environmental risk assessment was carried out in 2013 to estimate the impact of atmospheric and liquid discharges on fauna and flora. The dose rate values for the release limits have also been shown to be well below the threshold value of 10 µGy/h, below which no adverse effects occur. The current discharge limits therefore do not lead to harmful effects on the environment, which is also confirmed by the measurement results of the monitoring program of the FANC-AFCN and the operator near the site.

The shutdown of Doel 4 leads to the disappearance of some of the gaseous and liquid radioactive releases into the environment. The releases directly linked to the operation of the reactors (and which also contributes the most to the dose resulting from gaseous and liquid releases) will disappear. On the other hand, certain gaseous and liquid releases will continue in the post-operational phase.

Based on the experience in Germany, it can be conservatively estimated that the effective dose resulting from gaseous and liquid discharges, if Doel 4 is not extended (and thus no more reactors are in operation at the Doel site), in the first year after the shutdown, will have fallen to a level of the order of 0.007 mSv/year and in the following years will further decrease below 0.003 mSv/year. This can be compared to an effective dose in 2025, which will be of the order of (maximum) 0.02 mSv/year, and to the limit of 1 mSv/year.

If the project is carried out and the life of Doel 4 is therefore extended, it can be assumed that the gaseous and liquid discharges linked to the operation of Doel 4 will continue for 10 years at the same level as today, in assuming that the reactor will continue to operate at the same power and that the treatment of gaseous and liquid effluents will remain unchanged. A conservative estimate of the effective dose due to the operation of Doel 4 alone gives a value of 0.01 mSv/year or less, and this is constant over the 10 years of prolonged operation. This is well below the current operating license and also lower by a factor of 100 than the legal limit of 1 mSv/year. An effective dose of 0.01 mSv corresponds to the additional dose that a Belgian receives due to the increase in cosmic radiation if he goes skiing in the mountains for two weeks. The effective dose in normal operation of the project therefore has a trivial impact.

In this EIA , the effects of the projects were also considered on the dose that would result from the two design basis accidents and one beyond design basis accident. An analysis based on the safety case of Doel 4 reveals that the effective doses and the equivalent doses to the thyroid resulting from the two design basis accidents for Doel 4 remain within the set limits. If the analysis is based on the FANC-AFCN guidelines for new Class 1 installations, the criterion of equivalent doses to the thyroid is exceeded, which means that in such a case the administration of stable iodine to protect thyroid would be recommended. In the event of a beyond design basis accident, the effective dose seems to be of the same order as that of the two design basis accidents, but the equivalent dose to the thyroid is lower. In all 3 accident scenarios, contamination of the food chain could also occur, with activity levels typically exceeded in milk, leafy vegetables and meat, by 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.

The long-term impacts of the two reference accidents are negligible: the effective dose calculated throughout life (due to the radioactivity deposited in the soil and the consumption of food from one year after the accident) is well below the 1 Sv criterion for all age categories. This also applies to the long-term impact of the beyond design basis accident.

The project therefore involves a limited risk linked to an accident (both design basis accident and beyond design basis accident). For the whole KC Doel site, however, the risk for an accident will be lower, because during the 10-year period when the lifespan is extended, only Doel 4 will still be in operation at the site.

It is expected that the postponement of the deactivation of the Doel 4 nuclear reactor will result in an additional quantity of low and intermediate level radioactive waste of approximately 460 m³ for a production period of 10 years. This is mainly category A waste, with only a limited amount of category B waste. Compared to the approximately 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%).Assuming that the additional quantity of category B waste is negligible, the additional volume of waste corresponds to approximately 287 monoliths or 0.31 modules in the disposal facility for category A waste. The (volumetric) capacity of this repository is 34 modules.

Furthermore, extending the operation of Doel 4 for 10 years will generate an additional quantity of around 390 spent fuel assemblies. This represents an increase of 3.5% compared to the entire Belgian fuel inventory in the event of a permanent shutdown.

A long-term management solution will have to be developed for these fuel assemblies, which is geological disposal if the fissile materials are considered as waste. Assuming that the storage will be in lightly indurated clay, with supercontainers as the primary packaging, the above additional consumption would correspond to 98 additional supercontainers (Type SC-4) and an additional storage gallery length required of about 600m. However, an additional quantity of spent fuel to be stored will not cause a proportional increase in the dose or the estimated risk.

2.2 Summary of the transboundary impacts

Most of the non-radiological impacts attributable to the life-time extension of Doel 4 are limited to the immediate surroundings of the nuclear power plant and are of limited magnitude; they therefore do not lead to transboundary effects. Only for the Water discipline can there be a question of (limited) transboundary effects. Based on the monitoring of the temperature of the Scheldt at the height of the Dutch border (about 3.4 km from the discharge point), the influence of the discharge of cooling water can at most be considered negative. limited, which implies that the temperature increase due to the release will be less than 1°C. This temperature increase will continue to decrease slowly downstream in the Dutch territory.

If the life of Doel 4 is not extended, other means of production will of course have to be used to replace the drop in production capacity. Transboundary effects cannot a priori be excluded in such cases. However, the magnitude and nature of these transboundary effects will strongly depend on the sites where the (theoretical) replacement capacity is provided, the technical characteristics of these plants and their licensing characteristics.

The gaseous and liquid radiological releases from the operation of all KC Doel units have a trivial impact (of the order of 0.02 mSv/year) for the hypothetically most exposed person located just outside the KC Doel site. The dose that could come from direct radiation from the site remains within the limits of natural variations. Given the fact that the impact can only decrease with distance (dilution for discharges and the inverse square law for any direct radiation), it can be said that in normal operation of KC Doel, and therefore also during extension of Doel 4, no transboundary effects on people and the environment are to be expected.

Calculations of the transboundary radiological impact of the various accident scenarios reveal that the doses in the Netherlands, as well as the other neighboring countries, fall below the guideline values for direct countermeasures (such as sheltering or administration of iodine tablets). Countermeasures at the level of the food chain may prove essential in the Netherlands for iodine isotopes, similar in view of their proximity to those in Belgium. In the other neighboring countries, deposits where countermeasures are essential for the food chain are very unlikely, but cannot be fully excluded in the event of a LOCA accident in very adverse weather conditions. However, if there is an impact on the food chain, including in the Netherlands, it will be of short duration (no significant deposition of long-lived radionuclides such as Cs-137). The radiological impact in neighboring countries will therefore remain limited.

3 Environmental impact assessment - Tihange 3

3.1 Transboundary impacts of non-radiological aspects

Most of the non-radiological effects attributable to 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 transboundary effects.

Only the discharge of cooling water, influencing the temperature of the Meuse, could have an impact over a longer distance. However, in view of the temperature data of the Meuse at the level of the last measuring station before the Netherlands, the influence of the discharge of cooling water can be considered negligible (less excesses of 25°C and no daily average exceedance of 28°C recorded in the last 3 years).

It should be noted that several transboundary effects cannot be excluded in the reference situation if the deactivation is not postponed. The magnitude and nature of these transboundary effects will depend to a large extent on where the (theoretical) replacement capacity is planned, the technical characteristics of these installations and their permitting characteristics.

3.2 Transboundary impacts of radiological aspects

3.2.1 Normal operation

CN Tihange is located at a shortest distance of 38 km and 58 km respectively from the Dutch and German borders. However, given the ntrivial radiological impact (approximately 0.044 mSv/year due to gaseous and liquid emissions and possibly a limited dose of direct radiation, but within the limits of local variations in natural radiation) during the operation of all CN Tihange units for the most exposed person located on Belgian territory just outside the CN Tihange site and the fact that the impact only decreases with distance (dilution for releases and the inverse square law for any direct radiation from CN Tihange), it can be said that there are no transboundary effects on people and the environment during the normal operation of CN Tihange, and consequently also no effects when Tihange 3 is extended for 10 years.

3.2.2 Accidents

For the assessment of transboundary effects in the two design basis accident scenarios (LOCA and FHA) and the beyond design basis accident scenario (CSBO), we use the Flexpart methodology, as indicated in the methodology part § 2.3. 4.

The releases to the environment assumed in these scenarios are shown in Table 99.

Table 3 : Released activity of different groups of important radionuclides the impact.

Tihange 3	Basic design scenarios		Non design scénario
	LOCA	FHA	CSBO
Noble gases	16,1 PBq	8,39 PBq	53,2 PBq
Iodine	11,9 TBq (43,6 % I-131)	10,1 TBq (44,1 % I-131)	0.25 TBq (15.7 % I-131)
Aerosols (Cs-137 + Cs-134)*	11 GBq	-	0,38 TBq

* Cs-134 only applicable for CSBO accident

Given the greater distance (several tens of kilometres), the use of the Flexpart model is preferable to a static Gaussian dispersion model well adapted to the local impact (as used for the evaluation of the maximum impact Offsite).

Estimates are also very conservative:

- For the Flexpart calculations, we have tconsidered the source term for the LOCA (duration of release: 720 hours) as being a release of 1 hour (less dispersion), for the FHA of 2 hours (which is the actual duration of the release) and for the 6-hour CSBO (releases during different vents and continuous release over 10 days).
- It is assumed that all iodine exists in the elemental form (I_2)
- The maximum concentrations in the air and the deposition levels obtained for a series of simulations with the start of the release at each hour of a full year are used (ECMWF 2020 meteorological data – see methodology) in the countries concerned for the duration of the release (6 hours, 2 hours or 1 hour, depending on the scenario) and the groups of radionuclides considered (other deposits). This means that for each country, the worst weather situation over an entire year (the year 2020) is used to make the assessment.

Besides the impact in the individual countries, the maximum values at sea were also determined. Based on these concentrations in the air and the deposits, the total effective and equivalent dose to the thyroid was determined for the different age categories. The maximum over all age categories has been tabulated.

Tableau 4. The maximum effective dose and the equivalent dose to the thyroid for a critical individual and the maximum deposition for the different accident scenarios and for the different neighboring countries (Flexpart methodology).

Tihange 3	**LOCA**			**FHA**			**CSBO**		
	DET (mSv)	Dose à la thyroïde (mSv)	Dep. I131 (Bq/m²)	DET (mSv)	Dose à la thyroïde (mSv)	Dep. I131 (Bq/m²)	DET (mSv)	Dose à la thyroïde (mSv)	Dep. I131 (Bq/m²)
Netherlands	0,03	0 ,23	6520	0,02	0,20	5197	0,59	0,002	315
Germany	0,02	0,18	5000	0,01	0,14	3886	0,49	0,002	242
Luxembourg	0,01	0,12	2430	0,01	0,08	1964	0,30	0,001	118
France	0,03	0,28	3660	0,01	0,19	2751	0,64	0,003	177
United Kingdom	0,00	0,010	355	0,00	0,01	254	0,05	0,000	16
Sea	0,01	0,05	-	0,00	0,04	-	0,19	0,001	-

The accidents envisaged for Tihange 3 have a very low impact. The doses are such that no direct countermeasures such as sheltering or administration of stable iodine are required. It is highly unlikely, but not completely excluded, that the deposition of iodine isotopes (such as I-131) requires short-term food chain countermeasures in the Netherlands and/or Germany. The maximum values found are just above the value derived for soil contamination. Deposits of long-lived radionuclides are very limited. The radiological impact therefore remains very limited for these accidents.

3.3 Mitigation Measures: Contingency Planning

This is described collectively for Doel 4 and Tihange 3: see § 9.4.1

3.4 Knowledge gaps

This is described collectively for Doel 4 and Tihange 3: see § 9.4.2

3.5 Recommendations

As part of the assessment of radiological impacts, we would like to make a number of recommendations for the implementation of the Project:

1. The dose resulting from gaseous and liquid releases during the operation of Tihange 3 is largely determined by carbon-14, a radionuclide also naturally present. The released quantity has only been recently based on measurements from Tihange 2 (similar reactor). It was found that the actual carbon-14 (C-14) releases at Tihange 2 are lower than the calculated values (calculations show a conservative estimate). In this context, if Tihange 3 is extended, it is appropriate to quantify the carbon-14 releases from montoring C-14 of Tihange 3 in order to maintain the most realistic possible estimate of the doses in normal operation;
2. If Tihange 3 is extended for 10 years after 2025, operation will coincide with the post-operational phases and possibly the dismantling of the other reactors and certain auxiliary buildings on the CN Tihange site. It seems recommended to distinguish, as far as possible, between the radiological exposures which potentially result from the dismantling and those resulting from the operation for the continued production of electricity from Doel 4 and to report them separately to the public.

4 Synthesis and conclusion site Tihange - Tihange 3

4.1 Summary of impacts

4.1.1 Non-radiological impacts

Keeping Tihange 3 in service for another 10 years means that domestic wastewater (purified), treated industrial wastewater and cooling water (heated) will be discharged for 10 years. Since the discharge standards are well respected for the various parameters and the calculated contribution to the increase in concentration is limited (locally) to negligible, there is no reason to fear a deterioration in the ecological status of the Meuse due to the extension of the activity of Tihange 3 for an additional ten years, provided that particular attention continues to be paid to monitoring and the implementation of corrective measures within a reasonable timeframe.

Given the limited effects of the nuclear power plant on water quality and the continuous efforts that will be made to further reduce the effects during the period 2025-2037, it can be considered that the Project does not compromise the achievement of the good ecological potential of surface waters. The efforts made and to be made to comply with discharge standards will not affect the quality of the Meuse water. There is no reason to fear that the current (admittedly) unsatisfactory state of the Meuse will deteriorate following the prolongation of Tihange 3 for an additional ten years. Deactivation (baseline scenario) will of course make a positive contribution, but it is not certain that this is enough to change the unsatisfactory state of the Meuse to a good state.

Regarding flood risk, there is no problem in the current situation and no problem is expected in the short or medium term. The nuclear power plant is not located in an area susceptible to flooding and is also sufficiently protected against possible future flood risks following more intense rains (due to climate change). There is also no indication that the plant will cause or maintain undesirable flooding risks downstream. Therefore, keeping Tihange 3 open longer will not contribute significantly to reducing or causing the risk of flooding.

The capture of water from the Meuse and the discharge of cooling water are identified as the most impactful operations for local species. Nevertheless, the measures taken by the operator on the basis of the conditions of the environmental permit in force make it possible to drastically reduce the incidences linked to these operations.

Several nature protection sites are found in the region of the Tihange power plant. These sites are legally protected in order to achieve conservation objectives. These objectives, enshrined in Walloon legislation, aim in particular to protect internationally protected species and habitats. It is therefore important to determine whether the extension of the Tihange 3 reactor does not hinder the pursuit of these conservation objectives.

It was determined that the project could impact these species and habitats by pumping water into the Meuse, rejecting cooling water and modifying the quality of the water in this same river, by acoustic or light pollution, by indirect effects due to acid rain and the fact that the site occupies land that could potentially be used for conservation purposes.

The various analyzes led to the conclusion that the impacts of the project on aquatic environments were not such as to jeopardize the conservation strategies of these ecosystems in view of the measures taken voluntarily by the plant operator or within the framework standards imposed by its environmental permit (control of discharges, repulsion system, etc.). Considering that the river on the banks of which the plant is located does not present a great ecological value (ubiquitous species) and that only one reactor out of the three is destined to be maintained in the coming years, no negative evolution of the environment is expected.

Concerning the nuisances linked to the human presence (noise, lighting, etc.), these should not be significant given that the plant is located in an already highly urbanized region and that the operator has also put in place measures to reduce its acoustic impacts. In addition, facilities in favor of biodiversity have been placed at the site level. Finally, the contribution of the extension of Tihange 3 to acid rain will not be significant. Furthermore, it appears that the project will have a positive impact as the electricity that will be produced by the reactor will not have to be produced by gas turbine power plants which emit significantly more combustion gases responsible for an increased amount of acid deposition.Taking into account all the above elements, it can be considered that the extension of the Tihange

3 reactor does not seem incompatible with the conservation objectives set by Walloon legislation, itself transposing the European objectives aimed at protecting species and habitats of interest.

Over the entire period, the postponement of the deactivation of Tihange 3 makes it possible to avoid emissions of around 12 417 ktonnes CO_2eq. This is equivalent to an annual saving of almost 10% of emissions from the "electricity and heat production" sector in Belgium in 2021 (12.8 Mtonnes). The emissions attributable to the maintenance of the Tihange 3 unit are 16 760 tonnes CO_2eq., which represents 0.13% of the emissions avoided, which is negligible compared to these. The Project therefore contributes to the achievement of this objective and the score is positive.

During the 10-year reference period, the Project will have no additional impact on the resilience of the environment to the effects of climate change. The analysis presented in this EIA also clearly shows that the site is resistant to the impacts of climate change well beyond what is expected to occur in 2025. Whether or not Tihange 3 is in service over the reference period 2025-2037 does not change anything. The assessment is therefore neutral.

The relevant and predominant objective for this theme is to ensure the safety of the population. Insofar as the Tihange power plant is a Seveso establishment and, therefore, is subject to strict regulations, particularly in terms of fire prevention, prevention of major accidents and related domino effects and annual inspections, it is considered that the continuation of its activities for a period of 10 years does not hinder the achievement of the main political objective of this theme. Psychosomatic effects are also not expected. On the other hand, we can speak of a positive effect on health from keeping Tihange 3 open longer, insofar as the risk of power cuts and the potential health effects associated with it are considerably reduced.

4.1.2 Radiological impacts

Potential radiation exposure for humans and the environment during normal operation is linked to direct radiation from the radioactivity present on the site and from gaseous and liquid releases containing certain concentrations of radioactivity.

Readings from the TELERAD network operated by the FANC-AFCN show that the dose of external radiation near CN Tihange is well below the legal limit of 1 mSv/year and cannot be distinguished from local variations in the natural background.

Surveys taken during a helicopter flight over CN Tihange confirm this point of view. An increase in the dose rate is visible above one of the buildings where the radioactive waste is treated and stored and amounts to approximately 2 times the background value. However, the radiation is shielded laterally and can therefore only be measured above the building and is also well below the reference value of 10 µGy/h, below which the consequences for the environment (fauna and flora) are negligible (e.g. for birds).

The Tihange nuclear power plant has, in the current situation, no significant measurable radiological impact on the environment through atmospheric emissions or on the Meuse. This conclusion of course also applies if we only take into account the operation of Tihange 3.

A calculation based on current release limits shows that even for the "most exposed person" (hypothetically), the dose resulting from atmospheric and liquid releases will still be lower than the effective dose limit for the public of 1 mSv per year . Given that in practice the actual releases only make up a fraction of the authorized limits, the actual dose (for the entire CN Tihange site) is naturally even lower; it is only about 4.5% of the dose limit.

Shutting down Tihange 3 led to the disappearance of some of the gaseous and liquid radioactive releases into the environment. The releases directly linked to the operation of the reactors (and which also contributes the most to the dose resulting from gaseous and liquid releases) will disappear. On the other hand, certain gaseous and liquid releases will continue in the post-operational phase.

Based on experience in Germany, it can be conservatively estimated that the effective dose resulting from gaseous and liquid releases, if Tihange 3 is not extended (and therefore no reactor is in operation on the site of Tihange), in the first year after the shutdown, will have fallen to a level below 0.01 mSv/year and in the following years will fall further below 0.005 mSv/year.

If the project is carried out and the life of Tihange 3 is therefore extended, it can be assumed that the gaseous and liquid discharges linked to the operation of Tihange 3 will continue for 10 years at the same level as today, assuming that the reactor will continue to operate at the same power and that the treatment of gaseous and liquid effluents will remain unchanged. A conservative estimate of the effective dose due to the operation of Tihange 3 alone gives a value of 0.01 mSv/year, and this is constant over the 10 years of prolonged operation. This is well below the current operating license and also lower by a factor of 100 than the legal limit of 1 mSv/year. An effective dose of 0.01 mSv corresponds to the additional dose that an individual receives from increased cosmic rays over a regular flight of 5 hours, at a height of 10 km. The effective dose in normal operation of the project therefore has a negligible impact.

In this EIA , the effects of the projects were also considered on the dose that would result from two design basis accidents and one beyond design basis accident. An analysis based on the safety dossier for Tihange 3 reveals that the effective doses and the equivalent doses to the thyroid resulting from the two basic design accidents for Tihange 3 remain within the set limits. This also applies if the analysis is based on the FANC-AFCN guidelines for new Class 1 installations. In the event of a beyond design basis accident, the effective dose seems to be of the same order as that of the two design basis accidents, but the equivalent dose to the thyroid is lower.

The project therefore involves a limited risk linked to an accident (both design basis accidents and beyond design basis accident). For the whole CN Tihange site, however, the risk will become lower, because during the 10-year period of extension, only Tihange 3 will still be operating on the site.

It is expected that the postponement of the deactivation of the Tihange 3 nuclear reactor will result in an additional quantity of low- and medium-level radioactive waste of approximately 405 m^3 for a production period of 10 years. This is mainly category A waste, with only a limited amount of category B waste. represents a marginal increase (<1%).

Assuming that the additional quantity of category B waste is negligible, the additional volume of waste corresponds to approximately 253 monoliths or 0.27 modules in the disposal facility for category A waste. The (volumetric) capacity of this repository is 34 modules.

Furthermore, extending the operation of Tihange 3 for 10 years will generate an additional quantity of approximately 420 spent fuel assemblies. This represents an increase of 3.8% compared to the entire Belgian fuel inventory in the event of a permanent shutdown.

A long-term management solution will have to be developed for these fuel assemblies, which amounts to geological disposal if the fissile materials are considered as waste. Assuming that the storage will be in lightly indurated clay, with supercontainers as the primary packaging, the above additional consumption would correspond to 105 additional supercontainers (Type SC-4) and an additional length of storage gallery required of about 650 m. An additional quantity of spent fuel to be stored will not cause a proportional increase in the dose or the estimated risk.

4.2 Summary of transboundary impacts

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

Most of the non-radiological impacts attributable to 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 transboundary effects.

Only the discharge of cooling water, influencing the temperature of the Meuse, could have an impact over a longer distance. However, in view of the temperature data of the Meuse at the level of the last measuring station before the Netherlands, the influence of the discharge of cooling water can be considered negligible (less excesses of 25°C and no daily average exceedance of 28°C recorded in the last 3 years).

It should be noted that several transboundary effects cannot be excluded in the reference situation if the deactivation is not postponed. The magnitude and nature of these transboundary effects will depend to a large extent on where the (theoretical) replacement capacity is planned, the technical characteristics of these installations and their permitting characteristics.

The gaseous and liquid radiological releases in the operation of all CN Tihange units have a, trivial impact (around 0.044 mSv/year) for the hypothetically most exposed person who is just outside the CN Tihange site. The dose that could come from radiation from the site remains within the margins of natural variations. Given the fact that the impact can only diminish with distance (dilution for discharges and the inverse square law for all direct radiation), it can be said that in normal operation of CN Tihange, and therefore also during extending the lifetime of Tihange 3, there are no transboundary effects on people and the environment.

The doses calculated for the accidents considered for Tihange 3 for the neighboring countries are such that no direct countermeasures such as sheltering or the administration of stable iodine are required. It cannot be completely ruled out that very limited and short-term measures are necessary with regard to the food chain. The deposit of long-lived radionuclides is very limited and the radiological impact of these accidents therefore remains limited.

5 General summary of project impacts

5.1 Assessment of conventional impacts

The life extension of Doel 4 and Tihange 3 implies that for an additional period of 10 years sanitary wastewater (purified), treated industrial wastewater and cooling water (heated) will be discharged into the Sea Scheldt and the Meuse 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 waters being limited, this will not lead to a deterioration in the ecological status of the Sea Scheldt (Doel) or de la Meuse (Tihange), provided that sustained attention is paid to monitoring and timely adjustments. Nor does the project compromise the realization of the good ecological potential of the two bodies of water.

The Biodiversity discipline studied the effects of the project for the Doel site in terms of surface water quality, barrier effect, mortality, nuisance, occupation of space, eutrophication and acidification. No effects were to be expected with regard to the barrier effect and direct land occupation. For mortality, there may be a (limited) effect due to the suction of cooling water. In terms of disturbances, only changes with regard to noise pollution are to be expected. The importance is rather limited, since during the period of the life extension, the nuisance will only come from Doel 4. Furthermore, it is an existing noise which is continuous and predictable, one therefore does not expect a significant impact on nearby species.

The effects of the operation of Doel 4 in terms of acidifying and eutrophicating deposits are negligible. In addition, other factors such as the water quality of the Scheldt are much more decisive for the trophic situation there. On the other hand, positive effects in terms of nitrogen deposition 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 leads to a local deterioration of the water quality, which, however, in Doel remains limited to the area inside the longitudinal dike. Significant effects on the entire Scheldt ecosystem are avoided in this way. Locally, there is no indication that the effects are detrimental to the organisms present. Given the designation of the Scheldt itself as a Habitats Directive Area and the possible importance of this area for the birds of the Birds Directive Area this is an important conclusion.

For Tihange, the analysis shows that the effects of the project on the aquatic environment are not such as to question the conservation strategies of the ecosystems concerned, given the measures taken by the operator of the installation, that whether or not it is within the framework of the provisions of its environmental permit (control of discharges, repulsion system, etc.). Given that the Meuse near the Tihange power plant does not have a great ecological value (essentially ubiquitous species) and that only one out of three reactors is remains in operation in the years to come, no negative evolution of the aquatic environment is to be expected.

Disturbance of wildlife due 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 installation. In addition, measures have also been taken on the site to enhance local biodiversity.

The contribution of the life extension of Tihange 3 to acid deposition will not be significant. As for Doel 4, we can even assume a positive effect, since the electricity that will be produced by the reactor does not necessarily have to be produced by the TVG installations, which emit much more fumes responsible for acidification and the deposit nitrogen.

Considering all of the above elements, it can be assumed that the extension of the lifespan of Tihange 3 is not incompatible with the conservation objectives set by Walloon legislation.

The operation of KC Doel and CN Tihange can also have an impact on air quality. The main sources with a possible impact are steam boilers and diesel engines, which however only have a limited number of operating hours per year. As more incineration facilities are taken out of service as other reactors at both sites are shut down, the impact of these facilities will further decrease.

The impact calculations for KC Doel show that the impact on the air quality in the surrounding area is negligible (less than 1% of the limit values or test adopted). It is therefore not necessary to take mitigating measures.

If the lifetime of Doel 4 and Tihange 3 is not extended, electricity will instead have to be produced from (partially) fossil fuels. The emissions which occur (and which can be considered as "avoided" when the lifetime of Doel 4 and Tihange 3 is extended) are much higher than the emissions which occur during the operation of Doel 4 and Tihange 3, and the impact on air quality will also be greater.

The greenhouse gas emissions that can be attributed to the operation of Doel 4 and Tihange 3 together amount over the lifetime extension period to approximately 31 ktonnes (cumulative). The greenhouse gas emissions avoided by keeping Doel 4 and Tihange 3 open longer are of another order. Over the entire period, the postponement of the deactivation of the two reactors makes it possible to avoid emissions of around 24 830 ktonnes of CO_2eq. This represents an annual saving equivalent to nearly 20% of emissions from the “electricity and heat production” sector in Belgium in 2021 (12.8 Mtonnes). If we compare with the emissions released by the operation of Doel 4 and Tihange 3 over the same period (together 31 ktonnes), we can conclude that the emissions from the two reactors over the period covered by the extension of the duration of together represent only around 0.12% of emissions avoided over the same period.

Neither Doel 4 nor Tihange 3 have any influence on the resilience of their environment to the consequences of climate change during the reference period. In the temporal perspective of life extension, the two sites are also not vulnerable to the consequences of climate change, and this situation is independent of whether or not the operation of Doel 4 and Tihange 3 is extended. .

The project has no significant health consequences. Due to the measures taken and, in the case of Doel, also the specific circumstances (brackish feed water), Legionella has never been a problem in the past, and there is no reason to assume that it will be different during the life extension. With regard to the perception of risk related to nuclear accidents, it can be said that the perception of risk exists, but that there is no demonstrable link with psychosomatic effects. Finally, it can be confirmed that the extension of the lifetime of Doel 4 and Tihange 3 significantly reduces the risks of power cuts (especially in the first years of the extension of the lifetime), thus having an effect positive to avoid the health and safety effects that are likely to be associated with power outages. Finally, it can be said that in terms of external safety, no significant increase in risk is expected due to the extension of the service life.

5.2 Assessment of radiological impacts

5.2.1 Impact on people and the environment during normal operation

Exposure to ionizing radiation during normal operation and the associated impact on people and the environment result, on the one hand, from direct radiation from the sites and radioactive gaseous and liquid releases. The dose from exposure to direct radiation at the border with and outside the sites is very low. It is indistinguishable from natural variations in background radiation. External radiation also decreases sharply with distance (inverse square law).

With an extension of Doel 4 and Tihange 3 for an additional 10 years after 2025, liquid and gaseous discharges during normal operation will be at the same level as those resulting from the operation of Doel 4 and Tihange 3 currently and over the past years. Gaseous and liquid releases represent only a fraction of the release limits set in the operating licenses of KC Doel and CN Tihange and the dose is mainly determined by the gaseous releases of carbon-14 (C-14). This radionuclide, also of natural origin, is produced during the operation of reactors 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) resulting from gaseous and liquid releases for the most exposed person (critical individual) is estimated at 0.010 mSv/year, for the 10-year period of of additional operation. This is an insignificant dose, well below the legal limit of 1 mSv/year. Moreover, this dose is a very conservative estimate (critical individual: most sensitive age category, place of maximum exposure, food from the place where the radionuclide concentrations are highest, etc.).

Given the final shutdown, according to the current schedule, of the other reactors of the two sites, it is expected that the exposure resulting from the activities on the KC Doel and CN Tihange sites after 2025, also with the extension of Doel 4 and Tihange 3, will decrease compared to the situation of recent years. The typical effective dose for the critical individual from gaseous and liquid releases has been estimated in recent years at around 0.02 mSv/year for KC Doel and 0.03-0.05 mSv/year for CN Tihange, depending on the period considered. and assumptions. After 2025, and with the extension of Doel 4 and Tihange 3, the effective dose in the considered period of the project will decrease for the entire KC Doel site from 0.017 to 0.013 mSv/year and for CN Tihange from 0.020 to 0.015 mSv/ year. 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 of Tihange 1 and 2 for CN Tihange. The impact on the environment is also negligible and will decrease further for both sites KC Doel and CN Tihange, also with the extension of Doel 4 and Tihange 3. The monitoring of gaseous and liquid discharges and the monitoring of environment within the framework of the Belgian surveillance program of the territory and a specific program carried out by the operator will make it possible to constantly monitor the impact on people and the environment. Since the doses and impact on people and the environment at the site perimeter are negligible, there are also no transboundary effects during normal operation.

Finally, we would like to point out that during the period of execution of the Project, it is possible the dismantling will start of one or more of the other reactors. This could influence the radiological situation, but is outside the scope of this environmental impact assessment. This requires a separate environmental impact assessment.

5.2.2 Impact on people and the environment in case of accident

There were two design basis accidents, namely the Loss Of Coolant Accident – (LOCA) and the Fuel Handling Accident (FHA) studiedwhich can be considered overarching for this type of accident, and a beyond design basis accident, a Complete Station Black-Out (CSBO) with core meltdown, which in turn can be considered as representatitive for the two 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 according to the FANC-AFCN/Bel V guidelines for new Class 1 installations were also used for the impact analysis. The results of this analysis also fall within the limits of general data under Article 37 of the Euratom Treaty. Strictly speaking, this last assessment is not applicable here, as Doel 4 and Tihange 3 are already existing Class 1 installations. However, it is the single analysis that was used to assess the effects of the CSBO accident and this analysis also provides insight into a wider range of effects that may be associated with an design basis accident (LOCA and FHA), such as the soil contamination.

Although Doel 4 and Tihange 3 are reactors 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 (volume of the reactor building, rate of leakage to the outside, etc.) and to the safety systems with regard to the quantities of radioactivity released into the environment, but also to the height of the release (stack height) at both sites. It should also be noted that conservative estimates are made, both of the quantities of radioactivity released during accidents (in the scenarios envisaged) and of the calculation of the impact. This means that in the case of a real accident that takes place according to the scenarios envisaged (including the operation of the safety systems), the effects will always, or almost always, be lower.

For Tihange 3, for the 3 accidents considered, according to the directives for new Class 1 installations, the effective dose and the equivalent dose to the thyroid during the accident do not exceed the specific reference levels for immediate protective measures such as sheltering, evacuation or administration of stable iodine (ingestion of contaminated food is not considered, as this can easily be avoided). The effective dose is the highest for the beyond design basis accident (CSBO) and is 4.29 mSv over the duration of the accident (5 mSv in 24 hours is the reference level for sheltering). This dose is comparable to the dose that an average Belgian receives per year both from natural radiation and from medical diagnostic applications. The dose to the thyroid is limited in this accident due to the Containment Filter Venting System (CFVS) which, according to the operating license, must be used in such an accident. This system significantly filters out the iodine and aerosols present (including the long-lived Cs-137) and the effective dose is therefore largely due to radiation from the radioactive noble gases in the cloud. The FHA accident gives the highest dose to the thyroid of the accidents considered (4.95 mSv for Tihange for the 1-2 year age category). This is the result of the release of iodine isotopes. In this accident as well as in the LOCA accident, it is possible that the food chain will be contaminated by radioactive iodine and countermeasures will be essential. Given the limited half-lives of iodine isotopes, contamination will be limited in time. Contamination by long-lived radionuclides such as Cs-137 is very limited (LOCA only) and therefore no impact on the food chain is expected in accident scenarios. The lifetime effective dose (over 50 years for adults and up to 70 years for other age groups) resulting from accidents is limited and well below 1 Sv. The transboundary impact of all accidents considered for Tihange 3 is very limited due to the distance with neighboring countries. Doses are limited and radioactive iodine contamination is conservatively estimated possible, but at the limit to take countermeasures.

For the Doel 4 accidents considered, equivalent to Tihange 3, according to the analysis of the new Class 1 installations, the effective dose is the highest for the CSBO accident and amounts to 8.89 mSv, i.e. therefore exceeding the reference level for sheltering (5 mSv in 24 u), but remains significantly lower than the reference level for evacuation (50 mSv in 1 week). The equivalent doses to the thyroid are similar for the LOCA and FHA accident for Doel 4 and amount to approximately 35 mSv (age category 1-2 years). These values are above the reference level for the administration of stable iodine for children and pregnant women (equivalent thyroid dose of 10 mSv). Based on the conservative estimates of iodine isotope deposition, the values derived for the food chain will also be exceeded for the design basis accidents considered for Doel 4 and countermeasures for the food chain may therefore prove to be essentials (typically for milk, leafy vegetables and meat). Also for the CSBO accident scenario for Doel 4, it is possible that the derived level for the soil concentration of 4000 Bq/m^2 will be exceeded and that measures for the food chain are therefore essential. In this accident, however, the iodine deposition is lower than in the design basis accidents (LOCA and FHA). However, for all accident scenarios, this will again be limited in time due to the limited half-life of the major iodine isotopes (half-life of 8.02 days for I-131). Contamination by long-lived radionuclides like Cs-137 will be very limited and will not require countermeasures in the scenarios considered. One year after the accident, no countermeasures are therefore to be expected. Moreover, the lifetime effective doses are also much lower than 1 Sv for the Doel 4 accident scenarios.

The cross-border impact of accidents remains limited. For all the accident scenarios envisaged for Doel 4 and Tihange 3, no immediate countermeasures such as sheltering, evacuation or taking stable iodine to protect the thyroid gland are necessary in the neighboring countries. Mainly in the Netherlands, given the proximity of Doel 4, contamination of the food chain by iodine isotopes is possible, which would require countermeasures. In the other neighboring countries, this eventuality is very unlikely, both for Doel 4 and for Tihange 3, but is not totally excluded for certain countries. However, contamination with iodine isotopes is limited in time, given the limited half-life. Contamination by long-lived radionuclides such as cesium 137 is very limited and does not require countermeasures. The lifetime dose due to the considered accident scenarios is therefore very limited in all neighboring countries.

For the impact on fauna and flora, taking into account the quantities released and the associated deposits in the various accident scenarios, we can expect a very moderate to negligible effect for Doel 4 and a negligible effect for Tihange 3. These are again conservative estimates.

Given that after 2025, according to the current schedule, Doel 4 and Tihange 3 are the only two reactors on the respective sites of KC Doel and CN Tihange which are operated for the production of electricity, the probability of a serious accident on both sites decreases. After the final shutdown of the other reactors, the radioactive inventory drops rapidly, an accident remains possible (by loss of cooling for example), but the potential radioactive releases and therefore also the potential impact will decrease rapidly over time. The impact of any multi-unit events on the two sites (accidents involving more facilities, such as the Fukushima-Dai-ichi accident) will therefore also be less after 2025. Given the physical distance between the sites of the two reactors, the probability of a simultaneous accident involving Doel 4 and Tihange 3 is much lower than multi-unit events on the same site.

5.2.3 Impact on waste and spent fuel production

An extension of the operation of the Doel 4 and Tihange 3 units will lead to the creation of an additional quantity of low- and intermediate-level radioactive waste which, on the basis of long-term averages, is estimated at a total of 864 m^3 for the 10-year extension. This is primarily category A waste, with only a limited amount of category B waste, which may include some 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 case, 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 2161 of 400L packages which will be conditioned in 540 disposal units (monoliths) for surface disposal in the facility provided for this purpose in Dessel , for which the licensing procedure has been completed. The (volumetric) capacity of the repository is 34 modules, with a significant reserve of 20% or 5.4 modules, to take into account the uncertainties surrounding the 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. As this is the extension of an existing activity, giving rise to families of waste with known characteristics, no other impacts are expected for waste management in the short or long term.

An estimate has also been made of the cumulative number of fuel assemblies that will be consumed during a 10-year LTO period at Doel 4 and Tihange 3. For the two units combined, the LTO will result in an additional consumption of approximately 810 fuel assemblies. of fuel (type UOX 14ft). Weighted in relation to the entire Belgian fleet of reactors, this corresponds to a surplus of 7.3% in number of fuel assemblies, or 8.9% in tonnes of heavy metal (tHM).

Given this relatively limited quantity and assuming that the properties of these elements will be similar to those of existing fuel elements, no impact on their future management is expected.

Due to the postponement of deactivation of Doel 4 and Tihange 3, the disconnection of the grid from the units at both sites will be spread in time where it would otherwise be very condensed over a few years. Due to the under construction SF2 storage facilities 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 flows are generated during dismantling operations, the majority of which can be free released and recycled. However, the core of the installation, ie the reactor vessel and the internal parts, can be considered as radioactive waste. The classification of waste (category A or B) is based on the concentration of radioactivity of radionuclides important for safety and therefore depends on the neutron flux during reactor operation and the irradiation time. Calculations of activation of the various parts of the vessel steel demonstrated that the total activity barely increases, and that the small fraction of long-lived isotopes (important for long-term management) will increase by 25%, proportional to the duration of the 10-year operating extension. This limited increase in activity due to LTO is expected to have little or no effect on the delineation of the transition zone between Category A and Category B waste. No significant changes are therefore expected between the different volumes of waste.

5.3 Mitigation measures and knowledge gaps for non-radiological impacts

5.3.1 Mitigation measures

Given the (very) limited non-radiological effects of the project, mitigation measures are not on the agenda. However, a number of recommendations can be made for the discipline Water.

For the Doel site, these are:

1. Prevent groundwater and cooling water from draining into the mixed sewer system and separate rainwater (e.g. in new projects or maintenance work), which leads to dilution of the waste water and frequent overflows.
2. A permanent optimization of the wastewater treatment is recommended to continue to solve the old problems (nitrite, AOX), a more coherent reading of several other parameters allowing to check if the discharge standards are respected;
3. Future alterations and renovations must be sufficiently flood and climate resistant to absorb the consequences of more intense rainfall 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 to optimize water purification and (rain)water management for Doel 4.

The following recommendations apply to both Doel and Tihange:

1. Separate rainwater from sanitary waste water and reuse rainwater as sanitary water, avoid city water consumption as much as possible.
2. Softening (infiltration), creation of green roofs or water bodies (buffering) on the site to reduce the heat island effect, to retain and store (rain)water more locally and to avoid dryness;
3. Advance fine-tuning of cooling capacity based on temperature monitoring of the Sea Scheldt and Meuse.

5.3.2 Knowledge Gaps and Monitoring

For the theme Water, there is a lack of information on the precise proportion of wastewater coming from Doel 4 and Tihange 3 and therefore on the exact contribution of the operation of Doel 4 respectively Tihange 3 to residual pollution. being found in the Scheldt and in the Meuse.

For the theme Air, the main knowledge gaps are related to emissions from combustion units, as measured values and model characteristics are not known for all units. These gaps were filled using emission factors from the literature and assumptions. This leads to increased uncertainty in the results of the impact calculations, but even if this is taken into account, the impact can be said to be negligible.

Finally, there is uncertainty as to how any lost capacity of Doel 4 and Tihange 3 (if the project is not realised) would be filled. This means that effects on air quality and nitrogen deposition, among others, cannot be accurately estimated in the baseline situation.

For Tihange, it is proposed to check the Seveso status of the site after the shutdown of Tihange 1 and 2. Even if, in such a case, the plant was no longer classified as a Seveso installation, attention must be paid prevention of accidents in order to control potential risks in terms of safety for the population.

5.3.3 **Mitigation measures and knowledge gap**s regarding radiological impactsEmergency planning

5.3.3.1 Objectives and basic concepts

The objective of nuclear emergency planning is to ensure that there is sufficient capacity within the operational organization and at the local, regional, national and, where appropriate, international levels, to respond effectively to a nuclear emergency. This capability refers to an integrated set of infrastructure elements that include, but are not limited to: competent authority and responsibilities, organization and personnel, coordination, plans and procedures, instruments, equipment and facilities , training, drills and drills, and a management system .

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

a) Regain control of the situation and limit its consequences;
b) Save lives;
c) Avoid or minimize severe deterministic effects;
d) Provide first aid, provide critical medical treatment and manage the treatment of radiation injuries;
e) Reduce the risk of stochastic effects;
f) Keep the public informed and maintain public confidence;
g) Minimize non-radiological effects;
h) Protect property and the environment as much as possible;
i) Prepare, to the extent possible, for the resumption of normal social and economic activity.

Legal framework

International and European directives

Table 101 presents the main European and international directives relating to nuclear emergency planning.

Table 5 : Relevant European and international directives regarding nuclear emergency planning.

International and European directives	Contenu pertinent concernant la planification d'urgence nucléaire
2013/59/Euratom[i]	The Directive requires Member States to put in place a disaster management system including contingency plans for the different types of identified nuclear and radiological emergencies that may arise. Directive 2013/59/Euratom of December 5, 2013 is partially translated in the Royal Decree of March 1, 2018 establishing the nuclear and radiological emergency plan for Belgian territory (see Table 102).
IAEA Safety Standards Series No. GS-G-2.1[ii]	These guidelines describe appropriate responses to a range of nuclear or radiological emergencies.
IAEA Safety Standards Series No. GSR Part 7[ii]	This publication establishes the requirements for an adequate level of preparedness for a nuclear or radiological emergency. Application of these requirements is intended to mitigate the consequences of a nuclear or radiological emergency should it occur despite all efforts to prevent it.
ICRP Publication 63[iii]	This publication provides quantitative guidance for intervention levels. These guidelines relate to the introduction of protective measures in the very short term and their maintenance over a longer period.
ICRP Publication 109[iv]	This report provides guidelines on preparing for and responding to all radiation exposure situations in the event of a nuclear or radiological emergency.
WENRA Safety Reference Level for Existing Reactors 2020[v]	This report contains guidelines on a harmonized approach to nuclear safety in the different Member States.

Belgian legislation

Below is an overview of the relevant Belgian legislation for nuclear emergency planning (Table 102).

Table 6 : Belgian legislation relevant to nuclear emergency planning.

Nature	Content
Law of 15 April 1994 relating to the protection of the population and the environment against the dangers resulting from ionizing radiation and relating to the FANC.[vi]	This law includes provisions for effective protection of the population, workers and the environment against the danger of ionizing radiation. The law also provides for the creation of a public institution with legal personality: the "Federal Agency for Nuclear Control", abbreviated as AFCN, which is responsible for ensuring compliance with this law and its implementing decrees.
RGPRI (20/07/2001)[vii]	This regulation applies to all actions likely to lead to a risk following exposure to ionizing radiation emitted by an artificial or natural radiation source, when natural radionuclides are or have been processed due to their radioactive properties, their fissile properties or their culture properties. This royal decree notably sets the basic standards for protection against exposure to ionizing radiation.
Ministerial circular NPU-1 concerning emergency and intervention plans (26/10/2006)[viii]	This circular provides further explanations on the provisions and principles contained in the Royal Decree of 16 February on emergency and intervention plans.

RD on safety requirements for nuclear installations (30/11/2011)[ix]	This Royal Decree is intended for operators of class 1 nuclear installations, and in particular of nuclear reactors for the production of electricity. It promulgates a series of safety rules that the operator must apply.
Royal Decree modifying the RGPRI (20/07/2020)[x]	This Royal Decree amends various provisions of the RGPRI in order to partially transpose Directive 2013/59/EURATOM. Some additional provisions are also inserted.
Royal Decree establishing the nuclear and radiological emergency plan for Belgian territory, MB 6 March 2018[xi]	This RD establishes the nuclear and radiological emergency plan for Belgian territory. This plan aims to ensure the coordination of measures to protect the population and the environment in the event of a radiological emergency directly or indirectly threatening Belgian territory. The plan defines the tasks to be performed and the skills of all parties involved. Belgium has had a national nuclear and radiological emergency plan since 1991. Since then, many updates have been made. After consultation with all the (inter)national partners concerned, the nuclear and radiological emergency plan for Belgian territory was updated in 2018.

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

The emergency plan for each Belgian nuclear unit is systematically described in the safety report and approved when the license is issued. In addition, the "internal" emergency plan contains instructions for all actors.

In the event of an accident in a nuclear unit of KC Doel or CN Tihange, the control room in the plant concerned (i.e. the Technical Center on the site) is activated and manages all the technical problems in order to control the accident and to limit its consequences. At site level, the Emergency Plan Room (SPU Tihange) / Noodplankamer (NPK Doel) manages environmental impacts and liaises with the CGCCR (Government Center for Coordination and Crisis)[xii].

5.3.3.3 Harmonization between neighboring countries for KC Doel and CN Tihange

It is desirable that countries coordinate in advance their principles concerning the approach to be followed in the event of a transboundary nuclear accident. This prevents the measures taken on one side of the border from being significantly different from those taken on the other side. In this context, the European HERCA-WENRA cooperation agreement promotes harmonization in border areas around nuclear power plants. Harmonization means in this approach that the neighboring country does not take measures that conflict with or go beyond those of the accident country.

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

Table 7 : Indicative intervention values (VII) and emergency preparation or planning zones (radius of circles in km) (ZPU) set by Belgium, the Netherlands, Germany and France around the nuclear power plant of Doel and Tihange for immediate protective measures in the event of a nuclear emergency).

	Policy Belgium		**Policy Netherlands**		**Policy Germany**		**Policy France**	
	VII	ZPU	VII	ZPU	VII	ZPU	VII	ZPU
Reflex zone	-	3,5 km[1]	-	-	-	5 km[2]	-	2 km[1]

[1] Abri immédiat en cas de General Emergency – reflex mode.
[2] Évacuation immédiate en cas de General Emergency – reflex mode.

Evacuation	50 mSv(3	10 km	100 mSv	10 km	100 mSv(3	10 km	50 mSv	(5 km(4))
Sheltering	5 mSv(5	20 km	10 mSv	20 km	100 mSv(3	100 km	10 mSv	10 km (→ 20 km(4))
Stable iodine prophylaxis - ≤ 40 year	50 mSv(6	20 → 100 km(7	100 mSv	20 km	250 mSv(8	100 km	50 mSv	-
- ≤ 18 year and pregnant women enceintes	100 mSv(6	20 → 100 km(7	50 mSv	100 km	50 mSv(8	Allemagne	50 mSv	-

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

5.3.3.4 Organization of emergency planning exercises for KC Doel and CN Tihange

KC Doel and CN Tihange organize internal exercises several times a year. In addition, the nuclear and radiological emergency plan for Belgian territory provides for an annual emergency plan exercise to be organized for KC Doel and CN Tihange by the crisis centre. Every three years, a large-scale exercise must be organized for a nuclear site, in principle involving all disciplines. There are two types of exercises:

• Theoretical exercises: the different actors sit together around the table and discuss how they would act in reality;

• Field exercises: the exercise is organized at the location of the (simulated) emergency situation. In principle, there is a real deployment of men and resources on this place, but different modalities are possible.

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

Table 104 and Table 105 illustrate the exercises for KC Doel and CN Tihange over the last 10 years. There was twice an exercise for Doel 4, and 5 times an exercise for Tihange 3.

Table 8 : KC Doel exercises over the past 10 years (Source: NCCN).

Exercice	Date	Installation	Ampleur de l'exercice
Exercice KC Doel 2012	29 mars 2012	Doel 2	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercice KC Doel 2013	22 octobre 2013	Doel 3	**Exercice avec encadrement méthodologique et déploiement sur le terrain.**
Exercice KC Doel 2014	14 octobre 2014	Doel 2	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercice KC Doel 2015	26 mars 2015	Doel 4	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercice KC Doel 2016	15 mars 2016	Doel 1	Exercice d'ampleur limitée sans déploiement sur le terrain.

[3] Dose efficace intégrée totale sur 7 jours (inhalation et rayonnement externe).
[4] En préparation
[5] Dose efficace intégrée totale sur 24 heures (inhalation et rayonnement externe).
[6] Dose totale intégrée équivalente à la thyroïde (inhalation)
[7] Zone d'extension.
[8] Dose totale intégrée à la thyroïde sur 7 jours (inhalation)

Exercice KC Doel (DoelEx) 2017	21 novembre 2017	Doel 3	**Exercice avec encadrement méthodologique et déploiement sur le terrain.**
Exercice KC Doel 2018	8 mai 2018	Doel 4	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercice KC Doel 2019	21 mars 2019	Doel 2	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercice KC Doel 2020	14 septembre 2020	Doel 1	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercice KC Doel 2021	19 octobre 2021	Doel 2	**Exercice avec encadrement méthodologique sans déploiement sur le terrain.**
Exercice KC Doel 2022	17 mai 2022	Doel 3	Exercice d'ampleur limitée sans déploiement sur le terrain.

Table 9 : CN Tihange exercises over the past 10 years (Source: NCCN).

Exercice	Date	Installation	Ampleur de l'exercice
Projet d'Exercice Grande Ampleur Site Electrabel SA Tihange (PEGASE) 2012	20 et 21 novembre 2012	Tihange 3	**Exercice avec encadrement méthodologique et déploiement sur le terrain.**
Exercise Tihange 2013	5 décembre 2013	Tihange 1	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercise Tihange 2014	26 mai 2014	Tihange 3	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercise Tihange 2015	26 novembre 2015	Tihange 1	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercise Tihange 2016	29 novembre 2016	Tihange 3	**Exercice avec encadrement méthodologique et déploiement CELMES sur le terrain.**
Exercise Tihange 2017	24 novembre 2017	Tihange 1	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercise Tihange 2018	30 novembre 2018	Tihange 3	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercise Tihange 2019	16 mai 2019	Tihange 2	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercise Tihange (TihEx) 2020 phase 1* Exercise Tihange (TihEx) 2020 phase 2*	17 mars 2021 29 juin 2021	Tihange 3	**Exercice avec encadrement méthodologique et déploiement sur le terrain.**
Exercise Tihange (TihEx) 2022	28 novembre 2022	Tihange 2	Exercice d'ampleur limitée sans déploiement sur le terrain.
Exercise Celmes 2022	25 – 26 novembre 2022	Tihange ?	**Exercice avec encadrement méthodologique et déploiement sur le terrain.**

5.3.4 Knowledge gaps

Various uncertainties can play a role in the calculation of the radiological impact of the releases, such as the quantity and characteristics of the radionuclides released (the so-called source term), weather conditions, location and age of people and local lifestyles (e.g. diet). To calculate the impact in normal operation, the releases are well known and the meteorological conditions are taken into account for a complete (reference) year. In addition, the most exposed person is considered to have very conservative lifestyles with regard to the radiological impact. This results in a conservative estimate of the radiological impact. Also for accident scenarios conservative assumptions are made, but the actual exposure in an accident depends on the exact quantities of radionuclides released, the precise weather conditions (e.g. local showers) and the location and people's habits. This can possibly be supplemented in the event of an accident by countermeasures such as sheltering, administration of stable iodine and evacuation. Notwithstanding the uncertainties described above, in normal operation, the doses to which one is exposed are extremely low (well below 1 mSv/year), but also in an accident situation, in most cases, the dose incurred will be limited. for all or most of the exposed population (see §9.2.2). The doses are therefore much lower than those corresponding to the appearance of deterministic effects (deterministic effects must be avoided at all times, including in accident situations: see the basic concepts (see §2.3.2 and § 9.4.1), but also almost always well below effective doses when epidemiological studies can demonstrate stochastic effects of radiation (appearance of cancers and genetic effects (see §2.3.2) [reference to the § Basic concepts of radiation protection used in the assessment]. Indeed, the likelihood of these effects occurring is very low at such low doses, in addition to a strong spontaneous occurrence of the same effects. Although, under the precautionary principle, we associate the possibility of occurrence of stochastic effects with each additional exposure incurred (dose), no matter how small, it is not possible to confirm this occurrence with certainty. However we know with certainty that the probability of this occurrence is very low, or even non-existent (<0.57% at an effective dose of 100 mSv: see § 2.3.2).

6 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.

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[x] Arrêté royal du 20 juillet 2020 modifiant l'arrêté royal du 20 juillet 2001 portant règlement général de la protection de la population, des travailleurs et de l'environnement contre le danger des rayonnements ionisants et transposant partiellement la directive 2013/59/EURATOM du 5 décembre 2013 fixant les normes de base relatives à la protection sanitaire contre les dangers résultant de l'exposition aux rayonnements ionisants et abrogeant les directives 89/618/EURATOM, 90/641/EURATOM, 96/29/EURATOM, 97/43/EURATOM et 2003/122/EURATOM et le stockage de substances radioactives à l'extérieur des bâtiments.
[xi] Arrêté royal du 1er mars 2018 portant fixation du plan d'urgence nucléaire et radiologique pour le territoire belge.
[xii] FANC (2017) Sixth meeting of the Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. National report.