Part III. Environmental impact assessment deferred deactivation of Tihange 3 nuclear power plant.

1 Non-radiological effects Tihange 3

1.1 General

The following structure is used to describe and assess the impact of the various disciplines in this chapter:

Relevant policy objectives

A description of the various policy objectives that will be assessed. The source of these objectives are the various relevant policy documents. These are strategic level objectives.

Relevant effects and causal relationships.

A description of the impacts relevant to an assessment of the extent to which the project contributes to the achievement of policy objectives and the causal relationship to the project.

Delineation of the study area and description of the reference situation

In principle, the starting point is the situation in 2025, the year in which Tihange 3 would be shut down according to the Nuclear Exclusion Act. We also describe here any (autonomous or controlled) developments that may make the situation in 2025 (fundamentally) different from the current situation (2023), as well as developments that may affect the development of the reference situation over the lifetime extension period. If such developments occur, we take them into account when describing the effects (development scenario or second reference scenario).

Description of effects

Here we describe the effects relevant for the assessment in the next step. Where possible and relevant, we also give an indication of cumulative effects over the ten years (e.g., cumulative emissions; possibly taking into account annual fluctuations in emissions).

Assessment of impacts against policy objectives.

Here the extent to which the project does or does not contribute to the achievement of the various policy objectives (through impacts) is assessed.

1.2 Water

1.2.1 Relevant policy objectives

Directive 2000/60/EC establishing a framework for Community action in the field of water policy, commonly referred to as the Water Framework Directive, was adopted on October 23, 2000 (Official Journal of December 22, 2000).

It aims to protect and enhance the aquatic environment on the one hand and contribute to the sustainable, balanced and equitable use of water on the other.

The ultimate goal of the Framework Directive is to achieve "good status" of all EU waters. Separate environmental objectives are set for surface waters, groundwater and protected areas.

For surface waters, the main objectives are:

- Prevent the deterioration of the status of all surface water bodies;
- Achieve good ecological potential and good chemical status of all artificial and heavily modified water bodies;

- Progressively reduce pollution from priority substances and cease or gradually reduce emissions, discharges and losses of priority hazardous substances[92].

River basin management plans

On Oct. 23, 2000, the European Union adopted the Water Framework Directive (WFD), which establishes a legal framework for water management throughout Europe. The objective is to improve the quantitative and chemical status of all European waters by 2016. Wallonia is part of four international river basins or river basin districts (Meuse, Scheldt, Rhine and Seine) and has clearly defined the boundaries of 15 natural subdivisions, the sub-basins. Moreover, it has itself redefined the framework of its own hydrographic sub-basins (decree of September 13, 2001).

Implementation of this directive includes the preparation of management plans to protect, enhance and restore surface and groundwater bodies. These management plans must be regularly updated.

The first management plans (2009-2015) were approved in their final version on June 27, 2013 by the Walloon government, which is the competent authority for implementing the Water Framework Directive in the Walloon parts of the international river basin districts of the Meuse, Scheldt, Rhine and Seine rivers. The second management plans (2016- 2021) were also approved in their final version on April 28, 2016. The drafts of the third management plans (2022- 2027) were approved by the Walloon government on Sept. 29, 2022. They are currently subject to a public review that ends May 02, 2023. They should then be adopted in their final version and published in the Belgian Official Gazette in July 2023.

The "good status" scenario reduces to zero the target distance estimated for the different physico-chemical parameters and for the different sectors affecting the ecological status of water bodies. This target distance represents, for a given physico-chemical parameter, the difference between the concentration measured in the water body and the accepted concentration (standard) in this water body. A water body can be degraded by different physico-chemical parameters. Under the "good status" scenario, several measures are proposed to reduce the differences in each of the water bodies. Together, these measures would make it possible to achieve good status/potential for 72% of surface water bodies.

The proposed program of measures does not include all the measures of the "good status" scenario for achieving good status of surface water bodies. However, good status can be achieved for 69% of surface water bodies under this proposed scenario, provided that agricultural measures, particularly those that will be implemented through the Common Agricultural Policy, can achieve a maximum compliance rate (which depends in particular on the implementation conditions) in water bodies under agricultural pressure. In contrast, if these measures are applied to a limited extent or only in water bodies with good status/potential, or that are not under pressure from agriculture, the number of water bodies achieving good status could be limited to 58%.

This program of measures is elaborated in the following steps, which form the various chapters of these management plans:

- Assessment of pressures and impacts of human activities on water resource quality.
- Pressure comparison with declassification parameters.
- Estimate of effort required by sector to achieve good status.
- Proposal for a program of measures that is specific to each water body and proportional to the importance of the target distance.

[92] The list of 45 priority or priority hazardous substances is in Annex X of Directive 2000/60/EC.

The Tihange power plant is located in the Meuse river basin and more specifically in the Meuse- Aval sub-basin.

The Walloon part of the international Meuse District includes 257 water bodies divided into 8 sub-basins. The surface water bodies were defined by the Walloon Government Decree of September 13, 2012 (M.B. Oct. 12, 2012) on the identification, characterization and establishment of threshold values for the ecological status of surface water bodies and amending Book II of the Environmental Code, which contains the water code.

The Tihange power plant is adjacent to the surface water body "Meuse II" (code: MV35R)[93] . This is a so-called "heavily modified" water body with a surface area of 425 km² (336.6 km² in the lower Meuse sub-basin and 87.9 km² in the upper Meuse sub-basin). It includes the Meuse from its confluence with the Ruisseau de Tailfer to the Dutch border. The typology of this water body corresponds to "very large rivers of the Condroz with a limited slope". It is a heavily modified water body.

Protected areas

According to the Water Framework Directive, protected areas cover :

- Areas designated for the abstraction of water for human consumption;
- Water bodies designated as recreational waters under Directive 76/160/EEC, including bathing water areas;
- Nutrient sensitive areas, including areas designated as sensitive under the Nitrates Directive 91/676/EEC and areas designated as sensitive under the Urban Waste Water Treatment Directive 91/271/EEC;
- Areas designated as protection areas for habitats and species where the maintenance or improvement of water status is an important factor for such protection, including relevant Natura 2000 sites designated under Directives 92/43/EEC and 79/409/EEC;
- Areas designated for the protection of economically important aquatic species. The surface water body MV35R does not contain areas designated for human consumption or bathing zones. Therefore, no bathing zones are allowed downstream of the Tihange power plant.

The area of the "Cretaceous Hesbaye " and the area "North of the channel of Sambre and Meuse" are designated as "sensitive areas". About 1.8% (4,918 ha) of the area of the "Cretaceous Hesbaye" zone and about 5.15% (200,966 ha) of the area of the "North of the channel of Sambre and Meuse" zone are located in the catchment area of the water body MV35R. In addition, the entire territory of Wallonia has been designated a "sensitive area".

About 50.1% (246.3 ha) of the area of the Natura 2000 site "BE33010 vallée de la Meuse à Huy et vallon de la Solières" is located in the catchment area of water body MV35R. This water body contains neither wetlands of international importance known as "Ramsar" nor fish-rich wetlands.

In Wallonia, no areas have been designated for the protection of economically important aquatic species.

Flood risk management plans

The European Directive on Flood Risk Assessment and Management (2007/60/EC), transposed into the Water Code, aims to establish a framework for flood risk assessment and management. It aims to reduce the adverse impacts of floods on human health, the environment, cultural heritage and economic activity. Each Member State is asked to work in three phases

[93] Management Plan 2016-2021 - Water Body Characterization Sheet MV35R Meuse II V 2.1, Directorate of Surface Water, 2016.

to go: assess, map, and then manage the flood risk on its territory by implementing measures included in strategic plans, the Flood Risk Management Plans (Plans de Gestion des Risques d'Inondation - PGRI (Scheldt, Meuse, Rhine, Seine)). The purpose of these plans is to enable Member States to set flood management objectives based on preliminary analyses (flood plain map and flood risk map) and taking into account, in particular, costs and benefits.

The 'PGRIs include global objectives for the entire Walloon Region, resulting from the 'Plan PLUIES', and specific objectives for each sub-basin. To achieve these objectives, numerous projects are planned and implemented by a large number of actors active in flood management in Wallonia.

In 2016, the first management plans were approved by the Walloon government. In 2021, following an extensive and cross-cutting consultation process, Wallonia updated its 'PGRIs. The draft 'PGRIs for 2022-2027, approved by the government in March, were submitted for public consultation from May 3 to November 3, 2021. They were then modified based on the comments received from the public survey. Once validated by the Walloon government, the plans will be sent to the European Union.

The general objectives of these plans are :

- Minimal damage to people and property;
- Reduce the negative impacts of flooding on public health, the environment, cultural heritage and economic activity.

Operational objectives have been set for Wallonia:

- Improving knowledge of flooding phenomena through a multidisciplinary approach;
- Reduce runoff velocity and increase infiltration into the watershed;
- Respect the natural dynamics of rivers and promote flood expansion and water storage in their main beds;
- Reduce the flood vulnerability of areas subject to river flooding and mudslides;
- Promote the development of local emergency plans and an effective warning system;
- Reduce the financial and social burden of the consequences of damage.

Under the first cycle of "PGRIs," 42 global measures and 491 projects with a more local scope were implemented between 2016 and 2021. These projects were mostly related to the "protection phase." For the Meuse River Basin District (DH), the proportion of completed projects relative to planned projects is 21.4%.

The consultation process allowed the members of the sub-basin technical committees to define the strategic guidelines for the different sub-basins to which they belong. The strategic guidelines are not defined as actions, but as specific objectives for each sub-basin. From these strategic guidelines follows a whole series of actions to be implemented to achieve them.

The 2nd cycle of the PGRIs, which runs from 2022 to 2027, follows the 1st cycle. The global objectives of the PLUIES plan and the uncompleted projects remain. The second cycle includes new objectives specific to each sub-basin, 41 global measures (new or expanded) and 929 projects (including 103 for the downstream Meuse sub-basin), most of which are new projects.

For the Meuse, 79% of the local projects are aimed at solving a river overflow problem, while the remaining 21% are spread across the territory and concern discharge. "Overflow" projects mainly involve work on the summer bed and floodplain or work to regulate flow. The "runoff" projects mainly concern the natural management of floods, of runoff and of watersheds, as well as on flow regulation and surface water management in urbanized environments.

Objectives

Based on the plans and policy objectives described above, the following river system objectives can be used in the context of the impact assessment of the project to keep Tihange 3 open for 10 more years:

- Maintain and achieve good ecological status of surface waters and prevent their deterioration;
- Maintain and achieve good physical and chemical status of surface waters and prevent their deterioration;
- Reducing the risk of flooding.

1.2.2 Relevant effects and cause-and-effect relationships.

To assess whether or not the Project contributes to the achievement of river system policy objectives and to identify the Project's relationship to any environmental impacts, the most relevant foreseeable impacts of the Project (the deferral of deactivation of Tihange 3) on the river system are summarized below.

After nuclear fuel, water is probably the second most important raw material or resource of the nuclear power plant. The Tihange nuclear power plant relies heavily on the water system for its operation, as the tertiary circuit is fed with water from the Meuse River to cool the condensers of the second circuit. The Tihange nuclear power plant uses cooling towers, also called air coolers, to lower the temperature of the cooling water through natural air circulation. The heated water is sprayed at the base of the tower in the form of droplets and cooled by the rising airflow. Most of this water returns to the condenser, while the rest is discharged into the Meuse River. Only a small part, about 3%, evaporates in the atmosphere: this is the condensation plume (white plume) that escapes from the tower. Each unit has its own water circuit consisting of a water intake from the Meuse, a cooling tower and a cooling water outlet.

Two tertiary water circuits are present in the plant: the raw water circuit (RWC) and the circulating water circuit (CWC). The raw water circuit (CEB) draws water from the feeder canal, which is fed directly by water from the Meuse River and supplies cooling water (Meuse water filtered to 1 mm) to the nuclear and conventional auxiliary equipment (diesel engines, chillers, etc.) of the power plant.

The circulating water circuit (CWC) is the cold source that provides condensation for the steam leaving the turbines. It draws water from the supply canal, which is fed directly by water from the Meuse River upstream of the plant. Water from the CWC is sent to the condensers. After the cooling tower, some of the CWC water is returned to the Meuse. The discharge flow rate into the Meuse is controllable to meet the warming limits established in the permit. Thus, it depends on the flow rate of the Meuse, but also on the air temperature. When hydro-meteorological conditions require it, part of the cooling water leaving the cooling tower can be recirculated in the circuit, which has the effect of reducing the flow rate absorbed, the flow rate discharged and the thermal load discharged into the receiving water environment. When the recirculation flow rate increases, the absorbed flow rate, discharged flow rate and thermal load decrease significantly: thus, by adjusting the recirculation flow rate, the plant can reduce the effects on the aquatic environment and meet the prescribed discharge conditions when surface water availability decreases or when the temperature is high during the year. It should be noted that the recirculation of cooling water leads to a reduction in the efficiency of the plant's internal thermodynamic cycle and, therefore, to a reduction in the energy efficiency of power generation.

It should be recalled that a thermal power plant, whether nuclear or conventional, follows the Carnot principle and its efficiency is a function of the temperature of the hot source (the temperature of the reactor, which is fixed for reasons of mechanical strength) and the cold source (the temperature of the water at the inlet of the condenser). According to the Carnot principle, the colder the cold source, the higher the overall efficiency of the unit. The Tihange plant thus aims to optimize the overall efficiency of the three units while respecting the permit for water discharge and thus producing nuclear units that are less air-polluting than conventional units.

As a result, a large amount of surface water is brought in, heated and partially evaporated in the cooling towers, and then discharged into the Meuse River at a slightly higher temperature.

Water from the tertiary cycle is treated through the Water Treatment Circuit (WTC). The purpose of the WTC is to prevent the development of algae, mollusks and pathogenic organisms, to avoid production losses due to clogging or reduced heat exchange. This circuit allows the injection of :

- Sulfuric acid (H_2SO_4) in the CWC to prevent deposits on condensers and atmospheric coolers;
- Sodium hypochlorite (NaOCl), in the CWC and RWC circuits to prevent the proliferation of micro- and macro-organisms (mollusks: risk of tube clogging and loss of cooling capacity).

Therefore, in addition to the effect of temperature, the cooling water also has an increased content of chlorides and sulfates due to the addition of products to prevent microbial growth and foaming.

Surface water is also sometimes used for the production of process water (demineralization water) or for cleaning plants, which is discharged back to the Meuse after use and treatment.

The NPP also consumes city water (drinking water) for exclusively domestic use (sanitation, etc.). Wastewater from the sanitary facilities is treated in 16 treatment plants before being discharged to the internal sewer system and then to the Meuse River.

Domestic and industrial wastewater and cooling water must meet the discharge standards imposed by the 09/05/2008 environmental permit.

In the event of an incident, groundwater is extracted through 15 pumping units to ensure (emergency) cooling of the facilities. This water can also be used to produce demineralized water (only as backup).

Rainwater is not used. Some small subareas of Tihange 3 are located in a floodable area along the Meuse River. These subareas do not contain critical buildings, installations or storage areas. For the impact assessment, it is therefore assumed that the Tihange 3 plant is not located in a flood prone area. Also, no major problems are expected in the future due to climate change (with higher water levels and more intense rainfall).

At the level of the capture points, fish may die due to being sucked up by the pumps. This effect and the secondary effects of (thermal) discharges on the aquatic environment are investigated and assessed under the biodiversity discipline.

Therefore, the main expected impacts on surface water are the quantities of water consumed as a resource (hydrological balance), the impacts on the flow rate and the impacts on the temperature and quality of water in the Meuse River.

It should be noted that the water discharged into the Meuse does not come into contact with the primary circuit (the nuclear part of the plant). Thus, there is no risk of radioactive contamination (under normal operating conditions).

Since no work is planned on existing discharge or capture points in the Meuse, impacts on the structural quality of the Meuse are not considered significant.

1.2.3 Delineation of the study area and description of the reference situation

The study area for the Water discipline includes all surface waters belonging to the public hydrographic network whose quality, quantity and/or structure could be affected by the postponement of the deactivation of Tihange 3. The precise delineation of the study area depends on the extent of the impacts, which are the subject of the study. More specifically, the study area is defined by the zone of influence in which impacts on water quality due to thermal discharges and wastewater may occur. In view of the above, the section of the Meuse between the Andenne-Seilles dam, located upstream of the Tihange power plant, and the Seraing power plant, located downstream of the nuclear power plant discharge points, can be approximately defined as the study area.

Translated to the water bodies defined in the river basin management plan, the status of the surface water body Meuse-Aval is discussed.

The *reference situation* is the situation in 2025 (year of the start of the life extension). Possible autonomous or controlled developments that could lead to the situation in 2025 being (fundamentally) different from the situation in 2023 are, for the Lower Maas water body, on the one hand, a further improvement in water quality (due to additional remediation efforts in the catchment); on the other hand, one can also think of possible observable effects of climate change in this period (temperature-related effects or changes in flow).

Over the centuries, numerous developments and various detour and canal systems have been carried out to enable or facilitate navigation on the Meuse. Thus, from its source to its mouth (except for the section on the border between Flanders and the Netherlands), the Meuse has been made navigable over a length of about one hundred kilometers through civil engineering works and a series of locks and weirs. The Meuse has thus been canalized and consists of a succession of sections separated by dams or weirs. These developments have significantly altered the natural character and morphology of the river on many sections, particularly on the Namur - Lixhe (Visé) section, which is shown schematically in the figure below.

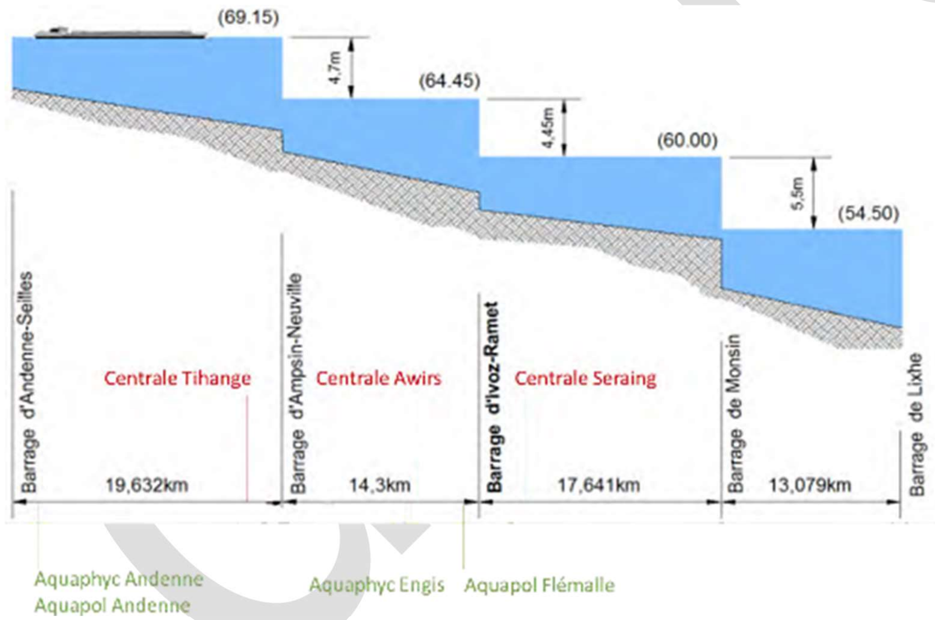

Figure 77: Dams in the Meuse between Andenne and Lixhe and location of the Tihange power plant (Source: SPW).

These structures alter the relationship between flow and level, allowing for navigation on the river and adequate management during flood periods. The closest structure, the Ampsin-Neuville dam, is located about 1 km downstream from the plant.

Moreover, the Meuse is a river fed primarily by rainfall. The flow is irregular and can fluctuate significantly from day to day and within a single day. The flow rate varies considerably from season to season and year to year.

Precipitation can give rise to significant runoff and cause sudden increases in flow. These flow fluctuations can be abrupt and lead to peak flows of up to 1,500 m^3/s for several days. Conversely, during certain periods of the year (mostly summer and autumn), the Meuse has prolonged periods of low flow (low water). The flow may then drop for several weeks to values of 20 to 30 m^3/s (average daily flows).

The flow of the Meuse is measured at several points along the river. The measurement point closest to the Tihange power plant is the Ampsin Bief Amont station, 1 km downstream (east) of the site. The flow of the Meuse is measured continuously with an ultrasonic device (measuring station SETHY 7.137 for Ampsin).

According to the SPW-DGH[94], the average flow of the Meuse measured over the period 1996-2021 at Amay is 205.05 m^3/s, with a minimum of 18.57 m^3/s and a maximum of 1,933 m^3/s.

It should be noted that other rivers flow into the Meuse between the Amay gauging station and the Tihange power plant, so the above flows represent a maximalist assumption for the analysis below.

For the description and characterization of the surface water quality of the Meuse in the reference situation (2025), reference can be made to the assessment of the situation in the second and third river basin management plans for the lower reaches of the Meuse in accordance with the Water Framework Directive.

The assessment under the second river basin management plan (2016-2021) is based on the results of measurements from the years 2005-2013 . The status of the water body is described in the "*Water body characterization sheet MV35R Meuse II*" (SPW-ARNE, 2016) and summarized in the following table.

Table 66: Ecological and chemical status of water body MV35R (2013).

MV35R	Elements of ecological quality		Ecological status	Chemical status	
Maas II	Biology	Good	Moderate	Quality without PBT***	Good
	Physicochemistry (general parameters*)	Good			
	Physicochemistry (specific pollutants**)	Bad		Quality with PBT	Not good.
	Hydromorphology	Inadequate			

** O_2 dissolved, BOD5, COD, SS, NH_4^+, NTK, NO_2^-, NO_3^-, P_{TOT}, Orthophosphate, T°, pH, Anionic surfactants, Cl^- and SO_4^{2-}*
***Metals and metalloids, agricultural pesticides, mixed pesticides, monocyclic aromatic hydrocarbons, chlorophenols, organochlorine compounds*
****ubiquitous PBTs: persistent, bioaccumulative and toxic substances*

As can be seen from this table, the status of the water body can be characterized as moderate, with vinyl chloride as the identified deteriorating parameter. According to Annex V of the Water Framework Directive, the status of a water body is characterized as moderate when: "*The values of the biological quality elements applicable to the surface water body type deviate moderately from those normally associated with that surface water body type under undisturbed conditions. The values show moderate signs of disturbance by human activities and are significantly more disturbed than under good quality conditions*.

The characterization map shows that, based on the analysis of the status of the water body and in the forecast of the application of the program of measures of the second management plans, the ecological and chemical objectives are not met.

The assessment under the third river basin management plan (2022-2027) is based on the results of measurements from the years 2016-2018.

[94] SPW - DGH : Public Service of Wallonia - Directorate of Hydrological Management.

Table 67: Ecological and chemical status of water body MV35R (2018).

MV35R	Elements of ecological quality		Ecological status	Chemical status	
Maas II	Biology	Inadequate	Inadequate	Non-PBT* quality	Not good.
	Macropollutants (BOD_5 , COD, SS, N_{TOT} and P $)_{TOT}$	Good			
	Physicochemistry (specific pollutants).	Good		Quality with PBT	Not good.

There are exceedances for Biphenox, Cypermethrin, ubiquitous PBTs: Mercury (in biota), Heptachlor/heptachlor epoxide (in biota), PBDE (in biota)[95] .

The overall ecological status of Meuse II has slightly deteriorated from moderate in 2013 to insufficient in 2018. Annex V of the Water Framework Directive defines water bodies of insufficient status as follows: "*Waters showing signs of significant changes in the values of the biological quality elements applicable to the surface water body type and in which the relevant biological communities differ significantly from those normally associated with the surface water body type under undisturbed conditions shall be classified as insufficient.*"

However, physicochemical improvement has occurred for specific pollutants.

Since the project may affect an industrial wastewater discharge, a more detailed study must be conducted to assess the impact on the status of the affected water body. The situation must not deteriorate.

The Aquaphyc service of the SPW has 6 monthly measuring and analysis stations on the Meuse, including the station Andenne (code 3260) about 13 km upstream of the site and the station Engis (code 3290) about 10 km downstream of the site (see figure above). A comparison of the analysis results for 2021 (the latest year available) with the lower limits of the status classes (Annex Xter.B.I of the Water Code) shows that the status of the Meuse water is generally very good, both upstream and downstream of the Tihange power plant. Only the levels of nitrogenous substances (Kjeldahl nitrogen, ammoniacal nitrogen, nitrates, nitrites) and phosphate substances (soluble orthophosphates and total phosphorus) are classified as good. However, there is a slight deterioration of water quality from upstream to downstream with respect to chlorides and sulfates.

The SPW also has a second monitoring network called Aquapol[96] . This is a network for continuous measurement of the physico-chemical quality of Walloon watercourses. Only conductivity, pH, dissolved O_2, oxygen saturation and temperature are monitored. The closest monitoring stations are Andenne, upstream of the project, and Flémalle, downstream. The evolution of mean daily temperatures at the two monitoring stations (Andenne upstream of the project and Flémalle downstream) is shown in the figures below.

[95] Project of the third management plans of the districts of the Walloon basin, DEE - SPWARNE.

[96] http://environnement.wallonie.be/aquapol/#/aquapol/home.

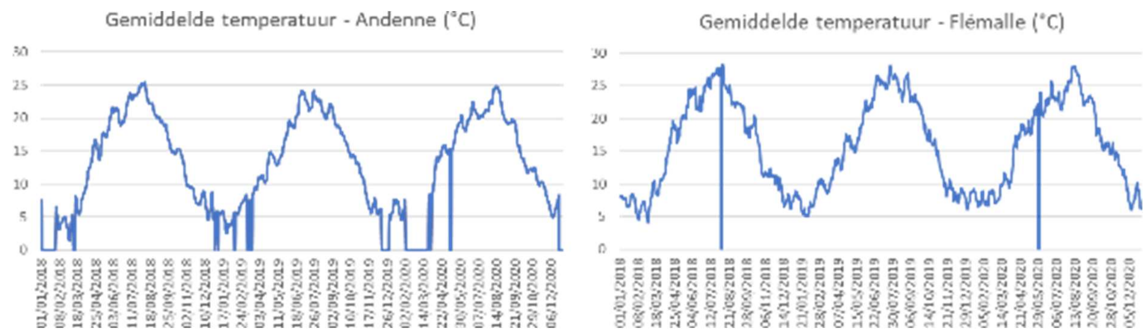

Figure 78: Temperature evolution (2018-2020) upstream (Andenne) and downstream (Flémalle) of the Tihange power plant.

The study of these graphs shows that the temperature of the Meuse water in Flémalle is generally higher than in Andenne. Indeed, the average daily temperature in Andenne fluctuates between 3°C and 25°C, while that in Flémalle is between 5°C and 27°C. One can therefore observe that the Meuse is warming between these two stations. Moreover, it seems that the water temperature of the Meuse increases slightly over time.

The table below shows, for the years 2018 to 2020, the number of days for which the daily average temperatures of the Meuse measured in Flémalle downstream of the Awirs power station (continuous monitoring network of the Walloon Region) are higher than 24, 25, 26, 27, 28 and 29 °C, with the lower limit of status classes (RIV_19) for temperature set at 24 °C.

Table 68: Number of days when certain temperature thresholds are exceeded - station ANDENNE.

Year	T>24 °C	T>25 °C	T>26 °C	T>27 °C	T>28 °C	T>29 °C
2018	22	11	1	0	0	0
2019	11	0	0	0	0	0
2020	14	4	0	0	0	0

Table 69: Number of days on which certain temperature thresholds are exceeded - Flémalle station.

Year	T>24 °C	T>25 °C	T>26 °C	T>27 °C	T>28 °C	T>29 °C
2018	49	25	4	0	0	0
2019	92	65	30	7	3	0
2020	70	48	30	20	6	0

These tables seem to confirm that the water in the Meuse gets warmer every year and that water temperatures are higher downstream than upstream.

Hydromorphological changes or impacts to the groundwater body are not applicable to the project.

An assessment must be made for the specific pollutants that help determine ecological status and the pollutants that determine chemical status for those parameters for which the environmental quality standard is exceeded in current status or for which the concentration would increase. Finally, biological quality elements must be assessed (if possible).

Description of effects

This description is based on available data and information in the different annual reports of the plant operator (PISOE, environmental statements, operating reports) and the different environmental impact assessments carried out in the period 2018-2019 (EIA of the SF² project - Spent Fuel Storage Facility). It should be noted that only data for the entire Tihange plant were available. In the absence of data for Tihange 3, it was decided, for the purpose of this study, to estimate the contribution of this unit based on the electrical power of the three units that make up the nuclear power plant.

Unit	Tihange 1	Tihange 2	Tihange 3	Total
Electric power generation (MWe)	962	1.008	1.045,8	**3.015,8**
Contribution of each unit (%)	31,9 %	33,4 %	34,7 %	**100 %**

Postponing deactivation by 10 years means that water will continue to be consumed and discharged by the Tihange 3 plant during this period. The plant uses drinking/urban water (as process water, for maintenance and in sanitation) and water from the Meuse River (as cooling water). Groundwater is only used in case of an incident and rainwater is not collected or used on site. The Figure 79 illustrates the water consumption for the year 2019 for the entire Tihange plant.

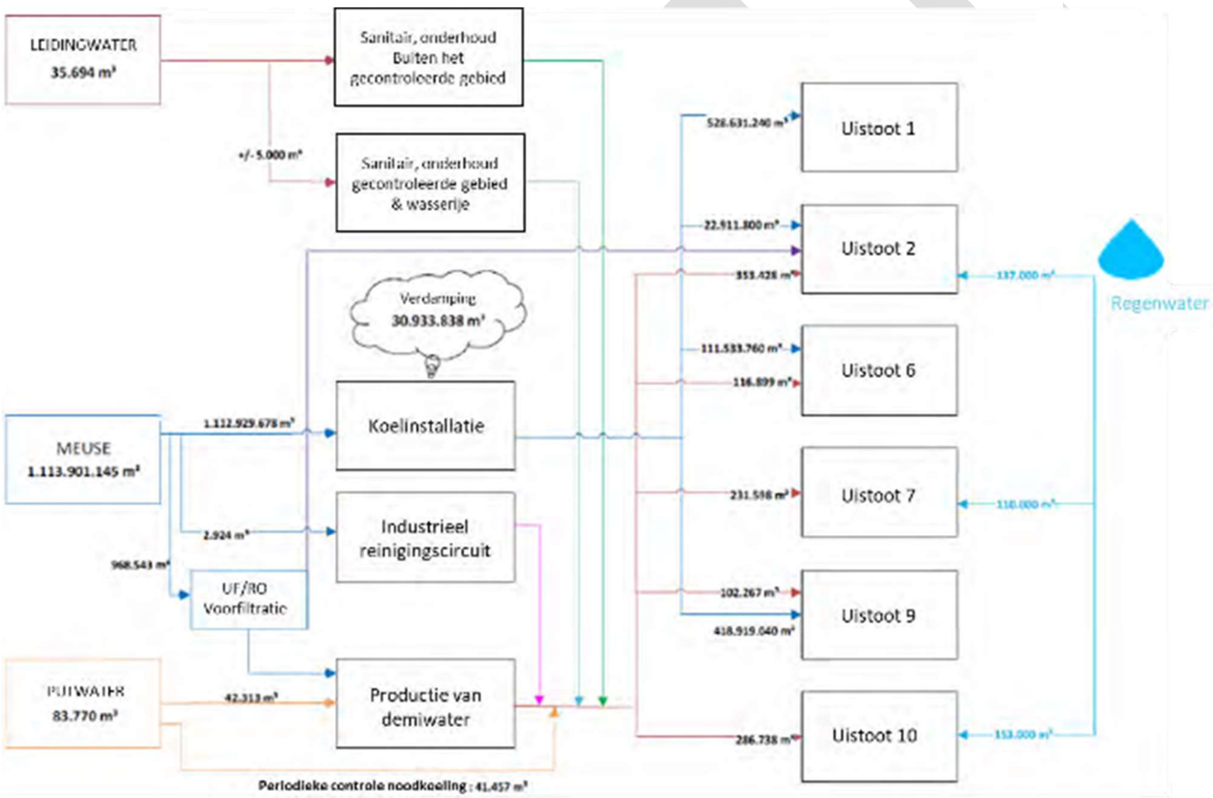

Figure 79: Water balance of the CN Tihange site for 2019.

The water supply is mainly used for sanitary purposes.

Domestic wastewater comes exclusively from sanitation (toilets, showers, sinks, etc.) and maintenance (building cleaning water, etc.). Domestic wastewater is treated in treatment plants before being discharged into the internal sewer system and then into the Meuse River. The station has 16 treatment plants (from 5 to 700 IU) for a total of 1,469 IU.

In 2021, drinking water consumption at the power plant site is 30,877 m³. Applying the 34.7% contribution, about 10,714 m³ would be consumed at Tihange 3. Site consumption fluctuates according to the number of hours worked by personnel (internal and external). Drinking water is almost exclusively for the sanitary needs of the personnel. It is assumed that all consumed water is discharged into the Meuse River after treatment.

Surface water, from the Meuse, is used almost exclusively for cooling the units. The pumping of water from the Meuse is variable to limit the warming of the Meuse in accordance with the provisions of the discharge permit. The pumped flow rate can vary between 2 m³/s (total recirculation from the plants and compensation of evaporation by the cooling towers) and about 110 m³/s for all 3 units (theoretical maximum discharge value without recirculation).

Some of it is also used for the production of demineralized water and plant cleaning. Almost 97% is discharged directly into the river, the rest in the form of water vapor through the cooling towers. In 2021, the quantity of water pumped from the Meuse will be 1,453 million cubic meters (± 500 Mm³ for Tihange 3 through application of the contribution factor), of which ± 1,020 Mm³ (± 355,000 m³ for Tihange 3) will be used for the production of demineralized water and the cleaning of installations. Regarding the amount evaporated in the cooling towers, the three atmospheric coolers operated a total of 24,989 hours in 2021. This results in a calculated evaporation of 36.5 million cubic meters of Meuse water (± 20 Mm³ for Tihange 3).

The *cooling water consists* of circulation water (CWC - water for cooling the turbo groups) and raw water (RWC - water for cooling a series of auxiliary equipment in open circuit). This water is discharged directly into the Meuse River.

Industrial wastewater consists mainly of :

- Regeneration effluent from the demineralization plants of the three units;
- Spraying the engine rooms of the three units;
- Effluents from the controlled area of the three units;
- The blowdowns from the steam generator (secondary circuit side) of the three units.

This water is discharged to the site's internal drainage system and then to the Meuse River.

By subtracting the amount of water evaporated in the cooling towers from the water taken from the Meuse, the discharge of cooling water and industrial wastewater can be estimated at 1,417 Mm³ in 2021 (± 500 Mm³ for Tihange 3). It is assumed that all the demineralized water is discharged into the Meuse and constitutes the discharge of industrial wastewater (1,020 Mm³ of which ± 355,000 m³ for Tihange 3).

The rainwater consists of runoff from the roofs of the buildings and water flowing onto the asphalt roads of the factory site. Assuming an average rainfall of 850 liters per square meter per year (source: www.meteo.be) and a collection area of about 382,000 m² (roofs, sidewalks, parking lots, etc.), the amount of stormwater runoff is estimated at 325,000 m³ per year.

Since the deactivation and decommissioning of Tihange 1 and 2 will be spread over several years, it is estimated that no substantial difference in cover is expected in the period 2025-2037. Therefore, the annual rainwater volume estimated above is also valid for the next 10 years (subject to fluctuations in annual precipitation).

Through its environmental permit dated 09/05/2008, the power plant is allowed to discharge its wastewater and rainwater to the Meuse via 6 direct discharge points for cooling water, industrial wastewater and treated domestic wastewater (discharge points No. 1, 2, 6, 7, 9 and 10 of the environmental permit).

The volume of cooling water discharged during the period studied (2025-2037) will be approximately equal to the volume estimated for the operation of Tihange 3 alone (± 500 Mm³/year). As a reminder, this volume was estimated by applying a factor calculated based on the power output of each unit, and is thus an order of magnitude. Moreover, this annual volume is expected to fluctuate depending on unit operating hours, cooling requirements, and whether or not the water is recirculated before discharge in order to meet the thermal standards of the permit. This is still a reduction of about a third compared to the situation where all three plants would be in operation.

For industrial wastewater, the same ratio can be applied as for cooling water. Therefore, it is estimated that the annual amount of industrial wastewater discharged into the Meuse will be about 355,000 m^3/year.

As a reminder, the water in the distribution system is mainly used for sanitary purposes and for cleaning facilities. The amount of water used is therefore highly dependent on the number of people present at the site. When this study was prepared, neither the duration of the decommissioning period of Tihange 1 and Tihange 2 nor the number of people who will be present at the site during that period was known. Therefore, the consumption of city water in future years cannot be accurately estimated. For the purpose of this study, consumption during the 10 years of the expansion is assumed to be the same as the current consumption (the 3 Tihange units in operation).

From the above, it can be concluded that the main effect of the operation of the nuclear power plant on the water system is the discharge of wastewater and cooling water into the Meuse. Effects on the quantity (flow rate) and quality of the Meuse are to be expected.

Quantity

Under normal conditions, about 120,000 m^3/h (± 50,000 m^3/h for Tihange 3) of water is pumped from the Meuse to the tertiary circuit for cooling purposes (average of the last 5 years). This corresponds to 17% (7% for Tihange 3) of the average flow rate of the Meuse, which is about 198.55 m^3/s at Tihange (average of the last 5 years).

In 2021, the Tihange nuclear power plant used 1,143,000,000 m^3 of Meuse water. About 36,500,000 m^3 was evaporated in the cooling towers and 1,106,500,000 m^3 was discharged into the Meuse. In addition to this volume, domestic wastewater (about 30,877 m^3 in 2021), industrial wastewater (1,020,036 m^3 in 2021) and rainwater (5,785 m^3) were discharged, for a total volume of 1,056,698 m^3. This volume compensates for most of the evaporative water loss in the cooling towers (about 97% compensation), although it is considered negligible compared to the cooling water flow (about 1,120 times smaller).

For the year 2022, a similar annual volume in order of magnitude is expected (1 143 million m^3, see above). From 2023, after the shutdown of Tihange 2, by applying the contribution factor of this unit calculated above, it is estimated that about 761 million m^3 will be abstracted. It should be noted that during the decommissioning of Tihange 2, water will still be used and it is estimated that the amount of water abstracted from the Meuse will be reduced by about 1/6 to 952 million m^3. The same logic can be applied after the shutdown of Tihange 1 planned for 2025.

Although the effect on the river system in terms of flow will be greater than in the reference scenario in which Tihange 1 and 3 cease to operate from 2025 and Tihange 2 from 2023, meaning no wastewater discharge, the effect remains limited. The effect with only the postponement of Tihange 3 is estimated at 34.7% on an annual basis, but in any case is negligible in terms of the effect on the flow of the Meuse.

Quality

As for the chemical quality of *the wastewater,* the daily activities of the plant employees and the operation of the circuits generate wastewater that is monitored based on conventional non-radioactive parameters. When discharging this wastewater into the Meuse River, regulations are strictly observed. A permanent monitoring program checks that the physical, chemical and biological characteristics of this water meet the discharge standards imposed on the Tihange nuclear power plant in its environmental permit.

As a reminder, the main sources of chemical discharges are :

- Water treatment for circuit demineralized water needs. It produces effluents loaded with salts from the regeneration of the ion exchange resins and suspended solids from the effluents of the demineralization plant (concentration and discharge of suspended solids from the Meuse water);
- Treatment of cooling circuits:
  - by injection of sulfuric acid, releasing sulfates to prevent tarnishing;
  - by chlorination treatments of the cooling water, the purpose of which is to eliminate the colonization of the circuits by fixed organisms (algae, mussels, etc.) that may compromise the operation of the circuit, as well as Legionella. The process currently used is chlorination by injection of sodium hypochlorite (bleach).
- The discharge of secondary wastewater (steam generator discharge and wastewater from engine room drains - CEM) conditioned with ammonia and hydrazine (anti-corrosion treatment).

According to the environmental statements of the Tihange power plant, the accredited laboratory identified only 6 exceedances of discharge standards for the period 2019-2021. The three exceedances in 2019 were related to sedimentary material. For two of them, the exceedance was due to the accumulation of sludge at the bottom of water tanks prior to discharge. Both tanks were cleaned. In 2020, a first exceedance of nitrogen could be associated with a trial to replace hydrazine with a less harmful conditioning agent, carbohydrazide. The second exceedance, of nitrite, was related to an excessive supply of wash water in the tanks prior to discharge. In 2021, only one BOD exceedance was observed on the sewer east of Unit 1. An inspection of the sewer upstream of the hydrocollector at Unit 1 was performed and a partial blockage in the sewer downstream of the treatment plant was noted and cleared. There were no further exceedances in subsequent samples.

It should be noted that in 2021 an exceedance of the standard for sedimentables was observed in the CEM well of Tihange 3. A replenishment of Maas water in the CEM well was observed at that time, which may explain the result for sedimentables from the Maas for this sample. Permit standards were not exceeded and this exceedance should not be considered.

It should be noted that all these exceedances are not directly related to activities specific to Tihange 3. Moreover, they relate to different pollutants and are not recurrent or constant over time. Each of the exceedances could be associated with a specific and isolated event. Once the cause of the exceedance was identified, corrective actions were taken and subsequent analyses showed that standards were again met. Although "incidents" may occur at the site that result in sporadic exceedances of specific pollutants relative to the standards established in the applicable permit, these remain relatively rare and are addressed relatively quickly by the operator, thus limiting the occurrence of such exceedances over time.

As a reminder, the ecological status of the water body MV35R Meuse II deteriorated slightly from 2013 to 2018 (from moderate to insufficient), although there was a physico-chemical improvement for the specific pollutants. Moreover, according to the data of the Aquaphyc service of the SPW, the water status of the Meuse is overall very good upstream (Andenne) and downstream (Engis) of the power plant, and only a slight deterioration of water quality is observed from upstream to downstream with respect to chlorides and sulfates. It should be noted that many industries such as the Wanze sugar factory, Recyfuel, Hydrométal, Revatech, Knauf and Prayon are located in this section of the Meuse. These industries also discharge wastewater into the Meuse and could contribute to the deterioration of surface water quality, although the contribution of each industry individually cannot be determined for lack of figures.

Since the quality of the Meuse water from 2013 to 2018 was not generally worse, it can be assumed that no significant effect of the wastewater on the water quality of the Meuse was observed for this period. No significant effect on water quality is expected for the future period (2025-2037) under normal conditions and the same operating mode. The planned closure of the Tihange unit

1 in 2025 and the Tihange 2 unit in 2023 implies the cessation of wastewater discharges from these units. Although the quality of the water discharged into the Meuse is likely to remain unchanged, the volume of wastewater, and thus the pollutant load, is expected to decrease in the coming years. Therefore, the impact of the plant on the water quality of the Meuse will be negligible.

In terms of quality, a further distinction must be made between discharged cooling water, domestic wastewater and industrial wastewater.

The *cooling water* has a thermal effect on the Meuse River, has an increased chloride content due to the dosing of NaOCl to prevent microbial growth, and has an increased oxygen content due to aeration in the cooling towers. Before returning to the river, the cooling water is cooled in the cooling towers, where rising airflow increases the oxygen concentration in the water and lowers the temperature. The environmental permit sets conditions for immission:

1. Temperature downstream of the Meuse River ;
   1.1. The temperature of the Meuse downstream, measured after mixing at the Ampsin-Neuville weir, must not exceed 28°C due to thermal discharges from the plant. However, this limit may be exceeded for 2% of the time without exceeding 29°C;
   1.2. The median annual temperature value downstream of the power plant, measured after mixing at the Ampsin-Neuville weir, is less than or equal to 25°C;
2. Heating the water in the Meuse River:
   The maximum daily average temperature rise is 4°C with the exception of :
   2.1. From 01/07 to 31/03:
      2.1.1. The maximum daily average temperature rise is 5°C if the flow of the Meuse is less than 300 m^3/s and the upstream temperature is less than or equal to 21°C, as a daily average. However, this limit may be exceeded for 2% of the time;
      2.1.2. For flow rates less than 28 m^3/s and an upstream temperature not exceeding 21 °C, the instantaneous heating is 5 °C, but the maximum heating in average daily value is 4 °C. However, this limit may be exceeded for 2% of the time;
   2.2. From 01/04 to 30/06:
   During the fish spawning period, the maximum daily average temperature rise is 5°C if the flow rate of the Meuse is between 28 and 50 m^3/s. However, this limit may be exceeded for 2% of the time.

Periods of high heat and drought or low flows therefore require increased vigilance in the management of thermal discharges.

The warming of the Meuse referred to is determined by the difference between the downstream and upstream temperatures of the Meuse relative to the location of the power plant. These temperatures are measured in 5 measuring stations managed by Electrabel S.A. and controlled by an independent organization approved by the Walloon Public Service.

To this end, a protocol exists between the Walloon Public Service, Electrabel S.A. and the company Luminus regarding the monitoring of the temperature of the Meuse between Huy and Liège. This protocol was signed on November 12, 1997 for a period of 10 years and is tacitly renewed every 10 years.

The 5 monitoring stations form the so-called "Temperature Network," located on the section of the Meuse between Hoei and the Val Benoit bridge, one upstream (Hoei) and 4 downstream of the power plant (Ampsin- Neuville weir, Amay, Serain and Liège).

To verify compliance with permit standards, the total thermal discharge is estimated by summing the calculated thermal discharge of each plant. This total thermal discharge, expressed in MJ/s, may not exceed 4 times the flow rate of the Meuse River.

The annual median temperature value downstream of the Tihange nuclear power plant was 15.40°C in 2019, 16.25°C in 2020 and 14.85°C in 2021 at a maximum allowable value of 25°C. The annual average temperature rise in the Meuse due to the nuclear power plant was 2.29°C in 2019, 2.01°C in 2020 (Tihange 1 shut down for more than 11 months; Tihange 2 and 3 shut down for periodic overhaul) and 2.61°C in 2021.

In 2018, 2019 and 2020, no exceedances of the site temperature limit for Meuse downstream were observed. The maximum allowable temperature is 28°C on a three-hour average. In addition, no exceedances of the allowable warming were observed. For information, the evolution of the 98th percentile of the temperature rise of the Meuse at the Tihange power plant site since 2006 is shown in the table below. It can be seen that the warming is relatively constant over time.

Ontwikkeling van het 98e percentiel van de CNT-verwarming sinds 2006 :

Jaren	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
°C	4,78	4,75	4,68	4,59	4,54	4,59	4,24	4,28	4,03	4,46	4,61	4,33	3,47	4,06	3,74

As mentioned above, the environmental quality standards for temperature in the Meuse are not always met, neither upstream (Andenne station) nor downstream (Flémalle station) of the Tihange power plant, although the exceedances downstream are more frequent and significant. A contribution of the plant's cooling water discharges to the warming of Meuse water cannot be excluded.

Since the three units of the Tihange power plant modulate their thermal discharges (through the use, sometimes in recirculation, of atmospheric coolants) in such a way as to maximize the cooling possibilities given in the discharge permit, and since the thermal discharges also depend on the operating hours of the units, it was not possible to determine the specific thermal discharge of the Tihange 3 unit. However, with the closure of Tihange 1 and 2, the cooling water volume discharged into the Meuse will be exclusively attributable to Tihange 3 and *de facto* smaller than the volume currently discharged. Therefore, it can be estimated that, with a discharge temperature similar to the current one, but with a lower flow rate, the warming of the Meuse will be lower, while the cooling capacity remains unchanged.

However, it should be mentioned that based on the political framework of phasing out nuclear energy and the primary energy consumption reduction targets set in the PACE 2030, the Walloon Region has granted permits to the company Luminus for the construction of a new combined cycle gas plant - CCGT and the conversion of the existing CCGT plant into an open circuit gas plant - OCGT in Seraing and to the company Engie for the construction of a CCGT in Flémalle (Les Awirs). These two power plants also discharge large amounts of cooling water into the Meuse River and contribute and will contribute to the warming of the Meuse. Although the warming of the Meuse due to the operations of the Tihange plant is expected to decrease in the coming years after the closure of two of the three units, the extent of this decrease will be limited by the operation of the two thermal power plants.

The Meuse temperature network also allows the thermal discharges of the Les Awirs power station to be managed under its surface water discharge permit conditions. It also makes it possible to provide the Seraing power plant with certain data essential for managing its thermal discharges in accordance with the terms of its wastewater discharge permit. Indeed, the CCGT permits contain provisions regarding temperature and refer to the Meuse measurement network. The impact is framed in the environmental permits to ensure an acceptable temperature increase in the Meuse (for biodiversity). As a reminder, the CCGTs were intended to partially compensate for the total closure of the nuclear park. If the lifetime of some of the nuclear units is extended, it can be expected that the CCGTs will operate less. In any case, based on the legal restrictions imposed in the various licenses of the three plants (Tihange, Les Awirs and Seraing), it can be concluded that the environment will not be affected. Moreover, according to the data provided by Tihange, all thermal conditions for discharges from these two plants will be met in 2020.

The possible effects of warming Meuse water on aquatic fauna and flora are discussed in the section on the biological environment.

In the longer term, climate change could have negative impacts on the Meuse River. It causes a series of changes in all environmental compartments, including the water cycle. In general, impacts will concern groundwater recharge, flood risk, river temperature and, to a lesser extent, possibly water consumption. Data from the European Climate Assessment & Dataset[97] show that :

- Maximum and minimum temperatures are higher today than in the 19th century, with an increase that appears to have been constant since at least the early 1960s;
- Total precipitation has increased over the long term, especially in summer. Currently, it rains about 100 mm more per year than at the end of the 19th century. Thus, there has been an average increase in precipitation intensity rather than in the number of rainy days.

These changes are likely to accentuate the seasonality of the Meuse hydrological regime, including flooding, low water and water quality[98] .

There is no evidence of an increase in the frequency of low water in the Meuse basin during the 20th century . Nevertheless, it seems that the most severe low water in the Meuse basin occurs in years when a dry summer is preceded by a dry winter.

Floods and low water levels directly alter water quality through dilution or concentration of dissolved substances. Air temperature must also be taken into account, which affects almost all physicochemical equilibria and biological reactions. During droughts, a general deterioration of water quality is observed in the Meuse River, involving water temperature, eutrophication, the main elements and certain heavy metals. This deterioration of water quality is mainly due to the favorable conditions created for the development of algae and to a decrease in dilution capacity in the effluent discharge zones as a result of the decrease in summer flows.

According to the European study "Impacts of Europe's changing climate - 2008 indicator-based assessment" (European Environment Agency, 2008), the water temperature of several European rivers and lakes has increased by 1 to 3°C over the 20th century, mainly due to the increase in air temperature, but also due to the effect of water discharges associated with anthropogenic activities, including cooling water from thermal power plants, which can have a significant local impact. This trend is confirmed by the analysis of measurements from the Aqualim network set up in 2012, which continuously records the water temperature of unnavigable watercourses at 240 stations throughout Wallonia[99] .

Regarding the flow of the Meuse and the amount of water available for abstraction and use as cooling water, since the Meuse is a navigable waterway, a minimum flow must be guaranteed at all times. However, the flow rate of the Meuse allows for the intended withdrawals. Moreover, it was estimated that almost all the water abstracted is returned to the Meuse, which will also be the case after the closure of Tihange 1 and 2 (reduction in the amount of water abstracted and returned).

If the temperature of the Meuse rises due to climate change, the temperature of the discharged cooling water will increase proportionally, with the possibility that the maximum daily thermal load to be discharged will be more frequently limited (see permit conditions), especially in summer. Regarding the effect of climate change on the temperature of surface waters, the Institute for Nature and Forest Research of the Flemish Government gives

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97 Klein Tank, A.M.G. and co-authors, 2002. Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment, Int. J. of Climatol, 22, 1441-1453.

98 A. Bauwens, C. Sohier and A. Degré, Impacts of climate change on hydrology and water resources management in the Meuse River basin (literature review), BASE Volume 17 (2013), May 22, 2012.

99 B. Georges, A. Michez and X. Rollin, Suivi de la température des cous d'eau wallons : potentiels et contraintes du réseau Aqualim, Forêt Nature : Outils pour une gestion résiliente des espaces naturels N°153, Octobre-décembre 2019.

(2015)[100] indicated that for "surface waters in general" an increase of 0.5 to 0.6 °C per 10 years should be taken into account. This would theoretically mean that the water temperature of the Meuse could increase by 0.5 to 0.6 °C during the additional 10 years. Assuming that this should be considered as a maximum for the Meuse, this loss of cooling capacity is not likely to cause major problems (increased heat load, exceedance of discharge standards, higher thermal barrier in summer during the most sensitive period - the low water periods) thanks to better monitoring of the Meuse temperature and adequate control of the cooling capacity available. Moreover, Tihange 1 and 2 will be decommissioned in 2023 and 2025, which means that the thermal load will already be reduced.

If Tihange 3 remains in operation for an additional ten years, this means that during these additional ten years of operation a volume of wastewater will be discharged that decreases by about one-third, but has a similar composition (and thus a lower total annual pollution load). Given the above, it is estimated that extending the operation of Tihange 3 will have a negligible impact on the Meuse.

Compared to the base scenario (Tihange 2 closes in 2023 and Tihange 1 and 3 close in 2025), the *concentrations* of pollutants in cooling water, including temperature and chlorides, are expected to be similar to those of the current situation and those of 2013-2014. In the new scenario (only Tihange 3 is extended until 2037), the Tihange 1 and 2 units and their cooling circuits will no longer be in operation, which means that the use of Meuse water as cooling water will also decrease to about 397 million m³ (see above). The pollutant discharges and thermal load of cooling water should therefore also decrease in the base case compared to the deferred decommissioning project.

Structural quality

As no work is planned on the existing discharge or collection points in the Meuse as part of the expansion of Tihange 3, impacts on the structural quality of the Meuse are not considered relevant.

Flooding

The risk of external flooding is related to strong flooding of the Meuse River north of the Tihange site, accidental breach of the Ampsin-Neuville dam or flooding of the air coolers of Tihange 2 and Tihange 3.

In order to prevent the risk of flooding, a protective dike was built along the banks of the Meuse River and upstream of the flood protection system for the Tihange power plant site (dam). Moreover, the Tihange site, including the lower parts, is fully protected by a flood protection system (dam, dike, check valves).

It should also be noted that the plant intends to collect and reuse rainwater.

Assessment of impacts against policy objectives.

It is then possible to assess the extent to which the effects described above, which may occur as a result of the continued operation of Tihange 3 for another 10 years, contribute, to a greater or lesser extent, to achieving or possibly impeding the policy objectives considered important for the river system. The relevant policy objectives at stake in this project are the achievement of good surface water status, the pursuit of sustainable water chain management, the mitigation of flood risks and the pursuit of a sustainable water supply.

[100] Van der Aa B., Vriens L., Van Kerckvoorde A., De Becker P., Roskams P., De Bruyn L., Denys L., Mergeay J., Raman M., Van den Bergh E., Wouters J., Hoffmann M. (2015). Effects of climate change on nature and forests. Reports of the Institute for Nature and Forest Research 2015 (INBO.R.2015.9952476). Institute for Nature and Forest Research, Brussels.

Achieving good surface water status

Keeping Tihange 3 in operation for another 10 years means that for 10 years (treated) domestic wastewater, treated industrial wastewater and (heated) cooling water will be discharged. Since the discharge standards for the various parameters are well met and the calculated contribution to the increase in concentration is negligible (locally), this means that for 10 years residual pollution will end up in the Meuse. The water body in which the discharge takes place is currently still in an "inadequate" ecological status and does not meet all environmental quality standards. In terms of total pollution, the nuclear power plant can in any case be considered a major polluter. The self-cleaning capacity of the Meuse has not yet been sufficiently restored.

Given the limited impacts of the NPP on water quality and the ongoing efforts that will be made to further reduce the impacts in the period 2025-2037, it can be stated that the Project will not jeopardize the achievement of good ecological potential of surface waters. Since the commissioning of the NPP, the status of the Meuse has not deteriorated; the efforts that have been and are being made to meet the discharge standards will ensure that the quality of the Meuse water is not degraded. There is no reason to fear that the current (admittedly inadequate) status of the Meuse will deteriorate as a result of the continued operation of Tihange 3 for another 10 years. Deactivation (base case) will obviously make a positive contribution, but it is not certain that this will be sufficient to change the inadequate status of the Meuse to a good status.

Flood risk reduction

Regarding flood risk, there are no problems in the current situation and no problems are expected in the short or medium term. The nuclear power plant is not located in a flood prone area and is also sufficiently protected from possible future flood risks due to more intense rainfall (as a result of climate change). There is also no indication that the plant will cause or maintain undesirable flood risks downstream. Therefore, keeping Tihange 3 open longer will not significantly contribute to reducing or causing flood risks.

Summary of key findings

The assessment against the river system objectives is summarized in Table 70.

Table 70: Summary of the assessment of objectives related to the river system.

Objective	**Project contribution (transfer over 10 years)**	**Score**
Good surface water situation	No worsening of condition.	Neutral
Flood risk reduction	No significant contribution	Neutral
Sustainable water supply	No efforts/plans for circular water use	Negative

1.2.4 Mitigating measures

a) Separate rainwater from sanitary wastewater and reuse rainwater as sanitary water and avoid using city water as much as possible.
b) Soilization (infiltration), green roofs or water features (buffering) on site to reduce the heat island effect and retain and store water more locally;
c) Precise advance adjustment of cooling capacity based on monitoring of Maas temperature.

1.2.5 Gaps in knowledge and monitoring

There are no gaps in knowledge that would make the assessment of impacts on the river system not accurate enough. However, there is a lack of information on the proportion of wastewater from the different units and thus on the exact contribution of the operation of Tihange 3 to the remaining pollution in the Meuse during the additional ten years of operation.

Additional monitoring beyond the existing monitoring program is not considered necessary.

1.3 Biodiversity

1.3.1 Relevant policy objectives

The Nature Conservation Law (Loi sur la Conservation de la Nature, LCN) of July 12, 1973 aims to protect the character, diversity and integrity of the natural environment through measures to protect flora and fauna, their communities and habitats. In this context, it is important to ensure that projects, including the decision to extend the life of the Tihange 3 reactor, are not incompatible with the protection of these species (killing, disturbing nests, destroying/damaging/disturbing/etc. of nests, holding, selling, picking, felling, etc.) or with the nature reserves established to protect areas of importance for the protection of flora and fauna, ecological environments and the natural environment.

The Decree of the Walloon Government of 6/12/2001 (Natura 2000 Decree) transposes into Walloon law Directive 79/409/EEC on the conservation of wild birds and Annex II of the Bern Convention on the conservation of wild animals and plants and their natural habitats.

In addition, the implementation of the EU directives in the LCN ensures that for Natura 2000 areas, i.e. areas covered by the Habitats and Birds Directives, it must be demonstrated not only that significant negative effects are avoided compared to the current situation, but also that the continued operation of the plant will not interfere with the achievement of the nature objectives set for these areas. This issue is addressed in an appropriate assessment.

The Decree of the Walloon Regional Executive of June 8, 1989 on the protection of wetlands of biological interest (ZHIB) aims to protect areas of marshes, fens, bogs or natural or artificial waters, permanent or temporary, where the water is stagnant or flowing, and whose ecological and scientific value has been recognized by decree of the Minister in charge of nature conservation, on the advice of the Walloon High Council for Nature Conservation (as defined in Article 1 of the Decree). Also in this context, it is important to ensure that the expansion of the Tihange 3 reactor does not disturb the species present in the "ZHBIs. These objectives do not seem to be relevant in the context of the present expansion project, as the site is not located in a ZHIB. They are nevertheless recalled because a ZHIB is found less than 3 km from the study site.

The Decree of the Walloon Government of January 26, 1995 regarding the protection of underground cavities of scientific interest (CSIS) aims to protect CSIS from destruction, even partial, or degradation by direct exploitation of raw materials, by tourist or sports exploitation, by pollution or by any other form of voluntary intervention leading to a significant reduction in their importance. These objectives also do not seem relevant to the current expansion project, since the area is not part of a CSIS. They are nevertheless recalled because a CSIS is found within 3 km of the study area.

Another objective is the draft Third Walloon River Basin Management Plans (PGDH3 - Cycle 2022- 2027)[101] that transposes the Water Framework Directive (2000/60/EC) into Walloon legislation. Section 6.2.2 of this draft lists the various environmental objectives for surface water, groundwater and protected areas. One of the objectives for surface waters is to achieve "good" ecological status for the different water bodies, while one of the objectives for protected areas is to achieve good ecological status (or good ecological potential) of the water bodies in all Natura 2000 areas. Therefore, it is relevant to examine whether the expansion of Tihange 3 will affect the achievement of the ecological status objectives of water body MV35R Meuse II and the Natura 2000 sites - with their species and habitats of Community interest - that are part of it.

The various components of the life extension project will be assessed against these objectives using the questions below:

- To what extent can the project be expected to avoid disturbance to protected species (cf. LCN)?
- To what extent can the project be expected to avoid disturbance to natural areas (cf. LCN)?
- To what extent can the project be expected to avoid significant impacts with respect to Natura 2000 sites (cf. LCN)?
- To what extent can the project be expected to prevent disruption of the HIBZ (cf. decision of the Walloon Regional Executive of June 8, 1989)?
- To what extent can the project be expected to avoid significant impacts related to CSIS (see AGW of Jan. 26, 1995)?
- To what extent can the implementation of the project be expected not to impede the achievement of the objectives set out in the draft Third Steam Area Management Plans for the 2022-2027 cycle (cf. Directive 2000/60/EC)?

1.3.2 Discussion of the effects to be studied

The Tihange 3 reactor lifetime extension project could affect the biological environment in several ways. The purpose of the impact study is to assess the impact that the lifetime extension of the Tihange 3 activity could have on the objectives related to biodiversity conservation in Walloon legislation, which itself transposes certain objectives from European directives. The compatibility of the project with nature conservation policies can then be determined.

In the context of the study of the project's effects on biodiversity, most of the expected effects are indirectly related to the effects that the reactor lifetime extension will have on the water, acoustic environment or air. However, it is important to note that if the project's impacts on these areas are considered insignificant, they are not addressed in this chapter.

Several potential impacts on biodiversity are related to water intakes and discharges into the Meuse River. Indeed, since the location of the power plant is directly opposite an intake dock that is part of a Natura 2000 site, it is possible that the expansion of Tihange 3 could affect habitats and species of Community interest covered by this site. Moreover, this expansion could also affect the objectives set out in the management plan of the river basin district that includes the Meuse River.

The impact of extending the life of Tihange 3 can be seen in several key areas:

[101] SPW ARNE (2022) Draft third management plans of the Walloon river basin districts. Implementation of the Water Framework Directive (2000/60/EC). eau.wallonie.be.

- Heat discharges into the Meuse: an increase in the temperature of the Meuse due to heat discharges can lead to a decrease in the saturation concentration of dissolved oxygen in the water, making the area less favorable for certain species (e.g., salmonids);

  - changes in surface water quality due to wastewater discharges. It should be noted that this chapter does not address the effects that radioactivity may have on Meuse water. These aspects are beyond the scope of the classic environmental impact assessment. They are discussed in the chapter on radiological effects;
  - Physical effect of pumping on fish, mollusks, crustaceans and other invertebrates due to direct withdrawal of cooling water from the Meuse River. The strong current generated by pumping can drag fish toward the pumps, killing them.

In addition to the potential impacts of the Tihange 3 expansion on the Meuse River, this study will also discuss impacts related to noise, light and other human impacts.

Indirectly, the expansion project is also likely to cause acidifying and eutrophying depositions due to emissions from the incinerators and traffic within the site. It should be noted that the emissions of sulfur dioxide, nitrogen oxide and ammonia from the operation of a nuclear reactor under normal conditions are small; therefore, it seems more relevant to study the avoided impact in relation to the emissions from an SGT (Steam Gas Turbine) power plant of equivalent capacity. However, given the presence of emergency generators that may emit combustion gases to a greater extent when their use proves necessary, it still seems relevant to discuss them in this impact study.

Effects on direct land use can be considered in principle, since the long-term operation of power plants means that occupied space cannot be used for nature development.

No change in the hydrology of the Meuse River is expected. The collected cooling water is almost entirely discharged into the river, so no impact on biodiversity is expected due to changes in the flow or level of the Meuse.

1.3.3 Delineation of the study area

The study area generally used for all biodiversity-related aspects in impact studies is the 3 km radius around the study site. Outside this radius, the impacts of the expansion project can be considered insignificant.

Consequently, all conservation areas that lie at least partially within the study area are considered in this impact assessment.

The conservation areas found within the study area are the following: the Natura 2000 site "Vallée de la Meuse à Huy et vallon de la Solières" (code: BE33010) located at the level of the insertion dock on the opposite bank, directly opposite the power plant site. It should be noted that the study area also includes forested areas and Meuse slopes with habitats of Community interest.

At 785 m northeast of the site is the state-owned "Carrière d'Ampsin" nature reserve (code: 6033). This quarry contains a variety of biotopes: exposed rocks, debris cones, water features, grasslands interrupted by more open and rocky areas, wooded and forested areas. These environments are of great entomological interest and the ponds are home to a rich community of odonates (dragonflies) and amphibians.

About 2.4 km east of the power plant is also an area of biological interest, namely the "Gravière d'Amay" (code: 6934), which is of ornithological interest because it is a nesting, stopover or wintering site for several species with heritage value. The area also hosts a rich fauna of amphibians and odonates.

A second Natura 2000 site is located about 2.4 km southwest of the Tihange site: "Valleys of the Hoyoux and Triffoy" (code: BE33011). Here there is a massif with different forest types (calcareous, neutrophilic, acidic, thermophilic, gully-bound and alluvial). "*The area is also characterized by a range of rocky environments and grasslands, and hosts several sparse grasslands of community interest [...] the presence of several caves and cavities makes it an important area for bats*" (SPW)[102] . It is also of great ornithological interest.

The underground cavity of scientific interest "Galerie minière de Statte à Huy" (code: 6879) is located about 2.8 km east of the power plant site. This gallery is classified as a CSIS with the aim of conserving bat populations and integrating this area into the network of hibernation sites in the Walloon Region.

The location of these various sites is shown in the following figure.

[102] biodiversity.wallonie.be.

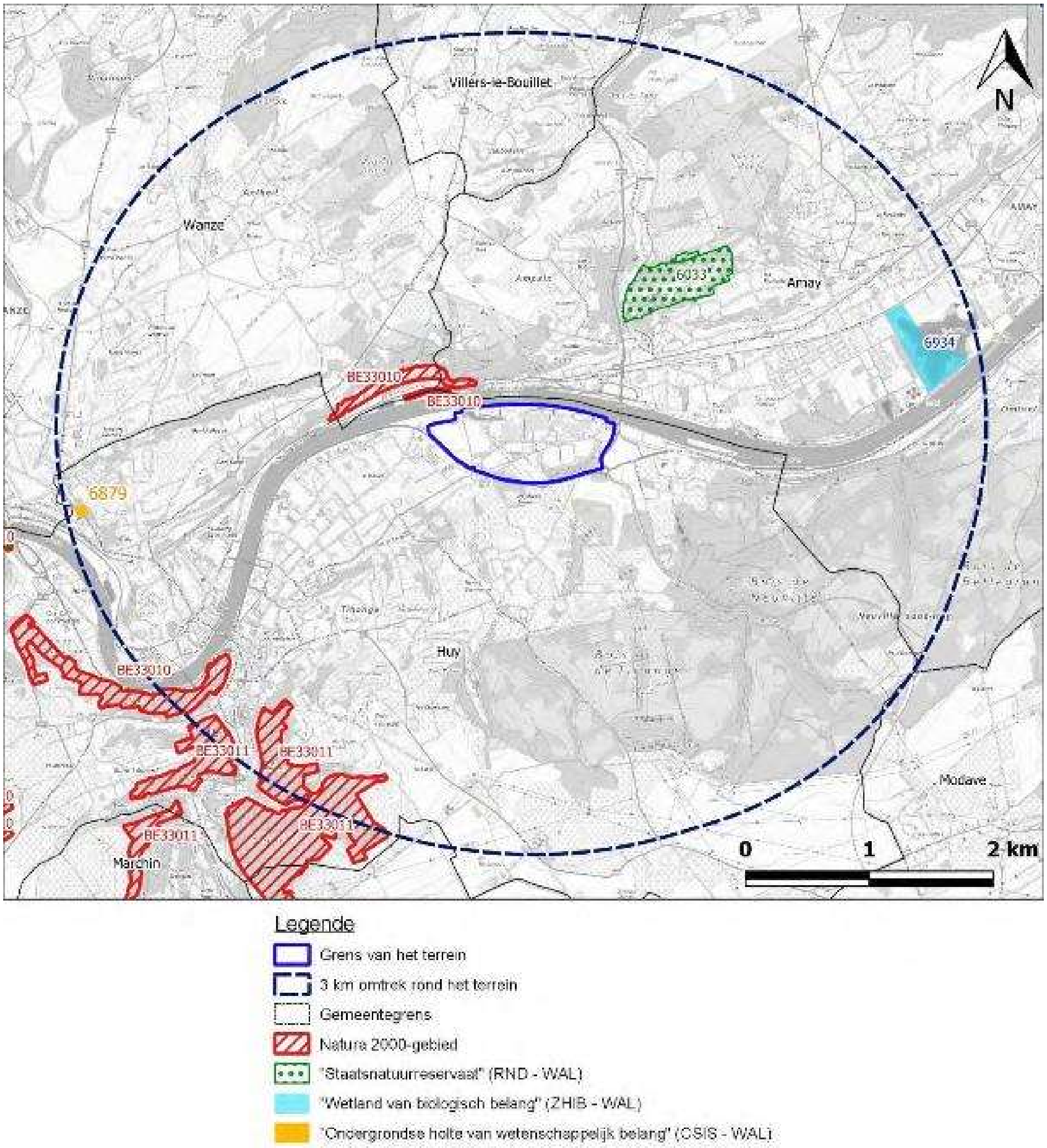

Figure 80: Nature conservation areas.

1.3.4 Description of the reference situation

Natura 2000 areas

As described above, the project area is located in a region where several special protection areas of the Natura 2000 network are located. The nature objectives set for these areas are therefore an important reference for the impact assessment. The Table 71 illustrates the target species for the two Natura 2000 sites located in the study area within a 3 km radius of the Tihange 3 reactor site.

Table 71: Target species for Natura 2000 sites within 3 km of the Tihange power plant site. x: species explicitly listed as target; /: species is not a target.

Target species	Valley of the Meuse near Huy and the valley of Solières BE33010	Valleys of Hoyoux and Triffoy BE33011
Birds		
Black stork (*Ciconia nigra*).	/	X
Honey buzzard (*Pernis apivorus*).	X	/
Tawny Owl (*Bubo Bubo*)	X	X
Stonechat (*Mergellus albellus*).	X	/
European kingfisher (*Alcedo atthis*)	X	X
Red kite (*Milvus milvus*)	/	X
Black woodpecker (*Dryocopus martius*).	X	X
Red-backed Shrike (*Lanius collurio*)	/	X
Mammals		
Pug bat (*Barbastellus barbastellus*)	/	X
European beaver (Castor fiber)	X	/
Griffon bat (*Myotis myotis*).	X	/
Greater horseshoe sparrow (*Rhinolophus ferrumequinum*)	X	/
Bechstein's bat (Myotis bechsteinii)	X	/
Lake bat (*Myotis dasycneme*).	X	/
Potted bat (*Myotis emarginatus*)	X	X
Lesser horseshoe sparrow (*Rhinolophus hipposideros*)	X	X
Fish		
River bullhead (*Cottus gobio*).	/	X
Brook lamprey (*Lampetra planeri*)	/	X
Insects		
Spanish flag (*Callimorpha quadripunctaria*)	X	X
Flying deer (*Lucanus cervus*)	/	X

In addition to species, habitats are also covered by the two Natura 2000 sites mentioned above. However, it should be noted that not all habitats listed in the fiche of these two sites are relevant to this EIA, as they do not occur within the 3 km radius of the project area. Only the Natura 2000 habitats within the study area are addressed here.

- Habitat type 6110: Calcareous or baophilic rock grasslands ;
- Habitat type 91E0: Alluvial forests ;
- Habitat type 8160: Limestone thicket ;
- Habitat type 9180: Gully and slope forests;
- Habitat Type 9150: Calcareous Beech Forest;
- Habitat type 8210: Limestone slopes.

In Wallonia, Natura 2000 habitats are grouped into management units (MU) that require measures to maintain them in a favorable conservation status.

The different management units with which habitats of Community interest are associated within the two Natura 2000 sites in the 3 km perimeter around the Tihange power plant· as well as their main objective,[103] are listed below:

- UG2 "Priority Open Areas": These areas are becoming increasingly rare in our landscape. Management measures are aimed at not changing the vegetation composition - **Habitat types: 6110, 8160 and 8210** ;
- UG7 "Priority alluvial forests": preserve this forest habitat along rivers and prevent its fragmentation - **Habitat type: 91E0** ;
- UG8 "Native forests of high biological importance": Conservation of this forest habitat by preventing any change in its structure and composition - **Habitat type: 9150**.

Nature Reserve

The site of the Tihange nuclear power plant is 786 m south of a state-owned nature reserve. As a reminder, this is the "Carrière d'Ampsin" (code: 6033). This former quarry was given the status of a nature reserve by the Walloon government's decision of May 21, 2015 to create the state-owned nature reserve "La Carrière d'Ampsin" in Ampsin (Amay).

This natural area is subject to a special management plan approved by this same decree.

The main objectives of this management plan are to promote biological diversification by utilizing the natural and man-made potential of the environment[104] :

1. Maintain the diversity of habitats resulting from extractive activities that contribute to the biological importance of the quarries (vertical walls, debris cones, wastelands, water features, etc.), which are beneficial to various species and rare or noteworthy in the region, e.g. wetlands for amphibians;
2. Improve the ecological interest of the area through the management or partial reconversion of the more common areas (fallow land with nettles, scrubland, etc.), taking care to preserve the areas that bear witness to these vegetations; maintain a maximum of open areas favorable to the original species of pioneer plant groups and grasslands, etc;
3. Development of new environments necessary for the development of certain animal and plant species (permanent or temporary pools, cavities in rock walls, reactivation of sandy or earthy cliffs, etc;)
4. Preserving the quarry as a witness to history.

Wetland of biological importance

As a reminder, the Decree of the Walloon Regional Executive of June 8, 1989 aims to protect the aquatic and wetland environment in wetlands of biological interest. To this end, an agreement was signed between the municipality of Amay and the SPW Agriculture, Ressources Naturelles et Environnement (SPW ARNE) for the management of the site " Gravière d'Amay " (code: 6934) located 2,357 m east of the site of

[103] Natagriwal vzw & SPW ARNE (2021) Management measures in the Natura2000 network in agricultural and forest areas. natagriwal.be.

[104] Amay.be.

the Tihange power plant. Therefore, care must be taken to ensure that the reactor's lifetime extension does not significantly affect the designated ZHIB environments and the species found there.

For your information, the Amay gravel pit is primarily of ornithological interest and facilities favorable to the nesting of the Sandpiper Swallow, a species of community interest, have been installed.

Underground cavity of scientific interest

The Statte mine corridor in Huy, located 2.8 km east of the Tihange power plant, was designated by the Ministerial Decree of October 10, 2008 establishing the CSIS. This decree implies the implementation of specific protection and management measures for the mine corridor. These protection and management measures consist in the development of the area to preserve it from a biological point of view and to increase its attractiveness for bats (art. 1 & 2).

Area of great biological interest

The inventory of sites of major biological interest (SGIB) aims to identify, locate and describe remarkable natural or semi-natural terrestrial or aquatic sites in Wallonia. It rationalizes the collection and management of numerous biological data (fauna, flora, habitats) and constitutes a fundamental tool for the scientific knowledge of natural heritage in Wallonia. It provides technical information on nature to territory managers and forms a basis for thinking about the development of nature conservation policies, especially for the most vulnerable environments.

The purpose of the database is to bring together in a single system all information on the biological importance of the sites. For this purpose, all data from the descriptive sheet prepared at the beginning of 1990 will be adopted and other data added to obtain a standard sheet as complete as possible. This will be applied to all existing inventories so that they can be compiled into one database. However, some inventories are too lacking in detail, too old or too large to be included directly as SGIB sheets. They are then stored in specific files to which the detailed SGIB sheets can refer.

Again, the SGIBs do not involve any legal restrictions, so these SGIBs are included in a 3 km radius around the plant site for information (see following figure). However, it should be noted that some of these sites contain species listed in Annex I of Directive 79/409 or Annex XI of the Decree on the Conservation of Natura 2000 sites.

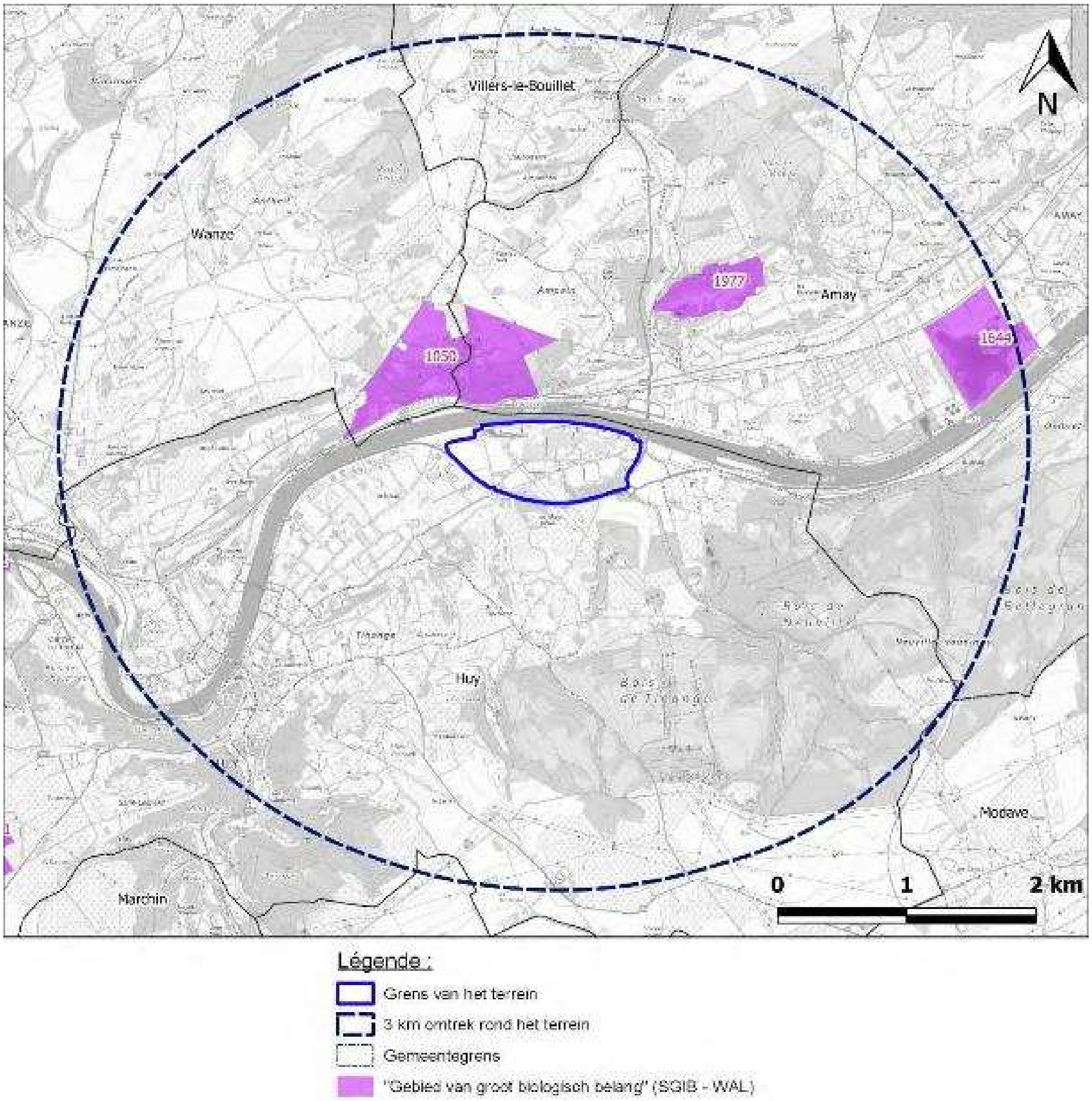

Figure 81: Areas of high biological importance in the project area.

Three SGIBs are found within a 3 km radius of the Tihange power plant (see previous figure), namely

- "Corphalie" (code: 1050), located 150 m north of the site. "*It is located on a very steep, south-facing rocky slope. There are limestone grasslands and wastelands, zinc grasslands, temporary pools, an old decantation basin, slope forests, a boxwood forest, exposed rocks, etc. This amazing mosaic of environments is the source of an exceptionally rich flora and entomofauna, including many remarkable species and often present in high densities (butterflies, orthoptera, etc.)*. "[105]
- "Carrière d'Ampsin" (code: 1977), located 967 m north of the area, a limestone quarry whose exploitation has been discontinued and which has been established as a state nature reserve (see above);
- The "Amay gravel pit" (code: 1644), located 2.4 km east of the site, whose importance lies mainly in the presence of interesting wetlands and aquatic environments and which is partially included in the ZHIB (see above).

[105] biodiversity.wallonie.be

Municipal nature development plan

According to Article D.48. of the decree part of the Environmental Code, the municipal council may establish a municipal environmental and nature development plan. This plan is adopted for a period of five years and remains in effect until it is replaced. The municipal nature development plan (PCDN) is an instrument offered to municipalities to organize, in a sustainable manner, the consideration of nature on their territory by integrating economic and social development. The PCDN aims to preserve, develop or restore biodiversity at the municipal level by involving all local stakeholders, having carried out a diagnosis of the ecological network and developed a shared vision of nature and its future at the local level (biodiversité.wallonie.be).

The preparation of this CNDP does not impose any legal obligations, but commits the municipality to promote and restore the natural and scenic heritage on its territory.

The purpose of the CNDP is "*to preserve or enhance the natural and scenic heritage of an area in its physical and biological components, while respecting and promoting the economic and social development of its inhabitants. The aim is to promote the development of natural and scenic values and to maintain or restore an ecological network at the municipal level by involving all local actors concerned*" (SPW ARNE).

The Municipality of Huy has a PCDN that was introduced in 2012 and has not been replaced since then, so it can be assumed that it still applies to the municipal territory.

In its application to the management of biological diversity, the concept of the ecological network is considered rather as a spatial planning tool aimed at dividing the territory into zones with specific objectives that allow the conservation of biological diversity. In general, at least three types of zones corresponding to three functions are maintained[106] :

- Core areas (ZC) are areas with populations of species and habitats of high heritage value that are still in good conservation status. Conservation of natural heritage is a priority and these areas deserve strong conservation status. Among these core areas, a distinction is also made between characteristic conservation areas (ZCc), i.e. areas with populations of species or habitats in good conservation status, and recoverable conservation areas (ZCr), which contain populations of species or degraded habitats for which recovery measures must be implemented to achieve a favorable conservation status;
- Development zones (ZDs) (or associated zones) are areas of lesser biological importance but with significant biodiversity potential. They are areas that require less protection than core areas and where the coexistence of different objectives is compatible. In the context of our study of the Huy ecological network, these development zones will be divided into 4 subcategories:
  - Deciduous Forest Areas (ZDff) - These are deciduous forest areas that are an integral part of the Main Ecological Structure but do not contain particularly rare habitats or species. Nevertheless, they play an important role within the Main Ecological Structure. Traditional forestry can be practiced here, complemented by biodiversity-friendly measures;
  - ZD for coniferous forests (ZDfr) - These areas correspond to coniferous forest environments. These plantations of exotic species are ecologically less interesting than deciduous forests, but nevertheless harbor a number of interesting species. Starting from these coniferous forest plantations, deciduous forest habitats or sometimes open semi-natural habitats can also be restored;

[106] Taymans J. (2012) Study of the ecological network in the context of the Municipal Nature Development Plan of the Municipality of Huy. Final report. Biodiversity & Landscape Unit Gembloux Agro-Bio Tech.

- o Bocage grassland (ZDb) - These zones correspond to grasslands of relatively high biological value, either because of peculiarities that do not allow excessive intensification (slope, soil moisture, etc.) or because of the presence of bocage elements that diversify the vertical structure of the grassland (hedgerows, pollarded willows, tree rows, etc.). These two parameters are also often linked;
- o Intensively managed grassland ZDp - These are grasslands of low biological value, as they are highly fertilized, grazed and/or artificially tilled. Nevertheless, they differ from an agricultural matrix of cultivated plots, giving them a certain importance within the ecological network;
- o ZDs with other intrinsic biological value (ZDa) - These areas contain species or habitats that are not strictly forest or grassland and have significant biological value, but do not warrant core area status because the measures required for their conservation are not particularly stringent. These areas may include castle parks, public green spaces, standard orchards, etc.

The core areas and development areas make up the Ecological Network (SEP). The location of the plant in relation to the ecological network of the municipality of Huy is shown in the following figure.

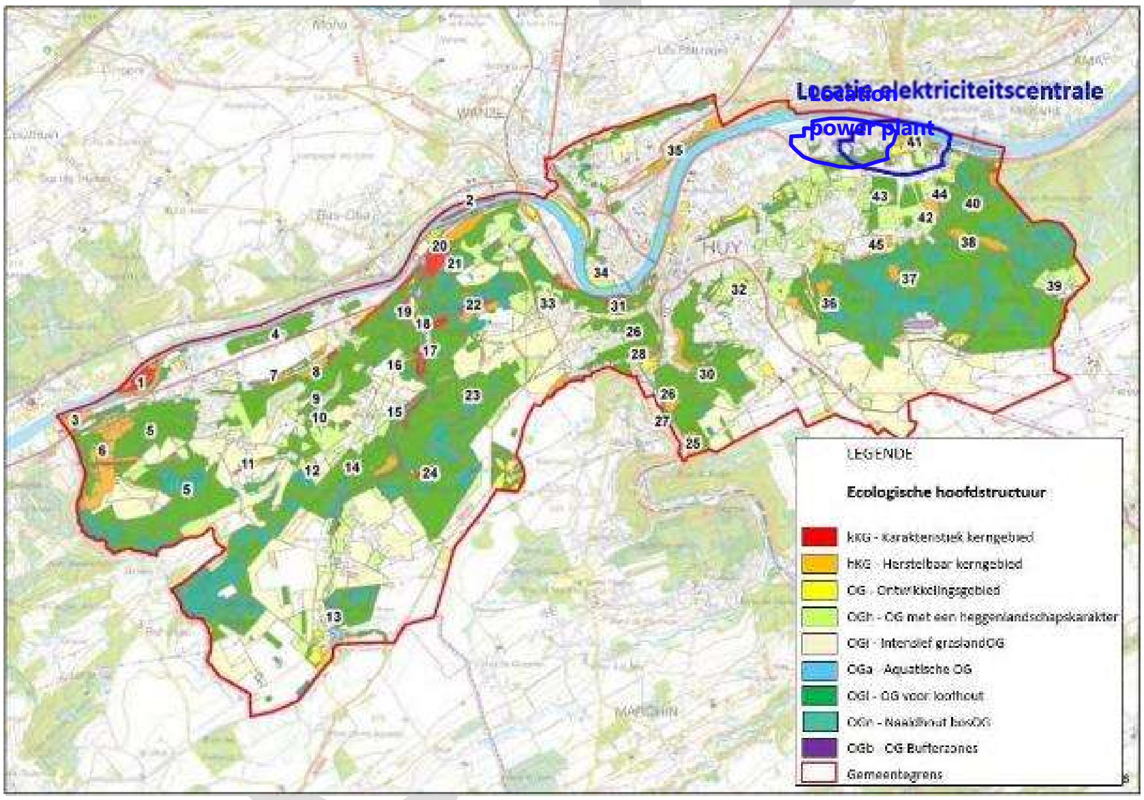

Figure 82: Main ecological structure (Source: GxABT 2012).

Part of the Tihange nuclear power plant site is included in the ecological network of the municipality of Huy. These are areas included in the development zone for deciduous forests (ZDff).

As part of the environmental impact study conducted by Vinçotte Environnement in October 2007 in the context of an application for an environmental permit for the Tihange power plant site, biological field studies were conducted that made it possible to identify several plant species that constitute the ZDff within the site:

- *Cotoneaster franchetii ;*
- *Cotoneaster 'Coral Beauty' ;*
- *Viburnum plicatum 'mariesii' ;*
- *Viburnum rhytidophyllum ;*
- *Spiraea arguta ;*
- *Paulownia tomentosa ;*
- *Lonicera nitida 'Elegant' ;*
- *Weigelia 'Eva Rathke' ;*
- *Osmanthus burkwoodi ;*
- *Deutzia gracilis ;*
- *Prunus glandulosa ;*
- *Prunus serotina ;*
- *Corylus maxima 'Purpurea' ;*
- *Sambucus racemosa ;*
- *Fagus sylvatica ;*
- *Fagus purpurea tricolor ;*
- *Pinus nigra "Nigra" ;*
- *Pinus nigra "Austriaca" ;*
- *Rosa nitida ;*
- *Pyracantha rogersiana 'Orange glow' ;*
- *Pinus mugo.*

It should be noted that the municipality of Amay, which is on the opposite side of the Meuse from the Tihange site, has a CNDP whose charter was signed in 2008. However, the Amay municipal department could not provide the relevant documents.

Developments in and around the area

As explained in the environmental impact study prepared by CSD Ingénieurs Conseils SA and SCK-CEN SA on April 24, 2019, Electrabel SA, in partnership with Natagora, implemented a redevelopment project to promote biodiversity. Two hectares of land next to the power plant and located along the N90 towards Namur were landscaped to restore flower meadows, hedges, wetlands and wooded areas. The aim of this project was to increase the biodiversity of this area and promote the development of fauna and flora. In total, nearly 4,000 trees and shrubs were planted.

Figure 83: View of the two remediated hectares along the N90 (Source: Electrabel nv 2018).

Other developments were also carried out: installation of beehives on the Natagora plot and nesting boxes. In 2014, about fifteen nest boxes were installed at various locations on the plant's property and about fifty young birds were ringed.

In 2015, Electrabel nv mapped the green areas on the site and determined an appropriate maintenance method for each plot. Twenty additional nesting boxes were also installed and a kilometer of hawthorn hedge was planted along the wall along the Meuse. This hedge is home to the bees that, in collaboration with a local beekeeper, are kept on the Natagora plot.

Figure 84: Photos of developments at the power plant site and on the Natagora plot (Source: Electrabel S.A. 2017)

It should be noted that these developments were not imposed by permit conditions or by any legal requirement.

River Basin Management Plan

The Tihange power plant is located in the Meuse river basin and more specifically in the "Meuse Aval" sub-basin.

The water body that may be impacted by the project is the "Meuse II" (code: MV35R). From its confluence with the Ruisseau de Tailfer, the Meuse flows to the Dutch border.

Within the framework of the river basin management plans (PGDH), which transpose the Water Framework Directive (2000/60/EC) into Walloon legislation, an assessment of biological status is carried out every 6 years. As part of the second PGDH, an assessment of the quality of these water bodies was conducted in 2013. A summary of this assessment is shown in the following tables.

The ecological status of water bodies is assessed by biological indicators such as macroinvertebrates, diatoms, fish and macrophytes, physico-chemical indicators (oxygen balance, pH, nitrogen and phosphorus, specific pollutants) and hydromorphological indicators such as the continuity of watercourses and the nature of banks. Chemical status is assessed against environmental quality standards for 45 priority substances.

The table below shows that the heavily modified water body Meuse II is of moderate quality. It can also be noted that the comparison of the ecological status of this water body between the 2007 and 2013 assessments shows that the moderate quality is maintained.

As a reminder, the objective of the draft third river basin management plan is to achieve "good" ecological status for this water body. At the time of the preparation of this study, this draft third river basin management plan is under public review.

Table 72: Assessment of the ecological and chemical status of water bodies in the vicinity of the site in 2013 (Source: eau.wallonie.be).[107]

Waterlicham MV35R - Maas II	**Ecological condition PGDH 2**		
	Medium		
	Organic quality	**Physicochemical quality**	**Hydromorphological quality**
	Good and more.	**General parameters**	Inadequate
		Good	
		Specific pollutants	
		Bad	
	Chemical status PGDH 2		
	Quality without PBT		
	Good		
	Quality with PBT		
	Not good.		
Legend: PBT = persistent, bioaccumulative, toxic and ubiquitous substances			

River contract

A river contract (contrat de rivière) is the result of a voluntary approach by river stakeholders with the goal of integrated management of the river basin, streams and water resources through consultation, awareness and participation.

The role of the river contracts (of which there are 14 in the Walloon Region) is to bring together all the actors involved in the management of water resources in a basin to draw up a program of action.

To this end, river contracts have several missions: inventory of damage to watercourses, establishment of an action program based on this inventory, promotion of and contribution to global and integrated water management (in particular through information and awareness-raising among local stakeholders and the population), but also contributions to the implementation of water management plans by the hydrographic districts, flood risk management plans, and participation in municipal initiatives such as PCDN, PCDR or CRIE. The procedures for drawing up river contracts are set out in the Water Code, Book II of which was amended by the Walloon Government Decree of November 13, 2008 on river contracts.

The Tihange nuclear power plant is located on the banks of the Meuse River. It is included in the "Meuse en aval" river contract, for which a local committee for the Meuse was recently established. However, the consultation on the 2023-2025 action program shows that there are no actions on the part of the river where the Tihange site is located.

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[107] SPW ARNE (2016) Characterization sheet for the water body MV35R Meuse II. International river basin district of the Meuse River. Implementation of the Water Framework Directive (2000/60/EC). Management plan 2016-2021.

1.3.5 Description of effects

Effects on aquatic ecosystems

The operation of nuclear power plants can affect organisms in the Meuse River in several ways. A distinction is made between sanitary wastewater/rainwater, industrial wastewater and cooling water. All these discharges are discussed in detail in the impact assessment for the Water theme (§6.2.2) and their effect on water quality is addressed.

- Water Quality

As a reminder, the Tihange nuclear power plant discharges domestic and industrial wastewater into the Meuse River. A permanent monitoring program checks that the physical, chemical and biological characteristics of this water meet the discharge standards imposed in the environmental permit issued by the Walloon Region in 2008.

The discharge standard is generally met for all parameters, although real exceedances have been reported for sediment (2018 and 2019), free chlorine (2018), nitrite (2020), nitrogen concentration (2020) and COD (chemical oxygen demand) (2021)[108] in the environmental statements for the entire Tihange power plant over the past five years. Each of these exceedances was reported to the person responsible for monitoring the plant and the causes were systematically investigated to prevent recurrence.

Because of the complexity of the factors that may affect the organisms found in the Natura 2000 area in the insertion dock, it is difficult to determine precisely whether the discharges will have a significant local impact. However, it can be assumed that, in a normal situation, the extension of the lifetime of the Tihange 3 reactor is unlikely to discharge water with a higher concentration of pollutants than at present into the Meuse, which would have an impact on aquatic fauna and, more specifically, on the fauna found in the Natura 2000 area in the insertion dock. The extension of Tihange's lifetime has no additional impact on the Meuse in this respect. By contrast, in the event of the closure of Tihange 3, emissions and associated impacts will gradually decrease until the inevitable decommissioning of the facility is completed.

- Cooling water

As a result of biomass mortality caused by the passage of water through the plant's circuits, the water returned to the river contains less living and active phytoplankton, leading to a decrease in oxygen production in the area downstream of the discharge. In addition, the water returned to the river contains dead biomass, which is an additional amount of organic matter whose decomposition by the microbial compartment leads to oxygen consumption. The two effects - reduced production and increased dissolved oxygen consumption - work together and lead to a reduction in dissolved oxygen levels in the Meuse, which may be noticeable in the area downstream of the power plant during certain times of the year[109]

. Some fish species are particularly sensitive to oxygen availability and may become scarce. There are no fish species with very high demands on oxygen availability (such as salmonids): such species can only live in fast-flowing rivers or in an oligotrophic environment. Only migrating fish (such as Atlantic salmon or European eel) could pass through the stretch of river on which the power plant is located.

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[108] Engie Electrabel SA (2018 to 2022). Environmental statement. Tihange nuclear power plant.

[109] Everbecq, E.; Bourouag, M.T.; Deliège, J.F.; Grard, A.; Smitz, J.; Descy, J.P.; Viroux, L. (2007) Etude d'incidence de la centrale de Tihange. Impact on the aquatic environment (the Meuse River). C.E.M.E - Aquôle - University of Liege. URBO. - Facultés Universitaires Notre Dame de la Paix Namur.

However, these fish appear to be able to detect and avoid cooling water discharges[110] so it is unlikely that the lifetime extension of the Tihange 3 reactor will significantly affect the migration of sensitive fish species.

These species are more likely to be threatened by dams and hydropower plants. In the Meuse, serious disruptions to the downstream migration of silver eel, salmon smolt and sea trout have been reported. According to experts, disruption of downstream migration is currently one of the main obstacles to sustainable recovery of migratory fish populations in the Meuse basin downstream of the Ourthe[111]. Therefore, Luminus - the operator of several hydropower plants on the Meuse River - in collaboration with SPW-ARNE[112] has set up the Life4Fish project. As part of this project, several measures were taken to promote the recovery of salmon and eel populations (repelling barriers, spillways, fish-compatible turbines, etc.). The lifetime extension of the Tihange 3 reactor will not affect the effectiveness of these measures, since the project does not require structures that could disrupt the downstream migration of these species.

The species present are cyprinids, which require less dissolved oxygen. Species such as carp, tench, bream, zander, roach, rudd, perch and gudgeon, which are found in the waters of the Meuse, can cope with moderately oxygenated water and have some tolerance to temperature rises.

The environmental declarations of the Tihange power plant state that the temperature of the discharged water is strictly controlled to comply with applicable standards. The environmental permit sets a threshold that varies depending on the time of year: a maximum temperature increase of 4 or 5°C is allowed between upstream and downstream of the plant. Nevertheless, the temperature of the Meuse downstream must never exceed the peak of 28°C. Periods of great heat and drought or low flows thus require increased vigilance in the management of thermal discharges. A software program enables optimal management of the thermal discharges by continuously adapting to the flow conditions in the Meuse and to the operating events of the three units. The results of the continuous measurements are available in real time in the control rooms so that appropriate measures can be taken immediately when the temperature approaches the permissible threshold. This monitoring is also communicated to the Walloon authorities. Over the past five years, no exceedance of the threshold set by the plant's environmental permit has been reported.

Impacts on macroinvertebrate and phytoplankton populations have not been studied. Within these populations, local changes can be expected in favor of less sensitive or thermophilic species and at the expense of other, perhaps more typical species. However, most of these effects will occur only locally, at the level of the power plant discharge into the Meuse, and will not affect the rest of the river system. Moreover, few demanding species occur in this section of the Meuse, as this is a river that has been significantly altered by human activities; the species encountered are generally common that are not disturbed by minor changes in their environment. Thus, the possibility of significant changes in species composition is more limited here than in other ecosystems.

It is also important to note that some studies suggest that thermal pollution may provide a local breeding ground for non-native species. There is always a risk that species will develop a more invasive character (e.g., through adaptation to cold) and spread further through thermal discharges. Since many species have planktonic larval stages, this spread can be very rapid and widespread.

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[110] Kerkum, L.C.M., bij de Vaate, A., Bijstra, D., de Jong, S.P. & Jenner, H.A. (2004). Effects of cooling water on the fresh aquatic environment. RIZA report 2004.033. Rijkswaterstaat.

[111] Baudouin, J-M; Burgun V.; Chanseau, M.; Larinier, M.; Ovidio, M.; Sremski, W.; Steinbach P.; Voegtle B. (2014) Ecological Continuity Information - ECI -Evaluation of barrier crossing by fish. Principles and methods. ONEMA.

[112] https://www.life4fish.be/fr.

After the deactivation of Tihange 1 and 2, there will still be a thermal effect due to the cooling water of Tihange 3 if the lifetime of the latter is extended, even though the thermal effect will be smaller than in recent years when the three reactors are operated simultaneously. Although the thermal effect of the plant on the Meuse will still be present after the extension of the plant's operation, it will be greatly reduced compared to the situation when the three reactors are in operation (only Tihange 3 will still be in operation).

- Water intakes in the Meuse River

The nuclear power plant draws cooling water from the Meuse via an intake. The physical effect of pumping on fish must be considered. The current generated by pumping is likely to carry fish to the pumps, where they are intercepted by the screening devices. This is especially important for intakes in estuaries or coastal areas. In freshwater, fewer fish are intercepted. According to a study conducted by ULiège at the Tihange water intakes[113], between 2001 and 2004, an average of about 1 fish per 1,000 m³ entered the water intake, i.e., 1.5 to 2 million individuals, corresponding to a biomass of 15 to 20 tons of fish over 4 years of monitoring. Therefore, the conditions of the plant's operating permit, when it was renewed in 2008, required the plant operator to install an infrasound suppression system at these inlets (see figure below).

Since only water will be pumped for the Tihange 3 reactor and the rejection system has been installed by the operator, the remaining fish mortality due to these intakes will not be significant. Therefore, it can be concluded that extending the operation of Tihange 3 will not lead to a significant increase in fish mortality in the Meuse River.

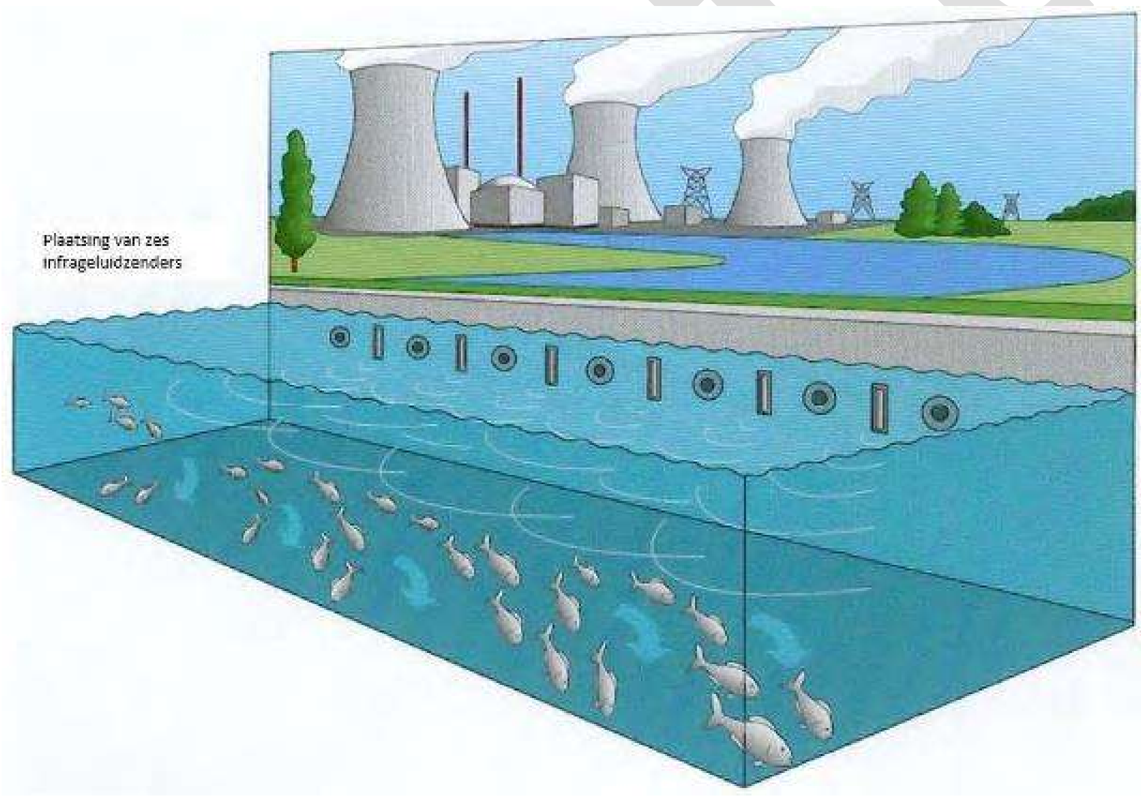

Figure 85: Repulsion system (6 infrasound emitters) at the water intakes in the Meuse (Source: ULiège 2009).

[113] Philippart, J.C. & Ovidio M. (2009) The impact of industrial water intakes and hydroelectric turbines on fish population dynamics and habitat quality in navigable rivers. The case of the Meuse and Ourthe rivers in Wallonia. University of Liege.

Disruption

Nuclear power plants can cause disturbances in the form of light, noise and human presence. Many of these factors are difficult to trace back to the operation of Tihange 3 alone.

- Lighting

The non-profit organization ASCEN has published a paper[114] on the effect of site lighting on bats. This non-profit organization uses the term "ecological pit," as defined by the DNF, which is an "artificial environment where certain ecological phenomena occur. Species in the adjacent environment disappear in greater numbers because they are subject to increased predation." According to ASCEN, public and private lighting cuts off the flight paths of bats, which flee from light, and also disrupts their prey and reduces their hunting area. For ASCEN, only the gated bat (*Myotis emarginatus*) tolerates light in its roost; the other species leave bell towers, buildings and cavities where they seek refuge as soon as the entrances or exits are illuminated. Some species seem to have adapted to lighting locally. The dwarf bat (*Pipistrellus pipistrellus*) has learned locally to hunt around streetlights, but at the risk of diminishing its prey. The most affected species are the Greater and Lesser horseshoe bat (*Rhinolophus ferrumequinum* and *Rhinolophus hipposideros*) and the Great-eared bat (*Plecotus sp.*).

Brussels Environment speaks of a "vacuum cleaner effect" due to light pollution: "*Night lighting acts like a vacuum cleaner that attracts some of the animals that live in its environment. Artificial night lighting, sometimes visible from afar, thus literally strips the area that is not directly lit of all the animals attracted by the light*.[115]

At the Tihange power plant, where several roads border the site (N90, N684, internal roads of Tihange) and given the location of the plant between the towns of Huy and Amay, the potential light pollution in the surrounding area will not change if only the Tihange 3 reactor is shut down.

- Noise

Regarding noise, an acoustic survey of the Tihange nuclear power plant site and its immediate surroundings in 2010 identified the main sources of noise generated by the plant's activities. Following this study, the operator carried out work in 2012 and 2013 to reduce the noise pollution noticeable to local residents.

According to the 2022 environmental declaration of the Tihange plant, the specific noises (engine hum) are likely to remain perceptible and will always be different from the ambient noise generated by the plant and road traffic. However, they should no longer cause noise pollution to local residents, even if the backup and emergency diesel plants are operated at night. Therefore, the lifetime extension of the Tihange 3 reactor is unlikely to cause bird scaring, as the plant site has been generating continuous noise for many years. These are not sudden, loud noises that could occur, for example, during explosions in quarries, which could then startle local wildlife.

[114] Association pour la Sauvegarde du Ciel et de l'Environnement Nocturnes (ASCEN) asbl (Publication date not shown). Effects of lighting on bats.

[115] Bruxelles Environnement (2022) Light pollution in the Brussels Capital Region. Collection Fiches Documentées (n°24) - Theme: Green spaces and Biodiversity.

- Developments in favor of biodiversity

It is also important to note that to the west of the site, facilities to promote biodiversity have been constructed in the form of flower meadows, hedgerows, wetlands and woodlands. Nesting boxes and beehives have also been installed. These facilities were constructed on a voluntary basis by the operator and will be maintained after the life extension of the Tihange 3 reactor. They are beneficial for nesting of various bird species and for hunting by bats.

Figure 86: Biodiversity facilities (Source: Engie 2022).

Given the above, the reactor expansion is not expected to disturb local wildlife by light, noise and human presence.

Acid and eutrophying deposition

The main facilities of the Tihange nuclear power plant, which use uranium as fuel, do not directly generate combustion gases responsible for acid rain. However, the auxiliary steam production facilities and emergency generators are fed with fuel oil (light fuel oil). The use of these plants, which emit flue gases, is relatively limited. In fact, when the units are in operation, they produce their own steam requirements, do not use auxiliary boilers and therefore do not produce fumes. When a unit is shut down, it benefits, if possible, from the main steam of the other units before resorting to the auxiliary boilers. In 2021, unit availability was very good. The reactors of Tihange 1 and 3 operated at 100% power throughout the year. Tihange 2 was shut down for two short periods in 2021 for maintenance work (from January 1 to January 21 and from May 14 to May 29). As a result, the auxiliary boilers were little used.

Therefore, it appears that not only will the lifetime extension of the Tihange 3 nuclear reactor not cause an increase in the frequency of acid rain in the region, but if one takes into account the emissions of

NO_x and NH_3 that will be released by the new Les Awirs CCGT plant (with a theoretical total capacity of 875 MW of electricity), the lifetime extension of this reactor can be considered positive since the electricity that will be produced by the reactor will not have to be produced by the CCGT plants.

In addition, even if the expansion of Tihange 3 were to lead to higher flue gas emissions (due to more frequent use of the emergency generators), it should be noted that moderately to highly acidic soils (with a pH of less than 5.5) are the most vulnerable, with the risk of aluminum release and plant wilting[116] . However, habitats of Community interest with low vegetation in the only two Natura 2000 sites in the project area have soils with generally higher pH, as they are located on calcareous soils (pH
> 7). Therefore, no impacts from acidifying precipitation are expected for these European protected habitats (6110, 91E0, 8160, 9180, 9150 and 8210).

Direct land use

Theoretically, the decision to keep the Tihange 3 nuclear power plant open longer could have negative impacts on land use. If the plant were to disappear, it would free up an area that could potentially be earmarked for nature development, given its proximity to the Meuse River and various nature development areas (PCDN). However, this reasoning is questionable.

Indeed, the Tihange site is located in an industrial area surrounded by urbanized areas (Huy, Amay). Therefore, after the shutdown, there is a real possibility that new industrial development will take place, rather than development for nature. Therefore, it can be said that the decision to postpone the shutdown has no impact in terms of direct land use.

1.3.6 Assessment of impacts with respect to policy objectives.

To what extent can the project be expected to avoid disturbance to protected species (cf. LCN)?

The capture of water from the Meuse River and the discharge of cooling water are identified as the operations with the greatest impact on local species. However, thanks to the measures taken by the operator based on the conditions of the applicable environmental permit, the effects of these operations can be drastically reduced.

The other potential disturbances that could affect protected species (lighting, noise, etc.) were considered insignificant due to the location of the plant (urbanized area, no sensitive habitats nearby, etc.). The lifetime extension of the Tihange 3 reactor does not violate the Nature Conservation Law (LCN) and no recommendations are made.

To what extent can the project be expected to avoid disturbance to natural areas (cf. LCN)?

Given the distance of the nearest natural area to the power plant site (almost 800 meters) and given that its importance is mainly botanical, the activities of the Tihange power plant cannot affect the habitats and species of this natural area, except indirectly through the increased frequency of acidifying precipitation.

However, the expansion of the nuclear reactor should reduce the need for CCGT plants to produce electricity (for example, the Les Awirs power plant). Thus, the project has rather positive effects in this regard. Thus, the life extension of the reactor will not disturb the natural reserves.

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[116] SPW DPS (2012) Fact Sheet 7: Soil acidification. https://sol.environnement.wallonie.be/home/sols/autres-menaces/acidification.html.

To what extent can the project be expected to avoid significant impacts with respect to Natura 2000 sites (cf. LCN)?

Like the species protected by the LCN, the species of community interest covered by the Natura 2000 sites in the region should not be affected by the reactor expansion. The habitats in and around the plant site are not conducive to the presence of most of these species.

Again, the plant's activities may only indirectly affect habitats of Community interest through acid rain. Apart from the fact that the life extension of the reactor is unlikely to increase the frequency of such precipitation, it should be recalled that habitats of Community interest with low vegetation in the project area are not sensitive to it.

Therefore, the proposed expansion has no impact on the European Protection Network.

To what extent can the project be expected to prevent disruption of the ZHIB (cf. decision of the Walloon Regional Executive of June 8, 1989)?

Overall, this study found no significant effects on aquatic ecosystems or their species.

Adding that the only ZHIB in the region is primarily aimed at protecting the Sandpiper Swallow, which is not frequent in the environments found directly in and around the Tihange power plant site, the project should not cause any disturbance.

To what extent can the project be expected to avoid significant impacts related to CSIS (see AGW of Jan. 26, 1995)?

The project does not compromise the integration of the region's only CSIS into the network of bat hibernation sites or the objective of bat species conservation.

The potential impact of the facility on bats is low, as the area is already highly urbanized and the biodiversity features introduced by the operator are positive for bat hunting. Therefore, no significant effect is expected on the CSIS and its conservation objectives; no recommendations are made.

To what extent can the implementation of the project be expected not to impede the achievement of the objectives set out in the draft third management plans for the Walloon river basin districts for the 2022- 2027 cycle (cf. Directive 2000/60/EC)?

The plant operator must comply with the discharge standards of its environmental permit, and all exceedances observed over the past five years have been systematically corrected. Regarding thermal discharges, flows will decrease due to the upcoming closure of the Tihange 1 and 2 reactors. Therefore, the lifetime extension of the Tihange 3 reactor is not considered an impediment to achieving the objectives of good ecological status of the Meuse water in 2027.

1.3.7 Conclusions

Several protected natural areas are located in the vicinity of the Tihange power plant. These areas are protected by law to achieve conservation objectives. These objectives, established in Walloon legislation, aim to protect internationally protected species and habitats. It is therefore important to verify that the expansion of the Tihange 3 reactor does not hinder the pursuit of these conservation objectives. Therefore, this study has tried to assess as best as possible the potential effects of the project on these protected species and habitats.

It was determined that the project may affect these species and habitats through pumping of water from the Meuse River, discharge of cooling water and changes in the quality of the Meuse River, noise and light pollution, indirect effects of acid rain and the fact that the site is located on land that could potentially be used for conservation purposes.

The various analyses led to the conclusion that the effects of the project on the aquatic environment are not such as to jeopardize the conservation strategies of these ecosystems, given the measures taken by the plant operator, either voluntarily or under the standards imposed by its environmental permit (control of discharges, drainage system, etc.). Since the river on which the plant is located is not of great ecological value (ubiquitous species) and only one of the three reactors will be maintained in the coming years, no negative development of the environment is expected.

The nuisance related to the presence of people (noise, lighting, etc.), should not be significant, since the plant is located in an already highly urbanized area and the operator has also taken measures to reduce its acoustic impact. Moreover, measures to promote biodiversity have been implemented on the site.

Finally, the contribution of the lifetime extension of Tihange 3 to acid rain will not be significant. Moreover, it appears that the project will have a positive impact since the electricity that will be produced by the reactor will not have to be generated by the STEFG plants that emit significantly more combustion gases responsible for the increase in acid deposition.

Taking into account all the above elements, it can be said that the lifetime extension of the Tihange 3 reactor does not seem incompatible with the conservation objectives of the Walloon legislation, which itself transposes the European objectives to protect species and habitats of interest.

1.3.8 Mitigating measures

Since the project will not have significant impacts on the policy objectives, no mitigation measures are recommended.

1.4 Air

1.4.1 Relevant policy objectives

The most relevant policy objectives relevant to this environmental assessment are the emission reduction targets as set at the European level relative to the federal level and further distributed at the regional level.

European directive on national emission ceilings

Directive 2001/81/EC, commonly known as the NEC (National Emission Ceilings) Directive, adopted on October 23, 2001, deals with the reduction of national emissions of certain air pollutants. This directive sets emission ceilings for several compounds that may not be exceeded as of 2010, namely

- Sulfur dioxide ($_{SO2}$);
- Nitrogen oxides ($_{NOX}$);
- Volatile organic compounds (VOCs) other than methane ;
- Ammonia ($_{NH3}$).

It was repealed by Directive 2016/2284/EU, which sets targets for 2020 and 2030, formulated as relative reductions compared to 2005 emissions.

This directive extends the list of compounds for which limits are set to $PM2_{.5}$.

The emission reduction targets set in the directive for the years 2020 and 2030 are shown in the table below.

Table 73: Emission reduction ceilings defined in Directive 2016/2284/EU for Belgium (Source: Air Climate Energy Plan 2030).

	Revised NEC Directive - 2020	**Revised NEC Directive - 2030.**	**Emissions 2005**
	% compared to 2005	**% compared to 2005**	**kton/year**
SO_x	43 %	66 %	142,1
NO_x	41 %	59 %	303,5
NMVOCS	21 %	35 %	145,8
NH_3	2 %	13 %	75,2
$PM_{2.5}$	20 %	39 %	34,8

It required member states to adopt a national air pollution abatement program by March 31, 2019. In Wallonia, on November 19, 2020, the decree was adopted approving the cooperation agreement of April 24, 2020 between the federal state and the regions (Flemish Region, Walloon Region and Brussels-Capital Region) on the implementation of several provisions of Directive 2016/2284 of the European Parliament and of the Council of December 14, 2016.

Since the period to be assessed is 2027-2036, the assessment will be based on the 2030 targets currently in place at the Belgian federal level.

In addition to emission targets, reference is also made to air quality targets. These objectives are also based on European regulations.

Air Climate Energy Plan (PACE).

In 2016, as part of its energy and climate vision for 2030, the European Commission published the legislative package to guide member states' climate and energy policies between 2020 and 2030. This package is called the Clean Energy Package. According to this package, member states must prepare a strategic energy and climate plan, integrating 5 dimensions, namely:

- Decarbonation ;
- Energy efficiency ;
- Supply security ;
- Market organization and energy; and
- Research and Innovation.

Given the important synergies between air, energy and climate, Wallonia decided to integrate the three policies into a common vision. In order to meet the requirements of the directive on the reduction of national emissions of certain air pollutants (see *European Directive on National Emission Ceilings* above) and the requirements of the Clean Energy Package, Wallonia has drawn up its own Air Climate Energy Plan (PACE). This Plan thus aims to contribute to Belgium's National Energy and Climate Plan and the National Program for Combating Air Pollution in order to achieve the 2030 climate and air quality objectives.

The PACE 2021-2030 was adopted by the Walloon government on April 4, 2019, and the final Walloon contribution to Belgium's National Energy and Climate Plan was approved by the Walloon government on November 28, 2019.

The PACE has been updated taking into account the recommendations of the European Commission. The updated PACE was adopted at first reading by the Walloon government on December 16, 2022, and is currently being consulted by stakeholders for final adoption in March 2023.

The plan includes 255 actions around 10 themes, aiming to mobilize all sectors and parts of society by anticipating and planning the necessary changes, informing all actors about the deadlines, supporting businesses and households and investing in sustainable alternatives. The themes are the following:

- Moving away from fossil fuels;
- Mass adoption of renewable energy ;
- Improving access to energy and supporting the energy transition ;
- Accelerate and massage the renovation of buildings;
- Improving the energy and climate transition of business and industry;
- Ensuring the sustainability of agriculture, soil and forests;
- Transformation of areas and mobility ;
- Ensuring the acceptability of PACE measures ;
- Support local energy and climate policies;
- Improve air quality.

It should be noted that PACE 2030 assumes a nuclear shutdown in Wallonia by 2025.

PACE allocates the emission ceilings set by the National Emission Ceilings Directive to the regions. The targets for Wallonia and Belgium are shown in the table below.

Table 74: Distribution of Belgium's 2030 emission ceilings by region (Source: PACE 2030)

Pollutant	**Emissions Belgium 2005 [kt/year]**	**2030 emission caps for Belgium [kt/year]**	**Emission ceilings 2030 for Wallonia [kt/year].**
NOX	303,5	124,4 (-59 %)	49,4
SOX	142,1	48,3 (-66 %)	15,4
$PM2_{.5}$	34,8	21,1 (-39 %)	8,8
NMCOV	145,8	94,8 (-35 %)	32,1
NH3	75,2	65,4 (-13 %)	27

European directive on air quality and cleaner air for Europe

One of the key elements setting limit values for pollutants in Europe is the European Directive 2008/50/EC on ambient air quality and cleaner air for Europe. This directive states that air quality should be maintained where it is good and improved otherwise.

It sets limit values and targets for the following compounds:

- Sulfur dioxide ;
- Nitrogen dioxide and nitrogen oxides ;
- Particulate matter (PM /PM102$_{.5}$);
- Lead ;
- Benzene;
- Carbon monoxide.

It also provides that when the established standard for one or more pollutants is exceeded, the period of exceedance should be as short as possible.

IED Directive

Directive 2010/75/EU, or the Industrial Emissions Directive, covers industrial emissions and applies to European companies with a high potential impact on the environment. It aims at a high level of protection of human health and the environment. This protection is achieved through the application of existing best available techniques across a range of sectors.

The Industrial Emissions Directive is based on several pillars, viz.

- An integrated approach that must consider the entire environmental performance of the industry;
- Permit conditions, including emission limits, are based on best available techniques (BAT);
- Flexibility for competent authorities regarding the emission limits they impose;
- Performing environmental inspections;
- Public participation in decision-making.

The Industrial Emissions Directive is relevant to this study because the Tihange plant falls under the activity IPPC/IED-1.1 - Large Combustion Plants in installations with a rated thermal input of 50 MW or more. Indeed, if we include the combustion installations (boilers, generators) related to the operation of reactor 3, the cumulative capacity of the installations exceeds 50 MW. It is important to specify that the emission limits established in the plant's non-radiological operating permit (environmental permit) are based on the applicable BATs and their associated limits.

Objectives

In summary, the air-related policy objectives to be assessed in this EIR are

- Maintain or improve air quality ;
- Contribute to achieving the 2030 national emission ceilings.

1.4.2 Relevant effects and cause-and-effect relationships.

To assess whether or not the Project contributes to air emissions policy objectives and the cause-effect relationship of the Project, the most relevant foreseeable impacts of the Project on air emissions are summarized below.

For a nuclear power plant of the type of the Tihange plant, air emissions are mainly related to the presence of on-site combustion installations required for the maintenance and safety of the plant. These facilities operate intermittently and are not used when the plant is in normal operation.

There are several types of incinerators on the site that play specific roles:

- **Auxiliary boilers** are used to produce steam for the start-up of nuclear plants and to heat certain buildings when the steam generators are not available. They operate only during the start-up phases of the units (basically once every 18 months after maintenance), or as a back up when the steam transformers in the nuclear plants are not available;
- The function of the **auxiliary generators** (**HGs) is** to provide the energy needed to ensure the safety of the plant's facilities when the external power supply fails completely;
- **Emergency generators** (NGs) are used to drive the emergency backup equipment needed to ensure the safety of the plant's facilities in the event of an accident where the external grids and auxiliary diesel generators fail completely;

- **Emergency power generators** (NSA) are placed at the highest points of the site to ensure their reserve function in case of exceptional floods (return period 10,000 years);
- **Operational Assistance Center** (GOH) **generators** help strengthen emergency management.

To ensure their availability, all the above facilities are tested monthly for 1 hour and a 24-hour test also takes place every 54 months.

The relevant impacts examined in this environmental impact assessment under the air discipline mainly concern air emissions associated with the use and testing of these combustion plants, which will remain functional for the Tihange 3 unit as it will be used for an additional 10 years.

In the context of this study, it may be relevant to estimate the emissions that would be generated to compensate for the lost electricity production if the project is not implemented (closure of Tihange 3). Indeed, if Tihange 3 is shut down, electricity production will be taken over by another technology using other energy carriers. It may therefore be relevant to assess the potential emissions of air pollutants associated with the other technologies used. In Wallonia, for example, gas-fired power plants are planned to partially replace nuclear power, despite the increase in renewable electricity. If the estimated emissions of another technology turn out to be higher than those of Tihange 3, it is referred to as "avoided" emissions.

Potential impacts may also be related to traffic in the vicinity of the site, associated with traffic to and from the site. However, these impacts will be limited to the edge of the road and decrease significantly with distance from the road.

Finally, effects on the air could be assumed in the plume emanating from the reactor cooling tower. It should be recalled that the plume consists exclusively of steam from the tertiary circuit water (reactor cooling is explained in the *Water* chapter). It is therefore simply steam from the Meuse, treated with sulfuric acid (H_2SO_4) to prevent deposits on the atmospheric condensers and coolers and with sodium hypochlorite (NaOCl) to prevent the spread of micro and macroorganisms. It should be noted that only a small part of the water from the tertiary cycle is evacuated in the form of steam; the rest is condensed and re-injected into the cycle or discharged to the Meuse River.

The Electricité de France (EDF) group has undertaken important studies to improve knowledge of the operation of air coolers117 . These studies have made it possible to estimate the impact of air cooler plumes on local air. The main conclusion is that the only observable effect of the operation of air coolers is a small reduction in insolation within a few kilometers of a power plant, and that this value is smaller than the natural interannual fluctuation of insolation.

Since the effects of traffic and the cooling tower on air are not considered significant, they are not analyzed in detail in the effects description section.

1.4.3 Delineation of the study area and description of the reference situation

Maintaining good air quality is a matter of great importance and is included in many regulations. Since pollutants can pose risks to human health and ecosystems, there are numerous standards and measurement tools.

Air quality standards referred to in various European directives are set based on maximum air concentrations of various air pollutants established by the World Health Organization. In Belgium, the BelAQi index is used to measure air quality at

[117] CNT - IED - Technical file, Tractebel Engineering SA, 2019

classify a given point based on the effects of air pollution on health. This index is calculated by measuring the concentrations of 4 pollutants in the air, namely fine particles $_{PM10}$ and PM2$_{.5}$, ozone ($_{O3}$) and nitrogen oxides ($_{NOX}$). On average, the Walloon Air and Climate Agency site[118] rates the air quality in the municipality of Huy as "fairly good" on the BelAQi classification scale. It is not easy to determine the area within which atmospheric emissions from the plant may have a significant effect on air quality; this is estimated to be several kilometers away. The effect will be greatest in the immediate vicinity of the plant site and will decrease with distance.

Air *pollutant* emissions are estimated thanks to legal regulations requiring analyses of emissions in the industrial sector. To characterize these emissions, emission levels are set, not only at the industry level, but also at the national and European levels. Ceilings are then set as incentives to reduce these emissions. Since plant emissions are affected by these emission levels, their impact will be assessed at the federal level to analyze their contribution to the targets.

The *reference situation* considered is the situation just before [1er] September 2025, corresponding to a shutdown of the Tihange 1 and Tihange 2 units and the "normal" operation of the Tihange 3 unit ". By September [1,] 2025, decommissioning of Units 1 and 2 is expected to have begun (at least the preparatory phase), but it is difficult to estimate what part of the facilities will still be in operation and likely to produce emissions. Since these issues must be addressed in the context of the decommissioning licenses, the reference situation considered in this chapter considers only the facilities related to the operation of Tihange 3.

1.4.4 Description of effects

Postponing the deactivation of Tihange 3 by 10 years means that during this period, emissions will continue to occur for activities related to the operation of the unit. As mentioned, the sources of air emissions at the facility are related to various activities on site. The activities and types of pollutants emitted are listed in the table below.

Table 75: Activities and types of pollutants emitted at the Tihange power plant.

Activity	Type of pollutants emitted
Auxiliary boilers	Flue gases ($_{CO2}$, $_{NOX}$, $_{SO2}$, $_{PM10}$, PM2$_{.5}$, CO)
Diesel Engines	Flue gases ($_{CO2}$, $_{NOX}$, $_{SO2}$, $_{PM10}$, PM2$_{.5}$)
Cooling Tower	Salt aerosols
Traffic to and from the site	Flue gases ($_{CO2}$, $_{NOX}$, $_{SO2}$, $_{PM10}$, PM2$_{.5}$)

Emissions from stationary installations (combustion plants).

As mentioned, the on-site combustion units are the auxiliary boilers and emergency generators. Each unit of the power plant has its own combustion facilities. For the Tihange power plant as a whole, the cumulative capacity of the combustion plants in 2019 was 264.86 MWth.

The list of installations related to the operation of Tihange 3 is in It should be noted that the domestic boiler, the COR diesel unit and the fire pump are general installations of the Tihange power plant, but in the reference situation, with the shutdown of units 1 and 2, they are considered to be related to

[118] Wallonair, Home (wallonair.be).

the activity of Tihange 3. The cumulative capacity of the facilities linked to Tihange 3 is 93.2 MWh.

Table 76: Description of combustion facilities related to the operation of Tihange 3.

Functional element	Type	Fuel	Power [MWth].	Operating time (average 2015-2019) [h].
PCT3-CVA-G19	Auxiliary boiler	diesel	29,28	442,36
PCT3-GDS-M01	Emergency diesel	diesel	13,24	37,10
PCT3-GDS-M02	Emergency diesel	diesel	13,24	31,34
PCT3-GDS-M03	Emergency diesel	diesel	13,24	34,72
PCT3-GDU-M01	Emergency diesel	diesel	6,4	32,59
PCT3-GDU-M02	Emergency diesel	diesel	6,4	36,08
PCD3-GDU-M03	Emergency diesel	diesel	6,4	30,30
PCT3-GMU-G01	Ultimate Diesel Unit	diesel	4,3	0,20
PCT3-OOO-Q01	Heating boiler	diesel	0,08	n.b.
PCT3-COR-G01	Diesel	diesel	0,12	nonexistent
PCT1-CEI-P02EI	Fire pump	diesel	0,5	8,4
Total			**93,2**	

According to the specific conditions of the 2008 environmental permit for the operation of the power plant, air pollutants NO_X and CO must be measured every three years on emissions from boilers operating more than 360 hours per year. The monitoring of emissions from diesel engines and boilers operating less than 360 hours per year is only done at the request of the supervising officer.

For the incinerators associated with the activity of Tihange 3, the only analyzed emission source is the auxiliary boiler, which operates on average about 450 hours per year. The last measurements of the boiler were carried out by the engineering firm Vinçotte in February 2021. However, there are no existing measurement results for the other plants. This is due to their very low annual operating time of about 30 h, which is less than 0.5% of the time. Therefore, it will not be possible to accurately assess the total air pollutant emissions from the Tihange 3 unit.

For information, it is nevertheless interesting to estimate an order of magnitude of emissions. A hypothesis can be considered to make this estimate based on the boiler data. Namely, if we assume that pollutant concentrations and gas flow rates are the same for the auxiliary boiler and all generators with a capacity greater than 1 MWth, and if we consider all generators with the same capacity as the boiler, the pollutant concentrations can be extended to all plants. The operating hours of the generators can then be added to those of the boiler to make one large plant. Thus a maximum estimate of consumption and emissions from all plants can be made.

Installations of less than 1 MWth have been excluded from the estimation because their impact is not very significant relative to the other installations, due to their lower power and very low usage (generally less than 10 h/year).

There is great uncertainty about the emissions from the generators. By expanding the generators to a capacity of nearly 30 MWth, i.e., doubling or quintupling their original capacity, it is possible to a maximum estimate will be made. This is considered to largely capture the uncertainty associated with the emissions from these units.

Thus, the estimated pollutant load based on flow data and boiler measurements can be calculated based on an annual plant operation of 645 hours per year, which corresponds to the cumulative hours of the boiler and all generators over 1 MWth.

Table 77 shows the calculation and estimation of pollutant loads for the Tihange 3 unit.

Table 77: Estimate of annual pollutant load generated by the Tihange 3 activity.

Data	Gas flow [$^{Nm^3}$/h]	22 214
	Cumulative plant operating hours [h/year].	645
	NOx concentration [mg $_{NO_2}$/Nm^3]	155,5
	Total dust [$^{mg/Nm^3}$]	2
	SO2 concentration [mg/Nm^3]	< 29
	CO2 $_{concentration}$ [mg/Nm^3]	5
Calculations	NOx load [kg/year]	2 228
	Total dust load [kg/year]	28,7
	SO2 load [kg/year]	415,5
	CO load [kg/year]	71,6

The order of magnitude of the pollutant load caused by the Tihange 3 activity is therefore as follows:

- $_{NOX}$: ~ 2,230 kg/year;
- Total dust: ~30 kg/year;
- $_{SO2}$: ~ 416 kg/year;
- CO : ~ 72 kg/year.

The main emission at the site appears to be $_{NOX,}$ with an annual load of more than 2 tons. This represents less than 0.05% of the emission ceiling of 50 kt/year for Wallonia.

Although the auxiliary boiler and some on-site generators have significant power, the annual pollutant load is low due to the low usage of these facilities. If we assume a usage of 450 hours per year for the auxiliary boiler, this represents only 5% of the time, which is very low.

Avoided emissions from the plant

The previous section estimated an order of magnitude of pollutant emissions for the operation of Tihange 3. If Tihange 3 is decommissioned, the lost capacity will have to be generated by other means. Depending on the technology and energy carrier used, this will have different impacts on air and other environmental aspects. The following sections therefore assess the possible direct emissions associated with electricity production through other vectors.

Since there are a wide range of options to compensate for the loss of generation at Tihange 3 (renewables, gas-fired power plants, etc.) and since this also depends on electricity imports, the present study only covers the options listed below:

- *Scenario 1:* capacity taken over by the Walloon energy mix[119] This is the most realistic scenario, but it should be treated with caution, since the energy mix is likely to evolve significantly in the coming years, and thus in the period 2027-2036, due to the commissioning of new gas-fired power plants and the increasing development of renewables;
- *Scenario 2:* Full takeover of capacity by an advanced natural gas power plant (taking into account the emission limits imposed in the BAT conclusions). This scenario exists only in theory, but is indicative of orders of magnitude.

The calculations are based on the average of the known net production of Tihange 3 over the last ten years (2012-2021, in which there were years of full operation as well as years with longer or shorter periods of shutdown for plant maintenance, so the average is relevant to the normal development of the activity. These data are shown in Table 82 with a measured average of 7,500 GWh/year.

Scenario 1: Walloon energy mix.

Emission data from electricity production are available for Wallonia for the year 2020. The calculations will therefore be based on this year. It would have been more relevant to base the calculation on the non-nuclear energy mix, but no non-nuclear emission data were found. The calculation is based only on Wallonia so that the results can be compared with the emission ceilings set for the region.

It should be noted that the intention is to indicate an order of magnitude of emissions, since it should not be forgotten that the situation in 2020 will not be the same as in the life extension period, given the evolution of the energy mix (gas plants, development of renewable energy, etc.).

Energy production in Wallonia for 2020 was 28,983 GWh[120]. Emission rates for the "energy" sector are available on the AWAC website (awac.be). All the data and the estimates based on them are shown in Table 78.

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[119] The Walloon energy mix was chosen in order to compare the results with the ceilings set for the region. Moreover, no recent emission values of the Belgian energy mix for the different pollutants were found.

[120] Bilan énergétique de la Wallonie 2020, SPW, May 2022.

Table 78: Data used to estimate the emissions that would be generated by the Walloon energy mix (Sources: Energy Balance Wallonia 2020; AWAC, 2020).

	Parameter	
Data	Net electricity generation Wallonia [GWh].	28 983
	NOx emissions [kt]	2 587
	Dust emissions [kt]	0,647
	SOx emissions [kt]	0,268
	Net electricity generation Tihange 3 [GWh/year]	7 500
	NOx emission factor [kg/GWh]	89
	Dust emission factor [kg/GWh]	0,02
	SOx emission factor [kg/GWh]	0,009
Calculatio n	NOx emissions [t/year].	668
	Dust emissions [t/year]	0,15
	SOx emissions [t/year]	0,068

The highest and most relevant emissions are those of nitrogen oxides. To estimate the "avoided" emissions in the event that the project is implemented and thus Tihange 3's activity is extended by 10 years, the emissions that would be generated by the energy mix must be subtracted from the emissions that would be generated by the operation of Tihange 3.

As a reminder, the orders of magnitude of emissions caused by Tihange 3 estimated in the previous section are about 70 kg/year for CO, 415 kg/year for sulfur dioxide ($_{SO2}$), 2,225 kg/year for nitrogen oxides ($_{NOX}$) and 30 kg/year for total dust.

The "avoided" emissions would thus be of the following orders of magnitude:

- $_{NOX}$: ~ 666 t/year;
- Dust: ~ 0.12 t/year;
- $_{SOX}$: no avoided emissions, emissions would be higher for Tihange 3 (415 kg/year versus 150 kg/year).

Scenario 2: latest-generation CCGT power plant (type: Les Awirs plant).

The estimates of replacement by only the most recent generation of natural gas-fired CCGT plants are shown in[121] . Actually, only $_{NOX}$ and $_{NH3}$ emissions are relevant when using (natural gas) CCGT plants. The legal limit values must be observed here, and therefore it is assumed that a denox unit will be required, which may lead to significant $_{NH3}$ emissions. Although significant $_{SO2}$ emissions could also occur based on the limit values, these are not included given the low S content of natural gas that Fluxys continuously monitors.

[121] The emission factors considered were taken from the environmental impact assessment conducted by SCK CEN in 2021 in the context of the postponement of the deactivation of the Doel 1 and Doel 2 nuclear power plants.

Table 79: Estimated emissions that would occur if the capacity is fully taken over by an advanced natural gas-fired CCGT plant.

	Parameter	
Data	Net electricity generation Tihange 3 [MWh/year]	7 500 632
	NOx emission factor CCGT [kg/MWh]	0,144
	NH3 emission factor CCGT [kg/MWh]	0,048
Calculations	Emission CCGT $_{NOx}$ [t/year]	1 080
	Emission CCGT $_{NH3}$ [t/year]	360

To estimate the "avoided" emissions in the event that the project is implemented, and thus that the operation of Tihange 3 is extended by 10 years, it is necessary to deduct from the emissions that would be generated by the CCGT plant the emissions that would be maintained for the operation of Tihange 3.

As a reminder, the orders of magnitude of emissions from Tihange 3 estimated in the previous section are about 70 kg/year for CO, 415 kg/year for sulfur dioxide ($_{SO2}$), 2,225 kg/year for nitrogen oxides ($_{NOX}$) and 30 kg/year for total dust. $_{NH3}$ emissions from Tihange 3 are considered negligible.

The "avoided" emissions are thus of the following orders of magnitude:

- $_{NOx}$: ~ 1 080 t/year;
- $_{NH3}$: ~ 360 t/year.

Taking into account the full duration of the Tihange 3 reactor expansion (10 years), this would amount to total "avoided" emissions of about 13,000 tons of $_{NOX}$ and 4,320 tons of $_{NH3}$.

1.4.5 Assessment of impacts against policy objectives.

Impact on air quality" objective

If the project is implemented, the impact on environmental air quality around the plant will be no greater than it is today. Emissions from the Tihange 3 unit will be maintained but not increased. Given the "fairly good" air quality, as indicated by the BelAQi index, the goal would be to maintain or even improve this good air quality. This will be the case if the project is implemented and thus meet the objectives of the Air Quality Directive. The project contributes to achieving this objective.

If we consider air quality in the immediate vicinity of the site, it will be improved at the time of the project by the deactivation of Tihange 1 and 2, which generate local emissions in the same area as the Tihange 3 unit, and will do so until their closure. However, the lifetime extension of Tihange 3 will still generate emissions, which would be avoided in case of shutdown.

Objective "Contribution to achieving the emission ceilings.

Table 80 compares the emission figures calculated above with the NEC targets for Wallonia. The operation of Tihange 3 generates very limited emissions due to the combustion parameters. This is due to the low plant operation rate (between 0.5% and 5% of the time for plants over 1 MWth). These emissions are negligible in relation to total emissions and the emission ceilings, they are of the order of no more than 0.004% (for nitrogen oxides). The emissions are also so small that they have little or no impact on air quality impacts and acidifying and fertilizing depositions.

Table 80: Estimation of the relative share of "avoided" emissions to the NEC target -2030.[122]

Pollutant	Emission ceilings 2030 for Wallonia (PACE). [t/year]	Emissions maintained by the Tihange 3 activity [t/year].	Avoided emissions from Tihange 3 activity - energy mix [t/year].	Avoided emissions from the activity of Tihange 3 - CCGT plant [t/year].
NOX	49 900	~ 2 (0,004 %)	~668 (1,3 %)	~ 1 080 (2 %)
SOX	15 400	~ 0,4 (0,003 %)	~ 0,068 (0,0004 %)	n.b.
Fabric	8 800	~ 0,03 (0,0003 %)	~ 0,15 (0,002 %)	n.b.
NH3	27 000	n.b.	n.b.	~ 360 (1 %)

With respect to the emissions that would result from the decommissioning of Tihange 3, it can be said that they would have a more significant impact with respect to the reduction targets for nitrogen oxides, dust and NH_3. In general, the share of these emissions relative to the regional emission ceilings can be considered relatively limited for most parameters. For NO_x, however, these emissions can be considered more significant. In the period 2025-2037, 1.3-2% of the national ceiling for NO_x would be avoided.

The effect on air quality of possible sources responsible for the "replacement production" of Tihange 3 can be assessed as limited in the immediate vicinity of these sources (a few kilometers). At greater distances, the effects are considered negligible due to increasing dispersion.

It is clear that if Tihange 3 is kept in operation longer, the emissions that would be generated during the life extension period by the combustion plants linked to the reactor would be much lower than the emissions that would be generated during the same period if the reactor were deactivated in 2025, with the exception of SO_X emissions (415 kg/year versus 150 kg/year), which could be higher. For the other pollutants (NO_X, dust and NH_3), the emissions attributable to longer plant operation are very low compared to the avoided emissions. The same obviously applies to the resulting effects on air quality and on acidifying and eutrophying deposition (see Section 6.1.3).

1.4.6 Summary of key findings

The assessment against the air objectives is summarized in Table 81.

Table 81: Summary of the assessment of objectives in relation to air quality.

Objective	Project contribution (transfer over 10 years)	Score
Maintain or improve air quality	Emissions maintained for Tihange 3. Positive contribution to the immediate environment if deactivation of Tihange 1 and 2 is taken into account	Neutral to positive
Contribute to achieving the 2030 emissions caps	Positive for NO_X, dust and NH_3, possibly negative for SO_X	Neutral to positive

[122] Based on European Directive 2016/2284.

1.4.7 Mitigating measures

Mitigation measures are not considered necessary.

1.4.8 Gaps in knowledge and monitoring

No measurement results are available for the generators present on the plant site. No measurements have been made because the operating time of these plants is small (about 30 hours/year) and measurements are not mandatory in this case. However, given their power (sometimes more than 10 $_{\text{MWth}}$), it would be interesting to know their emissions in order to calculate the total emissions of air pollutants associated with the reactor.

1.5 Climate

1.5.1 Relevant policy objectives

EU ETS - emissions trading scheme

The European Union has set up an emissions trading scheme , called " *EU ETS* ". Some greenhouse gas emissions are covered by this scheme, while emissions not covered by the scheme are called "*non-ETS*." The ETS is part of the goal of achieving climate neutrality by 2050, with an interim target of reducing greenhouse gas emissions by at least 40 percent by 2030 compared to 1990 emissions.

Since 2005, this system has thus created a carbon market that aims to reduce greenhouse gas emissions by limiting the amount of gas that may be emitted by energy-intensive industrial sectors, power generators and airlines. The ETS applies to "combustion installations with a rated thermal input of more than 20 MW" (see Annex I of Directive 2003/87/EC), and thus also to this project. In 2016, in its Nationally Determined Contribution (NDC), the European Union committed to reducing its total greenhouse gas emissions by at least 40 percent by 2030 compared to 1990 emissions.[1923] The European Union is also committed to reducing its total greenhouse gas emissions by at least 40 percent by 2030 compared to 1990 emissions.

The EU ETS is regulated by Directive 2003/87/EC, which established the European Union's greenhouse gas emissions trading scheme. Published on Oct. 13, 2003, this directive is based on the cap-and-trade principle and has been amended several times since then.

To meet the target of at least 40% reduction by 2030 (compared to 1990 emissions), the EU ETS sectors must reduce their emissions by 43% by 2030 (compared to 2005 emissions) for the EU as a whole. Thus, there are no specific targets at the member state level for the ETS sectors. The goal is to encourage the ETS sectors to reduce their GHG emissions under equal conditions across the EU. A major revision of Directive 2003/87/EC (via Directive (EU) 2018/410), applicable for the period 2021-2030 (fourth phase), aims to achieve this ETS objective. This includes a stricter reduction path, reducing the number of allowances by 2.2% per year from 2021 (in the third trading period it was 1.74%).

On Dec. 18, 2022, agreement was reached on a substantial "Fit for 55" component put forward by the Commission in the Green Deal in July 2021. The Green Deal includes the ambition to increase the 40% reduction target (see above) to at least 55% and be climate neutral by 2050. A reduction of this order is also necessary (globally) to limit global warming to 1.5°C above pre-industrial levels.

[123] See European Framework for Action on Climate and Energy to 2030.

As a result, the ETS will be strengthened and extended to the construction sector and road transport. Thus, the reduction in 2030 compared to 2005 will increase from 43% to 62%. Therefore, the annual reduction will increase from 2.2% to 4.3% per year between 2024 and 2027 and to 4.4% between 2028 and 2030.

A 30% reduction was assumed for non-EU sectors, also compared to 2005.

At the member state level, targets have been set only for *non-ETS emissions (*transport, buildings, waste and agriculture). Through the Effort Sharing Regulation, the EU 30% reduction target for Belgium has been translated into a 35% reduction (in 2030, compared to 2005). It is clear that the available (political) "climate space" will be more limited in the future than it is today, and that an even stricter reduction path must be followed after 2030. In 2009, EU leaders agreed to reduce European greenhouse gas emissions by 80-95% of 1990 levels by 2050. This ambition was reinforced in 2011 with the publication of a "*Roadmap for moving to a competitive low-carbon economy by 2050,*" which also set a series of mid-term milestones. As mentioned above, the proposals in the European Green Deal further refine this ambition of climate neutrality by 2050.

Directive on the environmental assessment of certain public and private projects

The EIA Directive 2011/92/EU, as amended by Directive 2014/52/EU, is relevant to this study. Indeed, Annex IV of this Directive (as amended) stipulates that an EIA must *include,* in addition to a description of the project's climate impact (e.g., *greenhouse gas emissions*), an assessment of the *project's vulnerability to climate change*.

Covenant of mayors

The Covenant of Mayors is a European initiative that unites local and regional authorities, mostly European. The city of Huy, where the Tihange power plant is located, has signed this covenant. It undertakes to reduce CO_2 emissions on its territory by at least 40% by 2030 and to increase its resistance to climate change.

The Covenant of Mayors requires the inclusion of a section showing that the vulnerability of the area to climate change has been assessed and that adaptation measures or options are planned. Vulnerability to climate change also relates to the energy sector, so it is relevant to assess it in this study.

Air Climate Energy Plan (PACE).

As explained in the Air chapter, the Climate and Energy Plan also relates to climate and aims to describe, in an integrated manner, the actions being implemented in the fight against greenhouse gas (GHG) emissions in order to strive for climate adaptation.

The PACE 2016-2022 formulated a series of measures regarding climate change adaptation, namely:

- Building a solid knowledge base ;
- Continued fight against soil erosion and increased flood risk;
- Encourage sustainable forestry initiatives that respect the natural functioning of the ecosystem;
- Improve knowledge of impacts and vulnerability at the city and town level.

Objectives

In summary, the climate-related policy objectives to be assessed in this study are

- The greatest possible reduction in greenhouse gas emissions;
- Achieve maximum ecological and social resilience to the impacts of climate change;
- Minimize the project's vulnerability to climate change impacts.

1.5.2 Relevant effects and cause-and-effect relationships.

The project that is the subject of the environmental assessment has a number of potential relationships to whether or not the policy objectives summarized above will be achieved.

Electricity generation requires a primary source: coal, gas, uranium, solar, wind or water. Because of the way it is produced, electricity is the main source of global CO_2 emissions. In the case of nuclear power generation, the operation of power plants is linked to auxiliary facilities that produce greenhouse gases, namely generators and boilers. These facilities are not used during normal plant operation. As mentioned in the *Air* chapter, the boilers are used for reactor start-up and steam production, and the generators are used in case of failure. However, these plants are regularly turned on to test their operation, and greenhouse gas emissions are generated during these tests or this use. With respect to the objective of reducing greenhouse gas emissions as much as possible, two effects are important.

The first is the fraction of greenhouse gas emissions from the plant that will be maintained if the project (extension of the Tihange 3 unit by 10 years) is realized.

The second impact concerns the estimated emissions that would arise to compensate for the lost electricity production if the project is not implemented (shutdown of Tihange 3). Indeed, the technology used to produce electricity is a determining factor in controlling CO_2 emissions. If Tihange 3 is shut down, electricity will be produced using other energy carriers. Therefore, it may be relevant to assess the potential emissions associated with the other technologies used. In Wallonia, for example, gas-fired power plants are planned to partially replace nuclear power, despite the increase in renewable electricity. If the estimated emissions from another technology turn out to be higher than those from Tihange 3, they are referred to as "avoided" emissions.

Regarding the project's vulnerability to climate change, the facility is subject to the potential impacts of climate change, such as floods and heat waves.

Finally, the location of the plant itself may affect the resilience of the immediate area to the effects of climate change, for example, by closing off a large area.

1.5.3 Delineation of the study area and description of the reference situation

Greenhouse gas emissions relate to a global problem - global warming. The impact of emissions is not determined by where they are generated. The greenhouse gas emissions that would arise in the event that the project is not implemented (in the event that Tihange 3 is decommissioned) could come from anywhere in Belgium, or even from abroad in the event that electricity is imported.

In terms of *environmental vulnerability and resilience,* the project area corresponds to the site of the power plant and its immediate surroundings, which may be affected by an environmental impact associated with or exacerbated by the presence of the plant.

The *reference situation* is the situation just before 1er September 2025, corresponding to a shutdown of the Tihange 1 and Tihange 2 units and the "normal" operation of the Tihange 3 unit. By 1er September 2025, the decommissioning of Units 1 and 2 is expected to have begun (at least in the preparation phase), but it is difficult to estimate how many of the fossil-fuel plants will still be in operation and probably emissions will generate. Since these issues must be addressed in the context of the decommissioning licenses, the reference situation considered in this chapter considers only the facilities related to the use of Tihange 3.

Possible developments that could cause the situation in 2025 to differ (fundamentally) from that in 2023 could relate to greenhouse gas emissions from non-nuclear production, which could increase on the one hand due to the increased use of gas-fired power plants, and on the other hand decrease due to the development of renewable energy sources.

1.5.4 Description of effects

Emissions from installations

As mentioned above, greenhouse gas emissions from the plant come from the operation of a number of generators (driving the pumps and emergency generators) and light oil-fired boilers. The inventory of greenhouse gas-emitting installations at the Tihange nuclear power plant, conducted in 2019 by Tractebel Engineering, distinguishes 4 light oil-fired boilers with a total capacity of 87.8 MWth, 23 emergency generators with a total capacity of 176.56 MWth and a fire pump with a capacity of 0.5 MWth.

Looking only at the plants linked to the Tihange 3 unit, which corresponds to the reference situation, the cumulative capacity is 93.2 MWth, i.e. about 35% of the total power plant capacity. Together, without counting the boiler, these plants operated an average of 653 h/year during the period 2015-2019. Since GHG emissions data are only available for Tihange as a whole, it will be assumed that the emissions attributed to the operation of Tihange 3 (reference situation) correspond to 35% of the plant's total emissions (power ratio assumption). Greenhouse gas emissions from the Tihange power plant attributable to Tihange 3 for the past 10 years are shown in the graph in Figure 87.

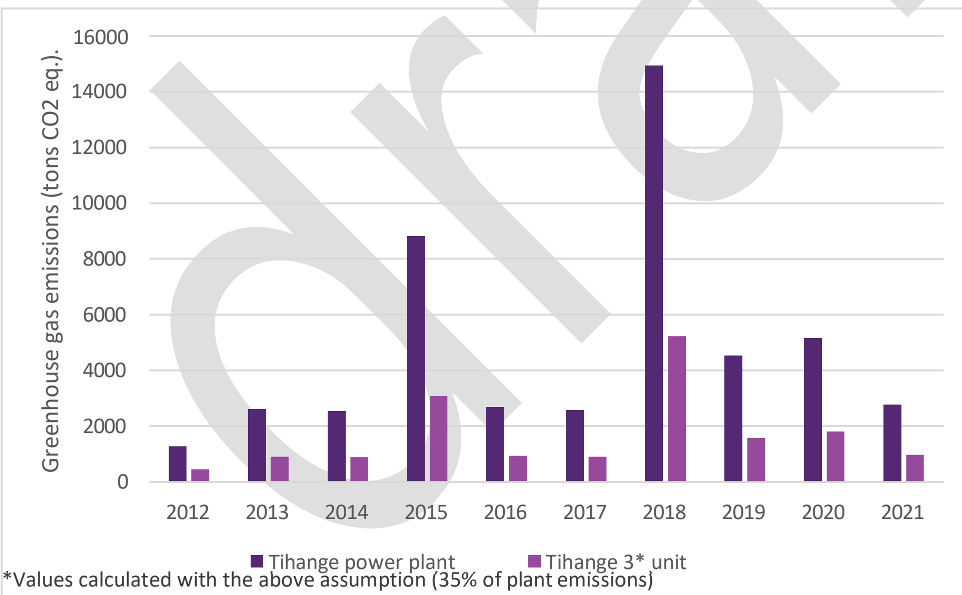

Figure 87: Greenhouse gas emissions (tons $_{CO2/year}$) for the Tihange power plant and attributed to the Tihange 3 unit

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Based on the emissions attributed to Tihange 3 and with knowledge of net production in recent years, it is possible to estimate the relative emissions associated with the operation of Tihange 3. The Table 82 illustrates the estimated greenhouse gas emissions for the Tihange 3 unit (reference situation for the project) for the years 2012-2021.

Table 82: Estimated greenhouse gas emissions (tons $_{CO2}$ eq./year) and emission intensity (g $_{CO2}$ eq./kWh) for the Tihange 3 unit for the period 2012-2021 (Source: environmental statements 2013-2022, Engie).

	Greenhouse gas emissions T3 (tons $_{CO2}$ eq. /year)	**Net production T3 (MWh)**	**Relative emissions T3 (g $_{CO2}$ eq. /kWh)**
2012	450,1	7 975 000	0,056
2013	908,95	8 094 000	0,11
2014	890,05	8 800 737	0,10
2015	3 085,25	7 336 436	0,42
2016	941,5	7 835 567	0,12
2017	901,6	8 963 786	0,10
2018	5 227,25	2 215 600	2,36
2019	1 586,2	8 945 120	0,18
2020	1 806,35	5 838 218	0,31
2021	971,6	9 001 857	0,11
Average	**1 676**	**7 500 632**	**0,39**

The high greenhouse gas emissions in 2018 for the Tihange 3 unit are due to the fact that the reactor was shut down for almost 9 months due to work. At the same time, emissions from the power plant were high that year. Since emissions from combustion plants are inversely proportional to production (since they are mainly used when the reactor is shut down), this explains why the emission factor (or relative emissions) is particularly high compared to other years.

If the average of the past ten years is taken as a representative sample for the operation of Tihange 3, the average annual greenhouse gas emissions would be estimated at 1,676 tons of $_{CO2}$ /year, which would amount to cumulative emissions in the order of 20,000 tons of CO2eq in the period 2025-2037 as a direct result of the postponement of the deactivation of Tihange 3.

If we express the emissions in relation to the electricity produced, we get a value that for the years considered varies between 0.10 and 2.35 g $_{CO2}$ eq./kWh, with an average over the last 10 years of 0.39 g $_{CO2}$ eq./kWh.

By comparison, an advanced CCGT power plant emits about 320 g $_{CO2}$ eq./kWh[124] . Specific greenhouse gas emissions from all Belgian electricity generation were 154 g $_{CO2}$ eq./kWh in 2021 (EEA, 2022).

As an indication, Figure 88 compares the latter figure with that of other EU member states. It clearly shows that the specific emissions of the Belgian electricity generation park are lower than, for example, those of the Netherlands (418 g $_{CO2}$ eq/kWh) and Germany (402 g $_{CO2}$ eq/kWh), two countries that still have a significant share of fossil energy (including coal and, in the case of Germany, lignite) in their energy mix in 2021. The countries outperforming Belgium are those with significant nuclear and/or hydroelectric capacity.

[124] Environmental Impact Assessment - Application for an environmental permit for a natural gas-fired combined heat and power plant and high-voltage connection at Les Awirs; Sertius SA; 2020.

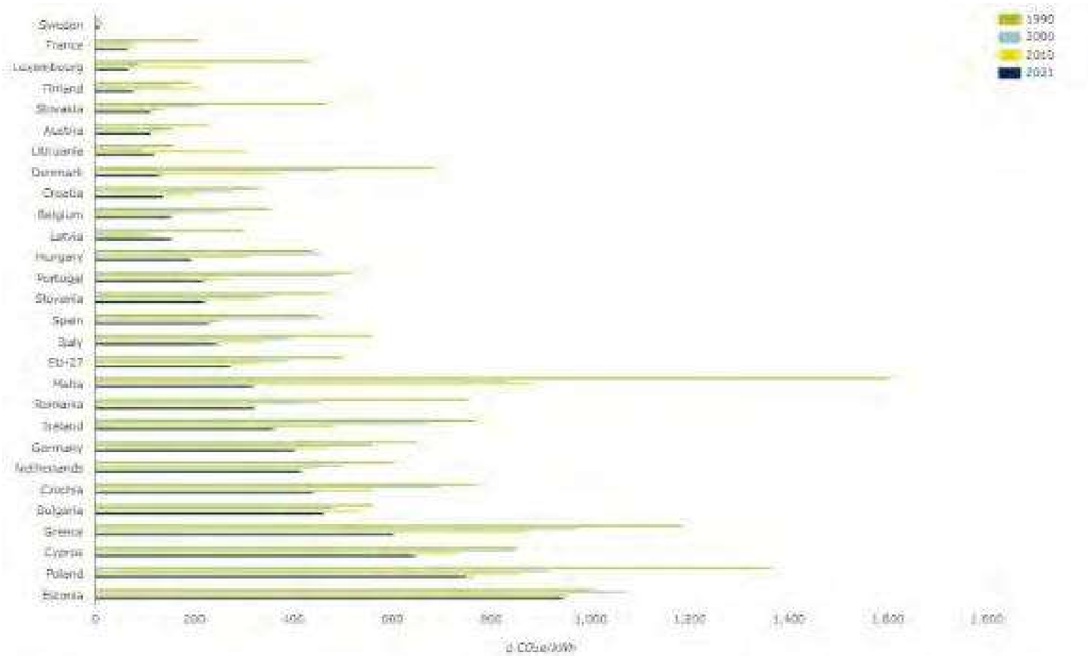

Figure 88: Greenhouse gas emission intensity (g $_{CO2}$ eq./kWh) of the electricity sector for different EU member states (EEA, 2022).

We can observe that the relative intensity of greenhouse gas emissions of the Tihange 3 activity is almost 400 times lower than the average emissions of the Belgian production fleet (0.39 g $_{CO2}$ eq./kWh versus 154 g $_{CO2}$ eq./kWh). Its impact in terms of greenhouse gas emissions is thus limited compared to other technologies, such as steam gas turbines. Given the technology used, this should not be surprising. The emissions that do occur are not due to the normal operation of the plant, but to the test cycles of plants used only in emergencies. These plants operate 0.5 to 5% of the time, which is very little.

Taking into account the average annual emissions over the period 2012-2021, as calculated above, the emissions generated by extending the lifetime of Tihange 3 by 10 years will result in additional emissions (compared to the reference situation) of 16,760 tons of $_{CO2}$ eq, representing 0.13% of the total emissions from the production of electricity and heat in Belgium in the year 2021 (12.8 Mton).

Avoided emissions from the plant

In the case that the Tihange 3 reactor is replaced for energy production based on a non-nuclear energy mix, it is relevant to discuss the emissions that would be generated for the nuclear production capacity that would be lost during the 10 years envisaged for the extension.

It is clear that the loss of nuclear capacity in Belgium will have to be met at least in part by using gas power plants. Ember[125] states that the carbon intensity of the Belgian electricity supply will be 229 g $_{CO2}$ eq/kWh in 2020, an increase of 71% over the current situation. Belgium is one of the few European countries where carbon intensity would increase rather than decrease. The reason, of course, is that the share of renewable energy in 2030 is still too low to achieve the

[125] Vision or division? What do national energy and climate plans tell us about the EU electricity sector in 2030? EMBER, November 2020.

offsetting lost nuclear generation. EMBER assumes a 57% share of natural gas and 40% renewable energy in 2030. Note that Energyville, in an update of the outlook for Belgian electricity supply in 2030 and 2050 (2020), assumes a noticeably lower share of 44% natural gas in 2030, and thus also a lower carbon intensity (see below).

Figure 89 shows a forecast of Belgian electricity generation and imports between 2022 and 2032, as included in Elia's most recent "Adequacy and Flexibility Report" (2021).

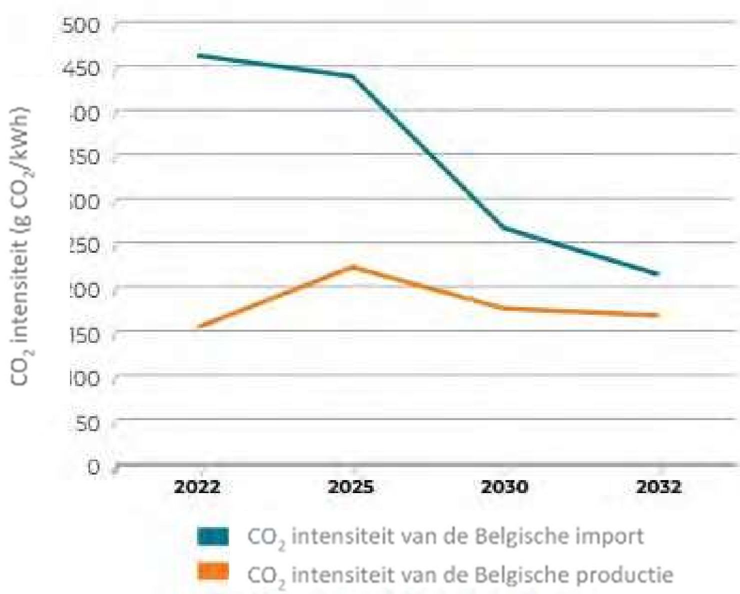

Figure 89: Projected carbon intensity of Belgian electricity generation and imports (Elia).

As this figure shows, Elia is a lot more optimistic (and probably more realistic) than Ember in terms of the CO_2 intensity of electricity generation. The reason is that Elia, like Energyville, assumes a significantly lower share of gas. In 2032, Elia takes into account a share of gas in electricity production of between 33% and 44%, with a share of wind energy of at least 37%. According to Elia's figures, carbon intensity peaks at around 225 g CO_{2eq}/kWh in 2025 (after all nuclear power plants are shut down), but steadily decreases thereafter.

Similar information can be found in the mentioned 2020 study by Energyville. With the data from this study, the graph below can be drawn up, showing the expected evolution of carbon intensity in, on the one hand, a "Central" scenario (without nuclear power after 2025) and, on the other hand, a "Nuclear 10" scenario, maintaining 2 GW of nuclear power for 10 years after 2025. The latter scenario corresponds to the one we assess in this EIA.

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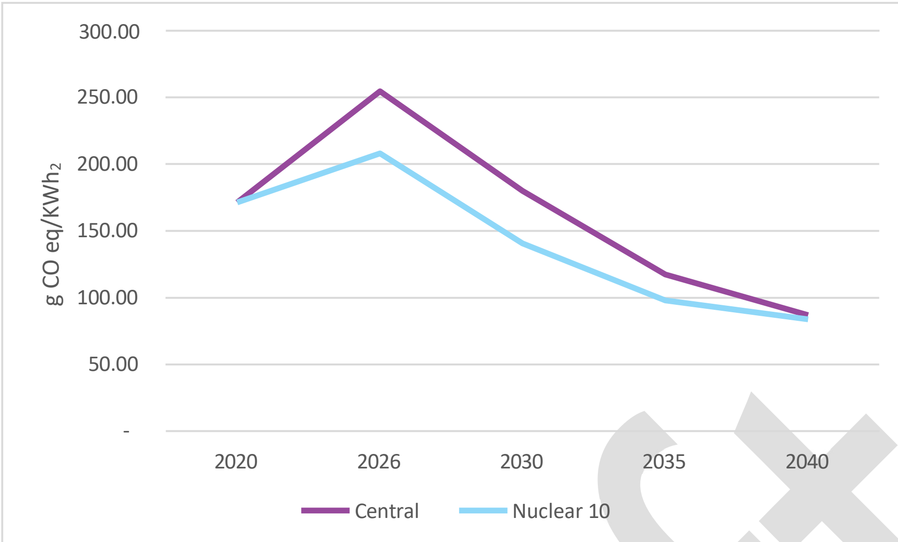

Figure 90: Evolution of carbon intensity of electricity generation under a scenario of full nuclear phase-out in 2020 (Central) and under a 10-year life extension scenario for 2 GW of capacity (Nuclear 10)

The trajectory of this figure, for the "central" scenario is quite similar to the figure in the Elia report, although Energyville assumes a higher peak in 2026. Similar to both graphs is the rapid decline in carbon intensity after 2025/2026, returning to a carbon intensity similar to today's from about 2030.

Through an interpolation of the figures that form the basis of the 'Central' curve from Figure 64, we obtain the data presented in Table 83. The table contains, by year from 2020 to 2040, the greenhouse gas emissions (in kton $_{CO2}$ eq) corresponding to an annual production of 7500 GWh of electricity (which is equivalent to (rounded) the average production of Tihange 3 over the period 2012-2021) to the carbon intensity of electricity production in the same year.

Table 83: Estimated $_{CO2}$ emissions (in a scenario of full nuclear phase-out in 2025 (Central)) caused by the production of 7500 GWh of electricity per year, at the average carbon intensity of electricity production in each year.

	Central	
	gram $_{CO2}$ eq/KWh	**Kton $_{CO2}$ eq**
2020	171,12	1.283,43
2021	185,02	1.387,67
2022	198,92	1.491,90
2023	212,82	1.596,13
2024	226,72	1.700,36
2025	240,61	1.804,60
2026	254,51	1.908,83
2027	235,87	1.768,99
2028	217,22	1.629,16

2029	198,58	1.489,33
2030	179,93	1.349,49
2031	167,40	1.255,54
2032	154,88	1.161,58
2033	142,35	1.067,62
2034	129,82	973,66
2035	117,29	879,71
2036	112,24	841,77
2037	107,18	803,84
2038	102,12	765,90
2039	97,06	727,97
2040	86,95	652,10

The accumulated emissions over the period 2027-2036 correspond to the emissions that would not be emitted (and thus "avoided") if 7,500 GWh of electricity based on nuclear generation (Tihange 3) were produced annually over that period. The value thus obtained is 12,417 kton or 12.42 Mton.

If we compare the emissions released from the operation of Tihange 3 over approximately the same period (16.76 kton), we can see that the emissions from Tihange over the period to which the deactivation deferral applies represent only 0.13% of the emissions avoided over the same period. The emissions attributable to keeping the plant open longer are thus negligible compared to the emissions avoided by it.

The 10-year lifetime extension of Tihange 3 leads to 12,417 kton less $_{CO2}$ emissions, or on average about 1242 kton/year. This means that the annual reduction is equal to 10% of emissions in the "production of electricity and heat" sector in Belgium in 2021 (12.8 Mton). The annual amount of GHG emissions saved decreases year after year over the period of the lifetime extension, as can be clearly seen from Table 83.

Impact on environmental vulnerability.

The question to be answered in this context is the extent to which extending the operation of Tihange 3 may affect the vulnerability of the environment to the effects of climate change. The effects that could theoretically be relevant relate to stormwater management on the one hand and the development of a heat island on the other.

Regarding the impact of **stormwater management, the** significant impervious surface formed by the area of the Tihange nuclear power plant can be pointed out. The water that falls on this area will not infiltrate into the soil and will therefore have to be collected and drained. This, of course, is what is happening now (see the description in the *section on water*). With climate change, rainfall may become more intense, so the collection and drainage system may not always be able to handle the rainfall. Thus, the presence of the plant could affect the occurrence of localized flooding.

The plant also forms a **heat island relative** to its surroundings. This effect results from the fact that the site is largely paved and has few trees that can provide shade or evaporative cooling. The paving and buildings store heat during the day and gradually release it at night. As a result, the temperature on the site are several degrees higher than in surrounding areas. This effect is amplified when summers are warmer. This warming is felt up to a distance of (at most) several hundred meters from the plant. These effects are present now and will remain present regardless of whether the plant is decommissioned or not (due to the long decommissioning time).

Finally, mention can also be made of the **problem of drought**, which will be exacerbated by climate change. At the plant site, little attention is currently paid to buffering and infiltration.

It should be noted that the Walloon authorities should take advantage of the next renewal of the (non-radiological) license for the plant in 2028 and decommissioning applications to ensure that drought and stormwater management aspects are further integrated into the environmental management of the site. Therefore, a gradual adaptation of the site to its vulnerability to the environment is planned.

Project vulnerability to climate change impacts.

Two different issues are addressed in this section:

- On the one hand, the effects that the project itself may suffer from climate change (in terms of drought, flooding, etc.). An example is the availability of cooling water, which may decrease if ambient and surface water temperatures become too high;
- Second, the extent to which project impacts, discussed elsewhere in this EIR, could change (be magnified or mitigated) as a result of climate change. For example, with increasing drought, river flows may decrease sharply, which could exacerbate the effects of a spill by causing much less dilution than expected.

Although these two types of impacts are different, they are treated together here because the underlying causes (heat, drought, flooding, etc.) are the same in both cases.

This project covers a clearly defined period, ending in 2036. Although the signs of climate change have become increasingly evident in recent decades and especially in recent years, these changes are not expected to lead to drastic changes in climate parameters during the life extension period. What is certain is that the expected and already observed developments will continue and also intensify. Therefore, the following elements should be considered in the context of the project's reference period:

- Higher average temperatures, with milder winters and warmer summers;
- More frequent heat waves, which can also be more intense and last longer;
- An increase in total annual precipitation, with more rain in winter (and possibly more flooding), but also significantly drier summers;
- An increase in the peak intensity of precipitation in the form of short, heavy showers, which can lead to flooding;
- Higher wind speeds.

The main elements relevant to the Tihange plant are flood risks and increases in maximum rainfall intensity.

Flooding

As explained in the section on *water,* the risk of external flooding *is* related to a strong flooding of the Meuse River north of the Tihange site, to an accidental breach of the Ampsin-Neuville dam or to flooding of the air coolers of Tihange 2 and Tihange 3.

In order to prevent the risk of flooding, a protective dike was built along the banks of the Meuse River and upstream of the flood protection system for the Tihange power plant site (dam). Moreover, the Tihange site, including the lower parts, is fully protected by a flood protection system (dam, dike, check valves).

In its October 2011 stress test report, Electrabel states that a flood with a return period of 10,000 years is the new design basis for the Tihange power plant, to meet international standards. The strengthening of the defenses was thus reconsidered at that time, with a view to making the necessary adjustments. A return period of 10,000 years is considered sufficient to take into account the evolution of risk related to climate change.

The Tihange 3 power plant is not located in a flood prone area. No major problems are expected in the future due to climate change, with higher water levels and more intense rainfall.

Strong winds

The maximum wind speed of 49 m/s, which was used as the basis for the design of all buildings on the site, has never actually been measured in Belgium. Moreover, the safety buildings are designed for loads higher than this maximum wind speed. Extreme wind speeds could lead to partial or complete LOOP. The LOOP scenario[126] is part of the design basis of the units. Such a situation does not jeopardize the cooling of the fuel, either in normal operation or in shutdown.

Tornadoes

The design of Tihange 2 and 3 takes into account a reference tornado unprecedented in this region (107.3 m/s while in Belgium a maximum of 70 m/s is considered to occur). The design of Tihange 1 takes into account a lower intensity (70 m/s). Since the phenomenon is usually not the decisive criterion for building design, important safety buildings will also be able to withstand tornadoes stronger than the reference tornado.

A severe tornado may lead to partial or complete LOOP, whether or not combined with a loss of the primary heat sink (shutdown of the Maas water circuit pumps - BHC). In case of loss of cold source for Tihange 3, other bunkered pumps remain available and compensate for the failure.

Higher average temperatures

If the ambient temperature is higher, the temperature of the discharged cooling water will also be higher. Climate change will increase average air temperatures, with milder winters on the one hand and longer and more intense heat waves in the summer on the other.

As a result, the temperature of the discharged cooling water will increase on average and additional measures may be required to meet the discharge standards for power plants. At the Tihange 3 power plant, the discharge flow into the Meuse is modulated to comply with the heating limits established in the permit. When hydrometeorological conditions require it, part of the cooling water leaving the cooling tower can be recirculated in the circuit, which has the effect of reducing the absorbed flow rate, the discharged flow rate and the thermal load discharged into the receiving aquatic environment.

In addition, the temperature of the discharged surface water will obviously also increase due to an increase in the average air temperature. If the temperature of the Meuse rises as a result of climate change, the temperature of the discharged cooling water will increase proportionally, with the possibility that the maximum daily thermal load to be discharged will be more frequently limited (see permit conditions), especially in summer.

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[126] LOOP = loss of off-site power, that is, the simultaneous loss of the external 380 kV and 150 kV grid. In such a situation, a turbine genset is automatically activated in island mode through the electrical protection devices. The generator set provides its own auxiliary systems. It is the first protection mechanism that powers the auxiliary systems of the unit. It is also possible to start the turbines of the Coo station (water storage in basins linked to a hydropower unit below it) that can power the auxiliary systems (via the high-voltage lines between Coo and Tihange).

The two phenomena described above (higher temperature of the cooling water to be discharged and higher temperature of the water in the receiving water body) may have a negative effect on the power generation of the plant. However, this effect is not expected to cause problems at the Meuse and during the (extended) lifetime of Tihange 3.

Temperature extremes

Extreme temperatures were also considered in the design basis and sizing of the equipment. Standards in this area were established based on statistics and the geographic location of the nuclear site. A period of extreme temperatures or extreme drought is not a sudden natural phenomenon. They are developments that can be predicted in time so that timely action can be taken. Tihange also has procedures in place to ensure safe operation in the event of a heat wave or frost.

It is not known whether and to what extent these procedures have already taken into account the recent increase in average temperatures and the more frequent and longer occurrence of heat waves. Since no problems in this area have occurred in recent years, with sometimes very hot periods in summer, it is assumed that this will also be the case for the period 2025-2037.

1.5.5 Assessment of impacts against policy objectives.

For the various high-level policy objectives related to climate discipline (see § 6.5.1), whether or not the project contributes to achieving these objectives is indicated below:

Objective "The greatest possible reduction in greenhouse gas emissions."

Over the entire period, deferring the deactivation of Tihange 3 avoids emissions of about 12,417 ktonnes of $_{CO2}$ eq. Emissions attributable to the maintenance of the Tihange 3 unit amount to 16,760 kt $_{CO2eq}$, representing 0.13% of the avoided emissions, which is negligible in proportion. Thus, the project contributes to the achievement of this objective and the score is **positive**.

In any case, it is clear that postponing the deactivation of Tihange 3 until the period 2025-2037 leads to avoided emissions in the order of 2,417 kton, or about 242 kton/year. This represents a saving of about 1.5% of Belgium's total greenhouse gas emissions for the year 2021 (110,800 kton).

Clearly, the magnitude of "avoided" emissions depends to a large extent on the assumed carbon intensity of energy production, and thus in particular on the share of renewable energy. In any case, since the exercise is only theoretical and illustrative, there is no need to aim for great precision in the assumptions.

Objective "Maximize ecological and social resilience to the impacts of climate change."

During the lifetime extension period, the project will have no additional impact on the resilience of the environment to the effects of climate change. The potentially relevant impacts will not increase if deactivation is postponed, partly because of the short time horizon (2037) in which climate change may manifest itself, and partly because the Tihange 3 site will remain hardened during the reference period, even in the case of deactivation in 2025. The project does not significantly contribute to achieving the objective, but neither does it significantly counteract it. The assessment is therefore neutral for this aspect.

Objective "Minimize project vulnerability to climate change impacts.

The analysis presented in this EIA clearly shows that the site is much more resilient to the impacts of climate change than is expected in 2025. Whether or not Tihange 3 is in operation in the reference period 2025-2037 does not change this. The assessment is therefore neutral.

1.5.6 Summary of key findings

The assessment against climate objectives is summarized in Table 84.

Table 84: Summary of the assessment of objectives in relation to climate on

Objective	Project contribution (transfer over 10 years)	Score
Largest possible reduction in greenhouse gas emissions	Limits $CO2_{emissions}$ for electricity to be produced	Positive
Maximizing ecological resilience to climate change impacts	The project could affect the vulnerability of the environment if measures are not taken to adapt to the impacts of climate change, but the contribution over time is small	Neutral
Minimizing project vulnerability to climate impacts	No significant contribution	Neutral

1.5.7 Mitigating measures

If the planned work to withstand climate change impacts is carried out, no mitigation measures of d climate discipline are required.

1.5.8 Gaps in knowledge and monitoring

There are no gaps in knowledge that would lead to other decisions. Additional monitoring beyond the existing monitoring program is not considered necessary.

1.6 Man and safety

1.6.1 Legal and policy context

In the context of this project, there is no significant overall health policy framework for non-radiological aspects. However, government agencies have prepared environmental health plans.

Environmental health is a concept defined by the World Health Organization (WHO) in 1993: "*Environmental health encompasses those aspects of human health, including quality of life, that are determined by physical, biological, social and psychosocial factors in the environment. It includes the theory and practice of assessing, correcting, controlling and preventing environmental factors that may adversely affect the health of present and future generations*.

The impact of the environment on human health is undeniable. The stresses can be multiple (air, water, soil, waste, food, products, radiation, noise, etc.) as well as the consequences (cancers, respiratory diseases, allergies, endocrine disruption, etc.) The WHO estimates that environmental stressors are responsible for 15-20% of all deaths in the 53 member states of the WHO European Region[127] .

According to the OECD, urban air pollution will be the leading cause of death worldwide by 2050[128] .

[127] EEA, 2010. Europe's environment: state and outlook 2010 - Executive Summary. European Environment Agency, Copenhagen.

[128] European Union, 2014, General Union Environment Action Programme for 2020, Living Well, Within Our Planet, doi:10.2779/67203.

Environment and health is the subject of much international work, particularly at the United Nations, European Union and WHO levels. At the first Ministerial Conference on Environment and Health, Belgium recognized through the European Charter on Environment and Health that every citizen has the right to "an environment that enables the attainment of the highest possible level of health and well-being." This point is also recalled in Article 23 of the Constitution.

In accordance with the commitment made at the second WHO conference on April 3, 2003, the Belgian Ministers of Health and the Environment adopted a first National Environment and Health Action Plan (NEHAP), which was followed by a second edition, the evaluation of which was completed during 2017. A third edition is currently in preparation.

At the regional level, complementary actions have been implemented, in particular through the development of specific projects and the adoption by the Walloon government, at its meeting of December 12, 2008, of a Regional Environment and Health Action Program (PARES) for the period 2009-2013, followed by the adoption by the Walloon government, on December 6, 2018, of the Walloon Environment and Health Plan, known as the "ENVIeS" plan.

Following the WHO's proposed health protection guidelines, air quality standards for SO_2, NO_x, NO_2, PM_{10}, $PM_{2.5}$, lead, benzene, CO, ozone, arsenic, cadmium, nickel, mercury and PAHs have been developed in several European directives, with which Member States must comply. These standards correspond to maximum ambient air concentrations of the various air pollutants and are based on guideline standards set by the WHO, without reaching the level of requirements desired by the WHO. Their main purpose is to protect human health and ecosystems.

In Wallonia, the Walloon Air and Climate Agency (AwAC) is responsible for air quality. It uses the air quality standards of European directives and the WHO to set emission limits for different industries, which are included as special conditions in their environmental permits.

In the area of safety, mention should be made of the Occupational Welfare Code, which includes all the implementing decrees of the Law of August 4, 1996 on the welfare of workers in the performance of their work. The code covers numerous aspects such as safety at work and the protection of the worker's health, as well as explosive environments (ATEX zones), fire prevention in buildings in general and risks related to chemical products.

Moreover, the presence of hazardous substances on industrial sites poses risks to human health and the environment. Directive 2012/18/EU ("SEVESO") aims to control major-accident hazards involving such substances.

Relevant effects

Regarding air pollution affecting human health and in particular the three main air pollutants ($PM_{2.5}$, NO_2, O_3), only nitrogen dioxide is included in the avoided emissions from nuclear power generation. The impact of the Tihange 3 unit extension on air quality, including NO_x, is discussed in Chapter 6.4, on the impact on air quality.

The discipline of "human health" or "human toxicology" can be defined as follows: the part of study concerned with collecting, processing and interpreting information about changes in the environment in order to estimate short- and long-term effects on public health. The World Health Organization (WHO) defines health as follows: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." This broad definition implies that the estimation of environmental effects must take into account not only the direct effects of stressors, but also the existing situation, longer-term effects, social context, indirect psychosomatic effects and public perception.

The table below provides a brief overview of the potentially relevant environmental stressors, adapted from Arcadis (2021). Arguments are given as to why some are not included further. Further on, the potential impact of the stressors highlighted in blue, for which meaningful impacts cannot be excluded a priori, is discussed in more detail. This discussion is also largely based on Arcadis' 2021 EIA, supplemented with information from the Strategic Environmental Assessment for the deferral of the deactivation of Doel 1 and Doel 2 (SCK CEN and KENTER, 2021).

Table 85: Overview of potentially relevant environmental stressors.

Stressors	**Specific description of stressor and/or source, health impact**	**Argument that stressor, if present, is not included**
Chemical stressors		
Air pollution	Emissions resulting from the operation of Tihange 3	The air discipline shows that the impact on air quality is negligible. Therefore, no relevant health effects are expected.
Contaminated soil and groundwater	Accidental emission	Within the Tihange site, the necessary measures are taken to avoid degradation of soil and groundwater quality. In case of accidental pollution, immediate action is taken. Exposure to accidental soil or groundwater contamination is therefore not investigated further in the Human Health discipline.
Surface water pollution	Discharge of wastewater	Sanitary and industrial wastewater are collected and treated before being discharged into the Meuse River.... Given that the water is not used for drinking water extraction, nor as recreational water, exposure to contamination via surface water is not relevant and is not investigated further in this discipline.
Fragrance	Emissions of substances with odor impact.	The main combustion gases emitted are odorless (CO, NO and CO_2) or only detectable at high concentrations (NO_2). Other substances with typical odor at CNT are ammonia and hydrazine, but their storage characteristics avoid odor emissions (see also Air discipline). Odor nuisance is therefore not sought further in the Human Health discipline.
Physical stressors		
Sound	Noise emissions from the operation of Tihange 3.	Noise emissions from the plant are limited (see also Biodiversity discipline), especially when measured against the plant's environmental characteristics. Moreover, noise impacts from normal operation will decrease as the other reactors are shut down, and decommissioning activities (which are outside the scope of this EIA) are likely to be a greater source of noise disturbance to the site's surroundings.

Stressors	Specific description of stressor and/or source, health impact	Argument that stressor, if present, is not included
Vibrations		The lifetime extension of Tihange 3 does not involve any activities that could give rise to vibrations.
Wind		Despite the presence of tall structures (cooling towers), no relevant wind disturbance is expected, given the distance from habitation.
Light, shadow	Shadow of the steam plume	French research (Méry, 1989) shows that reduction in hours of sun due to shadowing of the steam plume is largely limited to a distance of 1.5 to 3 km from a power plant.
Heat	Discharge of cooling water into the Meuse River	No human health effects are expected from the thermal effects of cooling water discharge into the Meuse River.
Electromagnetic radiation		No effects of electromagnetic radiation are expected outside CNT's site boundaries.
Biological stressors		
Infection hazard	Cooling towers may pose a risk of Legionella development.	The risk of exposure to Legionella is considered very low given the precautionary measures taken, in accordance with regulations. There have also never been any complaints in the past to our knowledge.
Acute poisoning from toxins		There are no relevant sources of toxins associated with the operation of Tihange 3.
Chronic toxicity		There are no relevant sources of biological toxins associated with the operation of Tihange 3
Allergens		There are no relevant sources of allergens associated with the operation of Tihange 3.
Other		
Dust nuisance		The lifetime extension of Tihange 3 does not involve any activities that could give rise to dust pollution.
Proximity to green space	Occupation of green space	The project is located within the boundaries of CN Tihange. The site is enclosed with a fence. This means that the site currently has no public function. Proximity to green space is therefore not further relevant in the Human Health discipline....
Psychosomatic aspects	Concerns of local residents because of activities in CNT (operation phase)	The potential for psychosomatic effects from the operation of the Tihange 3 will be investigated.
	Public concern over supply uncertainty	Affordability (in)security is treated as a topic in this EIA.
Effects of blackouts		The possible (health) effect of power shortages is discussed.

Moreover, the expert considered it relevant to study the possible consequences in terms of industrial safety and fire prevention. The activity could be a source of risk or stress for residents or neighbors.

SEVESO establishments are distinguished according to the quantity and hazardousness of the substances present or likely to be generated. This legislation requires preventive measures, inspections, the preparation and submission of a safety report by high-threshold establishments, which can be consulted by the authorities (DRIGM), and the preparation of an internal emergency plan and, for high-threshold establishments, an external emergency plan. Seveso risk refers to the probability of a major accident occurring in a Seveso establishment.

A big accident:

- Can have various causes, e.g., system failure, human error, chain reaction;
- Has serious consequences for the environment, people present in the company or living in the vicinity. These consequences may be apparent immediately or may not become apparent until later.

There are four different types of risks in a Seveso plant:

- Fire hazard ;
- Explosion hazard ;
- Risk of toxic emissions ;
- Ecotoxic risk.

1.6.2 Delineation of the study area

As mentioned above, this chapter mainly assesses the potential safety effects on the persons present on site and the population around the plant. As a reminder, this is the non-radiological environmental assessment of the project; thus, the objective is not to assess the possibility of a nuclear accident. For this reason, the study area for this topic is limited to a perimeter of 3 km around the power plant, a perimeter commonly used in environmental impact studies in Wallonia. In addition, this perimeter includes the residential areas of Tihange and Ampsin and the plants classified as Seveso.

1.6.3 Description of the current situation

The populated areas closest to the project are in the Tihange and Ampsin entities.

The nearest hospital is Huy Hospital, which is located 3.7 km southwest of the project. The Huy fire station is about 650 meters west of the project. It is located opposite the entrance to the power plant, on the other side of the N90.

The nearest schools are

- Ampsin Elementary School (Amay) is located 1.1 km northeast of the project;
- The free elementary school "Saint-Pierre" (Amay) is located 1.3 km northeast of the project;
- Tihange elementary school and kindergarten are located 1.4 km southwest of the project;
- The municipal school of Bons-Enfants (Huy) is located 2 km west/southwest of the project.

The nearest Seveso site to the project is about 1.3 km to the north. This is the company EPC Belgium (formerly Dynamichaines nv) located in the municipality of Amay, rue Bois de Huy 5d. It is indicated on the figure below. It is a low threshold establishment.

EPC Belgium mainly operates in :

- The importation of explosives for open quarries and construction sites;
- The transportation of explosives between France and Belgium ;
- The storage of explosives in its warehouses in Amay;
- The storage of matrix and ammonium nitrate at its site in Amay;
- The sale and supply of explosives, percussion cords, detonators and all accessories related to the use of explosives in quarries or opencast mines;

- The manufacture of special explosives in quarries thanks to mobile explosives production units (MEMUs).

As shown in the figure below, the vulnerability zones of the EPC Belgium site run across the plant site.

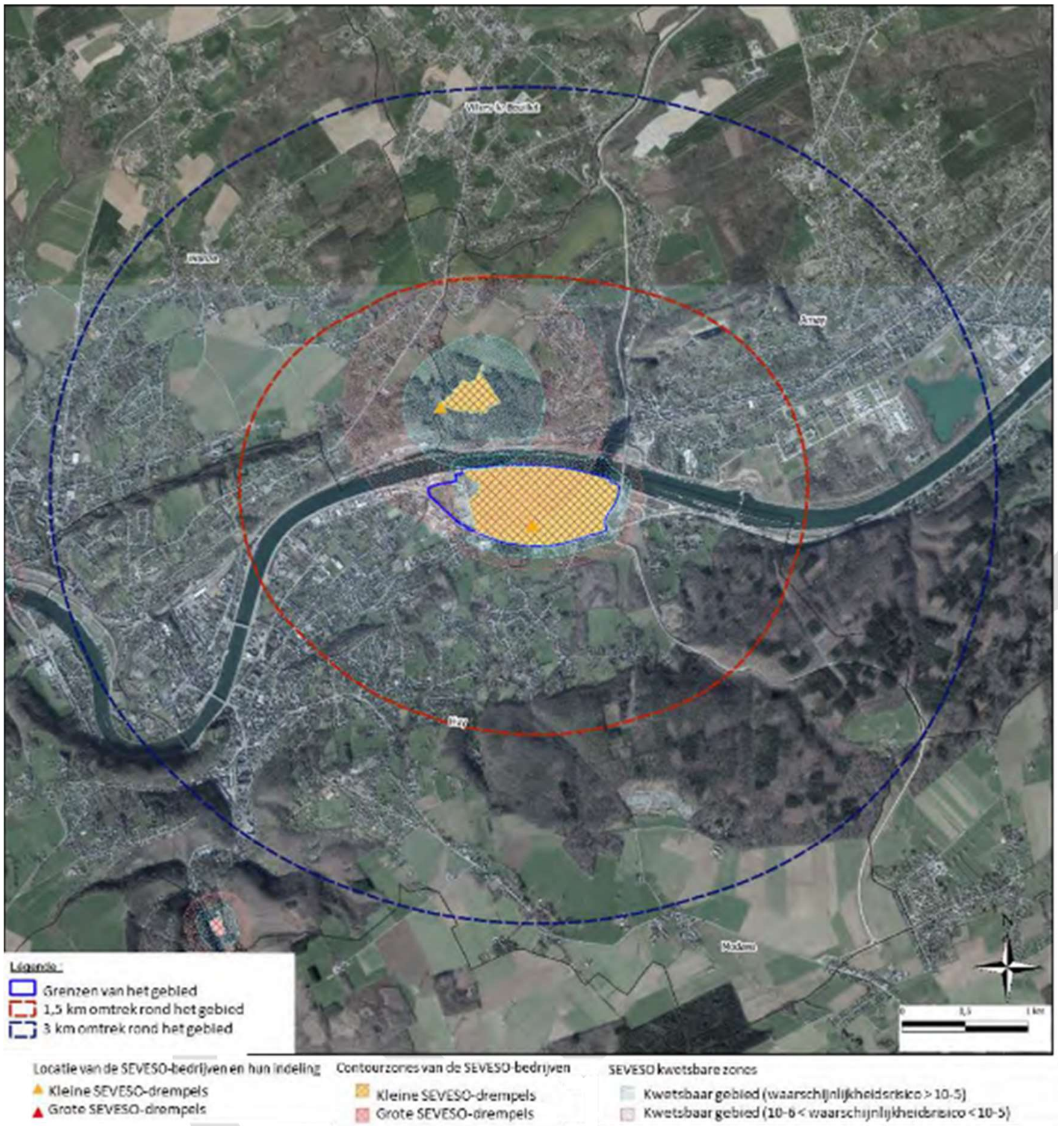

Figure 91 : Seveso establishments within a 3 km radius of the Tihange power plant.

1.6.4 Project impact assessment.

1.6.4.1 Psychosomatic aspects and risk perception

In risk perception, psychosomatic effects can be observed. The "psychosomatic" effect is not always the most important factor. There is always a combination of factors underlying it. Psychological problems are usually caused by specific situations and are not necessarily a consequence of biomedical, genetic or neurological reactions or of a certain type of behavior.

Data on the incidence of psychosomatic complaints due specifically to the operation of the Tihange nuclear power plant are not available. However, data are available from questionnaires and surveys on attitudes (including risk perception) of nuclear energy, nuclear technology and nuclear power plants in Belgium among the general Belgian population.

SCK CEN has been surveying public perception of radiation risks and attitudes toward nuclear energy since 2002. The survey is conducted via the "SCK CEN Barometer". This is a broad survey of the population (more than 1,000 people), representative of adult Belgians (18+), divided by provinces, regions, level of urbanization, gender, age and employment status.

The SCK CEN Barometers include recurring topics such as perceptions of various radiation risks, trust in nuclear industry actors and opinions on the use of nuclear energy, as well as more detailed questions on specific topics.

The SCK CEN Barometer shows that in 2018, environmental pollution and the non-compliant use of nuclear technology are of the highest concern to the public: 61% consider environmental pollution to be a major or very major risk in the next 20 years, and 54% consider the potential for the use of nuclear technologies by terrorists to be a major or very major risk. A separate study found that the potential for the use of nuclear weapons and radioactive waste in the next 20 years is a major and sometimes even a major risk to public health. There is general consensus to reduce the number of nuclear power plants. Confidence in the authorities for the measures they take to protect the population from risks of a nuclear accident is decreasing between 2013 and 2018.

In 2018 (SCK CEN Barometer, representative data 18+ of the Belgian population), about half of the Belgian population considers the risks linked to nuclear accidents as high to very high. A large part of the population (75%) considers that even a low dose due to a nuclear accident is harmful to public health.

The above reflections show a mixed picture; it can by no means be determined whether the use of nuclear energy or the existence of the nuclear power plants gives rise to specific psychosomatic or psychosocial complaints. However, it can be assumed that if there were such complaints, they would mainly be related to nuclear electricity production in general, rather than to the functioning or non-functioning of the specific Tihange 3 reactor unit.

Although a significant portion of the population is concerned about a nuclear accident, as mentioned, there are no data to show that this perceived high risk also causes psychosomatic effects. Nothing is known about the specific situation regarding the Tihange site, let alone Tihange 3. However, it can be assumed that with a lifetime extension of Tihange 3, the perception of risk (among local residents and more broadly) will also remain ten years longer; admittedly, this perception of risk will have decreased because two of the three reactors at Tihange will have been shut down. Since there is no concrete evidence that risk perception also concretely gives rise to psychosomatic complaints specifically attributable to the operation of nuclear power plants, we can assume that the effect of risk perception in life extension does not give rise to attributable psychosomatic complaints.

1.6.4.2 Security

The Tihange power plant is a low threshold Seveso facility mainly due to the ecotoxicity criterion of the products stored at the site. The main contributing products are hydrazine hydrate[129] (4.95 and 15%), sodium hypochlorite at 14% and light fuel oil.

The plant has a strategic reserve of 2,695 tons of fuel oil, distributed among about fifty tanks. Annual consumption is relatively low, about 1,100 m³/year at normal operation. This fuel oil is mainly used to feed the auxiliary boilers for steam production and the emergency diesel generators when the external power supply fails. With the planned closure of Tihange 1 in 2025 and Tihange 2 in 2023, with certain

[129] Hydrazine: chemical reagent used for conditioning water-steam circuits.

facilities and depots will be removed, the question is whether the low Seveso threshold will still be exceeded after the implementation of the project (extension of Tihange 3 from 2025 to 2037). In the absence of figures on the closure and decommissioning of these two units, this could not be determined as part of this environmental impact assessment.

Every Seveso company must have an environmental permit before it can begin operations. Regional authorities must be able to determine whether the establishment or expansion of a Seveso company poses an acceptable risk to the environment, for example to residential and natural areas. The operator must therefore demonstrate that it can control the risks on its site and limit the consequences of any accident.

To this end, the operator of a Seveso lower-tier establishment must attach to its permit application a notification listing the selection of feared events (based on risk analyses) and presenting the risk management measures taken. This notification also includes a table listing the establishments causing domino effects that reach other Seveso establishments and a description of the measures taken. In addition to this document, prepared in the context of applications for non-radiological operating permits (environmental permits), the Tihange power plant has established an internal emergency plan to be activated in the event of a major accident or an incident that could lead to a major accident.

It should also be noted that the RAM unit conducts regular inspections of Seveso sites.

As mentioned above, another low-threshold Seveso facility (EPC Belgium) is located within 1.5 km of the Tihange power plant. The sensitive areas of this establishment extend to the Tihange power plant.

These zones are defined by the RAM Unit in accordance with Art. 25 of the Cooperation Agreement, which obliges the Regions to include in their urbanization policies around Seveso establishments a control of new establishments or modifications to these establishments. To this end, the RAM unit has calculated Neighborhood Protection Perimeters (curve $^{10-6}$ /year delineating the vulnerable zone) for all Seveso industrial sites in Wallonia. These curves are used to control new developments around Seveso establishments. Thus, for each permit application, the impact of the project on these curves must be assessed. If necessary, these curves are recalculated. Any increase in these curves toward already urbanized areas may result in a negative opinion on the permit application.

Given that the two low threshold Seveso establishments have obtained their licenses and taking into account the above elements (preparation of hazard warnings, study of domino effects, consideration of neighboring establishments, implementation of risk control measures, internal emergency plan), it is considered that the non-radiological safety risks are under control and that the extension of the operation of Tihange 3 will have a negligible impact.

Another safety risk that may affect workers and local residents is the risk of fire. In view of this risk, the plant has implemented numerous fire prevention measures and has firefighting equipment on site.

Intervention equipment is constantly evolving to adapt to firefighting techniques and to better handle all industrial risks.

The CN Tihange has a large fire truck. This equipment is available from the regional fire department located opposite CN Tihange. All buildings with fuel tanks are equipped with fire detection and sprinkler systems.

Making use of two vacant buildings following the construction of the SF2 [Building130,] the department in charge of fire prevention and protection has had a new fire station since early 2021. This

[130] [SF2]: Building for the temporary storage of spent fuel.

new base allows greater efficiency thanks to the organization and centralization of equipment: intervention vehicles (fire trucks, pickups, logistics vehicles and specific trailers), equipment for the management of classic incidents (personnel accidents, fire, pollution, etc.) and a laboratory for masks to ensure the maintenance and control of respiratory protection adapted to specific risks.

The Tihange power plant has an internal fire department on site 24 hours a day. In case of an incident, they act in cooperation with the operational teams (trained as members of the first intervention team) and with external emergency services (the fire station of the HEMECO emergency zone[131] is located opposite the power plant). An agreement links the Tihange nuclear power plant to the HEMECO emergency zone, allowing close operational cooperation (training, joint exercises, sharing of experience, etc.) between the ESI team and civil security.

Given all the preventive measures and fire-fighting resources present at the Tihange power plant, and given that these measures and resources will remain in place until the decommissioning of Tihange 3, it is considered that the extension of the operation of this unit until 2037 does not pose any additional risks, especially since these risks are under control.

1.6.4.3 (Avoided) health effects of a blackout.

Lifetime extension of Tihange 3 is aimed at guaranteeing security of supply, pending a situation where that guarantee can be obtained using other energy sources.

Thus, life extension dramatically reduces the risk of blackout (and associated health effects). Indeed, blackouts potentially entail significant economic and social costs.

A 2014 study by the Federal Planning Bureau did a quantitative evaluation of the impact of power outages in Belgium, based on an Austrian model (Black-out Simulator). A one-hour blackout on Belgian territory during a working day at a time when all Belgian companies are active would cause a total societal economic loss of about 120 million euros (both in winter and summer). Some alternative methods were also calculated and yielded a range between €61 million (the "GDP method") and €278 million (the "RTE method"). The economic damage mentioned includes the damage suffered by households, which, however, is "only" 8 million euros per hour. The industrial sector has the largest share of the total costs, at 49%; the tertiary sector is responsible for about 40% of the costs. The model used also allowed for spatial allocation of the calculated losses. This showed that the largest loss was recorded in the province of Antwerp (24.74 million euros, or almost 21% of the total), followed at some distance by the Brussels Capital Region (15.67 million euros or 13%).

It is important to note that this estimate always looked at a 1-hour breakdown. The impact of a 2-hour breakdown is not necessarily twice as great. This is also shown by the simulator figures: the cost of a 2-hour breakdown in Belgium amounts to almost 170 million euros (or 42% more than a 1-hour breakdown). However, the longer a disruption lasts, the consequences increase linearly with time, and after about 8 hours, the damage will increase exponentially. An outage of more than 8 hours can be referred to as a disaster situation: the number, but especially the severity of the consequences will then be difficult to oversee (and estimate).

Clearly, with the above economic losses also come health risks'.

Power outages can affect the operation of emergency services. All hospitals have emergency power systems to support the most critical activities, such as operating rooms, intensive care units, emergency services, etc. Depending on the facility, emergency power systems can potentially

[131] zone HEMECO: zone Haspengouw, Meuse and Condroz.

not support some other services, including X-rays, air conditioning, refrigeration, elevators, etc. In addition, technical problems can arise with auxiliary generators, as was evident during the 1977 New York blackout. Some hospitals struggled to bring generators online and faced generators that overheated.

The factors that determine this effect include direct parameters such as duration or frequency, as well as contextual parameters such as outdoor temperature and scale. Safety problems also arise during a blackout, but these are not the subject of the health discipline. Classic safety problems can arise in hospitals, elevators, traffic jams, etc.... .

An important study (Dominianni 2018), reports the health effects of a power outage based on three events. For two of the three power outages, the context is a contributing factor; in fact, the outages occurred during a heat wave. Effects based on this study include respiratory problems and likely increased mortality. Power interruptions during heat waves can lead to kidney failure. In extreme cold, it leads to more common causes of death and heart disease.

Casey et al. (2020) conclude, based on an extensive meta-analysis, that power outages have significant health consequences ranging from carbon monoxide poisoning, temperature-related illness, gastrointestinal illnesses, and mortality in all cases of cardiovascular, respiratory, and renal diseases, especially for individuals dependent on electricity-dependent medical equipment

Thus, it is clear that the reduction in the likelihood of power outages associated with the project also reduces the likelihood of associated negative health effects, and thus can be evaluated positively.

1.6.5 Evaluation of policy effects

It is now necessary to consider whether or not the effects described above can contribute to the achievement of policy objectives.

The relevant and overriding objective for this topic is to ensure the safety of the population. Since the Tihange plant is a Seveso facility and is therefore subject to strict regulations, in particular in the areas of fire prevention, prevention of major accidents and related domino effects and annual inspections, it is assumed that the continuation of operations for a period of 10 years will not impede the achievement of the main political objective of this theme. Nor are psychosomatic effects expected. However, one can speak of a positive health effect of keeping Tihange 3 open longer, to the extent that the probability of a blackout and the potential health effects associated with it are significantly reduced.

1.6.6 Mitigating measures

No mitigation measures are proposed at project level, except to verify the Seveso status of the site after the closure of Tihange 1 and 2. In case the plant is no longer classified as a Seveso facility and therefore no longer subject to the regulations, special attention will still have to be paid to the prevention of accidents and incidents in order to control safety risks to the population (the current safety level must be maintained even if the site is no longer Seveso).

1.6.7 Gaps in knowledge

For the impact assessment of this topic, there are no gaps in knowledge. The granting of a license to the Tihange plant, a low threshold Seveso facility, and the regular inspections by the RAM cell indicate that the plant meets the legal requirements and that the potential major-accident hazards are under control.

1.7 Cross-border effects

Most of the non-radiological consequences of 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 impacts.

Only the cooling water discharge, which affects the temperature of the Meuse, could have an influence over a longer distance. However, considering the temperature data of the Meuse at the last monitoring station for the Netherlands, the influence of cooling water discharge can be considered negligible (fewer exceedances of 25°C and no exceedances of 28°C on average during the last 3 years).

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

2 Radiological effects Tihange 3

2.1 Direct radiation and discharges during normal operation

2.1.1 Current situation

As discussed in the general methodology (§2.3.3), the potential radiation exposure for humans and the environment under normal operation are related to direct radiation and the gaseous and liquid effluent discharges containing certain concentrations of radioactivity. We describe here the current situation for CN Tihange.

Direct radiation

The TELERAD network operated by the FANC-AFCN continuously measures the radiation present in the environment (see §2.3.5). Specific to the CN Tihange site, the TELERAD network consists of 20 ring stations placed along the perimeter of the site and some 15 stations in the wider vicinity of CN Tihange (agglomeration stations). The ring stations are spectroscopic stations that register gamma spectra in addition to the dose rate (they also measure the energy of the gamma radiation). This allows to identify specific/typical radionuclides linked to the operation of CN Tihange if they are present. All stations measure dose rate (ambient dose equivalent rate H*[10]) and are able to accurately measure both background levels, where the variation in the natural background radiation as a function of time can be observed (e.g. if there is enough snow a lower dose rate will be measured due to shielding of the natural radiation coming from the soil), as well as to estimate the annual dose of external gamma radiation at the location of each station, as well as to make accurate measurements in case of strongly increased dose rates (accident situations).

In addition to natural radiation from the environment, the ring stations can pick up both direct radiation (direct radiation) from radioactivity on and radiation from the site as well as from radioactive discharges. Figure 92 shows the annual dose[132] recorded by the ring stations. Table 86 shows the data for all the years considered. We see that average values vary between 0.72 and 1.00 mSv per year for the different ring stations. These values correspond to typical values of background radiation in the region around Huy in Wallonia, which is around 0.85-0.95 mSv/year (0.3 mSv/year cosmic radiation and 0.55-0.65 mSv/year terrestrial radiation). The variations can be attributed to natural radioactivity in the immediate vicinity of each station. Since these stations measure both natural and artificial radiation, it cannot be ruled out that a contribution, though very small and within the variations of the natural background, comes from the operation of CN Tihange.

In any case, these measurements show that the dose from external radiation is much smaller than the legal limit of 1 mSv/year and indistinguishable from local variations in the natural background.

[132] The average annual dose was calculated for each Telerad ring station by determining the average dose rate from the 10-minute data for each year from the period and multiplying it by a factor (365.25*24) for the average number of hours in a year and then averaging it over the different years.

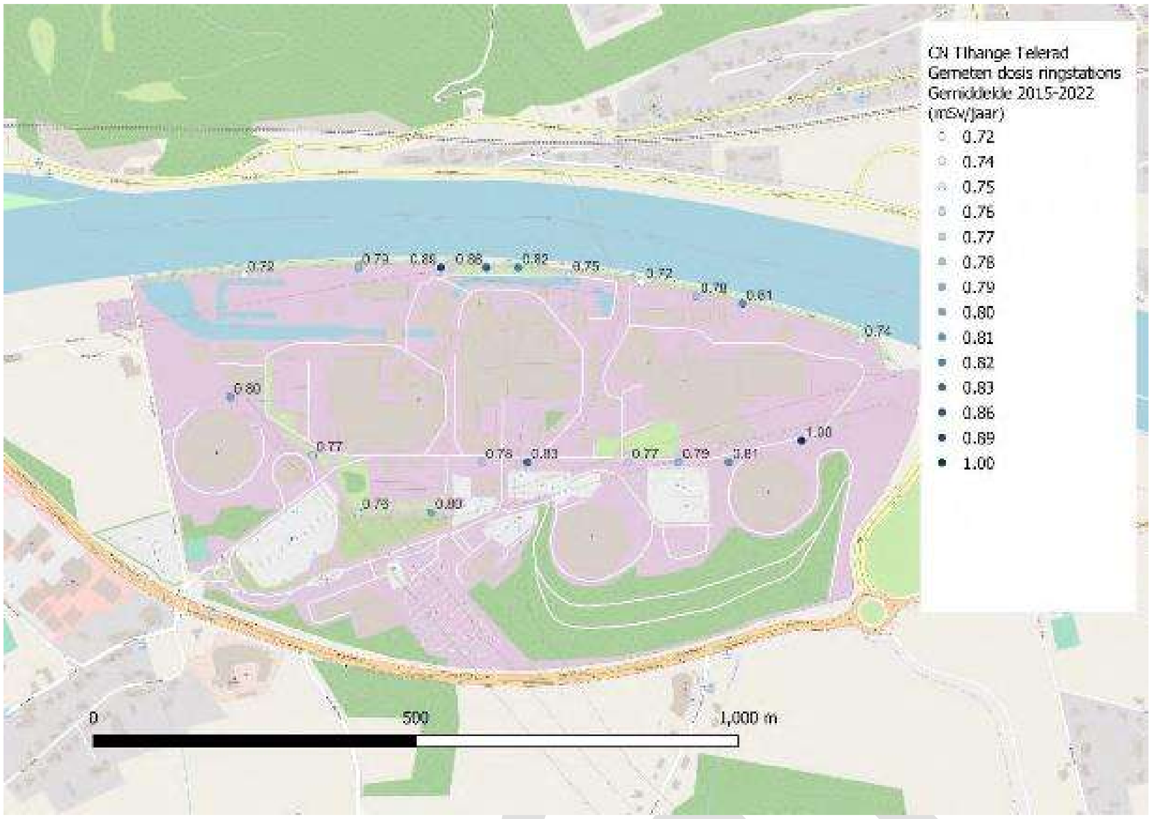

Figure 92: Annual dose in mSv (average over period 2015 to 2022) as measured by the Telerad stations operated by the FANC-AFCN around the CN Tihange site (Figure made on the basis of 10-minute data obtained from the FANC-AFCN).

Table 86: Annual dose in mSv of external radiation as recorded by the 20 Telerad stations around the CN Tihange site (Data based on 10-minute data FANC-AFCN). Mean and standard deviation are also given.

	2015	2016	2017	2018	2019	2020	2021	2022	gem	stdv
BE501	0,790	0,796	0,793	0,809	0,807	0,811	0,778	0,777	0,795	0,013
BE502	0,757	0,770	0,753	0,781	0,780	0,762	0,757	0,752	0,764	0,011
BE503	0,781	0,784	0,781	0,782	0,764	0,760	0,758	0,763	0,772	0,011
BE504	0,790	0,817	0,818	0,807	0,818	0,796	0,783	0,784	0,802	0,014
BE505	0,748	0,725	0,755	0,754	0,706	0,697	0,693	0,695	0,722	0,026
BE506	0,817	0,782	0,792	0,807	0,802	0,774	0,777	0,768	0,790	0,016
BE507	0,967	0,860	0,878	0,918	0,899	0,885	0,871	0,853	0,891	0,035
BE508	0,917	0,858	0,853	0,889	0,857	0,832	0,850	0,838	0,862	0,026
BE509	0,848	0,820	0,823	0,843	0,823	0,832	0,801	0,793	0,823	0,018
BE510	0,804	0,766	0,774	0,766	0,760	0,725	0,725	0,719	0,755	0,028
BE511	0,757	0,732	0,733	0,732	0,699	0,696	0,696	0,696	0,718	0,022

BE512	0,753	0,752	0,749	0,751	0,798	0,825	0,827	0,822	0,785	0,034
BE513	0,826	0,803	0,802	0,820	0,825	0,825	0,790	0,784	0,809	0,016
BE514	0,749	0,738	0,740	0,750	0,752	0,754	0,729	0,726	0,742	0,010
BE515	1,201	0,965	0,880	1,111	1,154	1,041	0,828	0,809	0,999	0,141
BE516	0,815	0,824	0,819	0,820	0,821	0,805	0,809	0,806	0,815	0,007
BE517	0,788	0,797	0,801	0,803	0,806	0,807	0,781	0,774	0,795	0,012
BE518	0,807	0,749	0,752	0,753	0,764	0,795	0,791	0,784	0,774	0,021
BE519	0,820	0,832	0,837	0,847	0,845	0,840	0,815	0,815	0,831	0,012
BE520	0,781	0,777	0,778	0,786	0,784	0,788	0,785	0,781	0,783	0,004

In the framework of a nuclear emergency planning exercise, on June 8, 2021, in a collaboration between SCK CEN, IRE, Defense, FANC-AFCN and in consultation with the operator of CN Tihange, a helicopter flight was conducted over CN Tihange and wider surroundings with radiological equipment on board specifically designed to map post-accident contamination. This equipment consisting of 4x4 liter NaI(Tl) detectors is also sufficiently sensitive to detect variations in the natural background or artificial sources of radioactivity. The results of these measurements are shown in Figure 93Figure 94: The distribution of the dose rate for all measurements performed above CN Tihange and wider surroundings (7 km x 7 km). Only a very small number of measurements show values above 0.100 µSv/h.. This figure is the result of 2 flights: one in parallel flight paths following the Meuse valley and one flight with flight paths perpendicular to the Meuse valley. The figure shows the dose rate in microSv/hour (µSv/h) every second along the path of the helicopter, corrected for the height above ground, which varies greatly because of the location of CN Tihange in the valley of the Meuse. The correction for height above ground ensures that the dose rate obtained is representative of the exposure due to external radiation at ground level, possibly for an average value over the area of a circle with a radius roughly corresponding to the height at which the helicopter flies above ground since the measuring equipment from the helicopter detects radiation coming from different directions. The typical flight altitude is 150 meters.

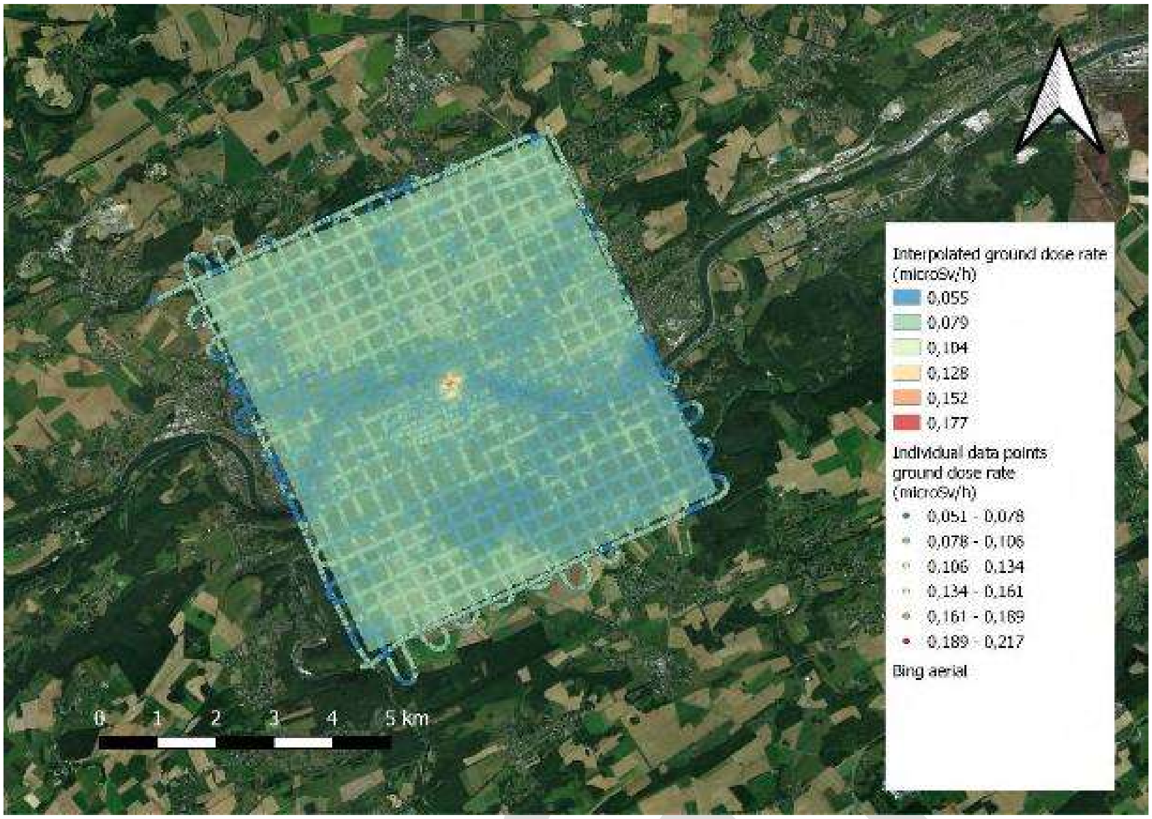

Figure 93: The dose rate in microSv per hour (µSv/h) on the ground determined from helicopter measurements after correction for height above ground above the CN Tihange and wider surroundings. The scale and colors are chosen to visualize small differences in the dose rate, e.g. you can very clearly recognize the course of the Meuse River, due to the lower natural radioactivity levels measured above water. A small increase is visible above CN Tihange: see also Figure 95 and text).

The dose rate varies over the entire region where the helicopter flight was conducted, including the CN Tihange site between 0.050 microSv/hr and 0.217 microSv/hr, with, however, all but a small number of measurements (over the CN Tihange site and to which we will return further) having results between 0.05 microSv/hr and 0.10 microSv/hr (Figure 94). This corresponds to an external radiation dose of 0.44 mSv to 0.88 mSv/year if we consider the helicopter values as representative of a full year. The spread is somewhat larger compared to the Telerad measurements, with especially more values at the lower end. This is largely due to the fact that water (the Meuse) contains lower natural concentrations of radioactivity than soil and that the Meuse is always in the field of view of the radiation detectors in the helicopter over the Meuse Valley area (also clearly visible in Figure 93). Furthermore, these are data measured for only 1 second, whereas the TELERAD data are averages over several years. There was no rain at the time of the helicopter measurements and all three reactors were in operation for electricity production at the time of the flight. The range of values is consistent with typical background values, beyond the limited elevation measured above the CN Tihange site (see below). The scale and colors used were chosen to visualize small differences.

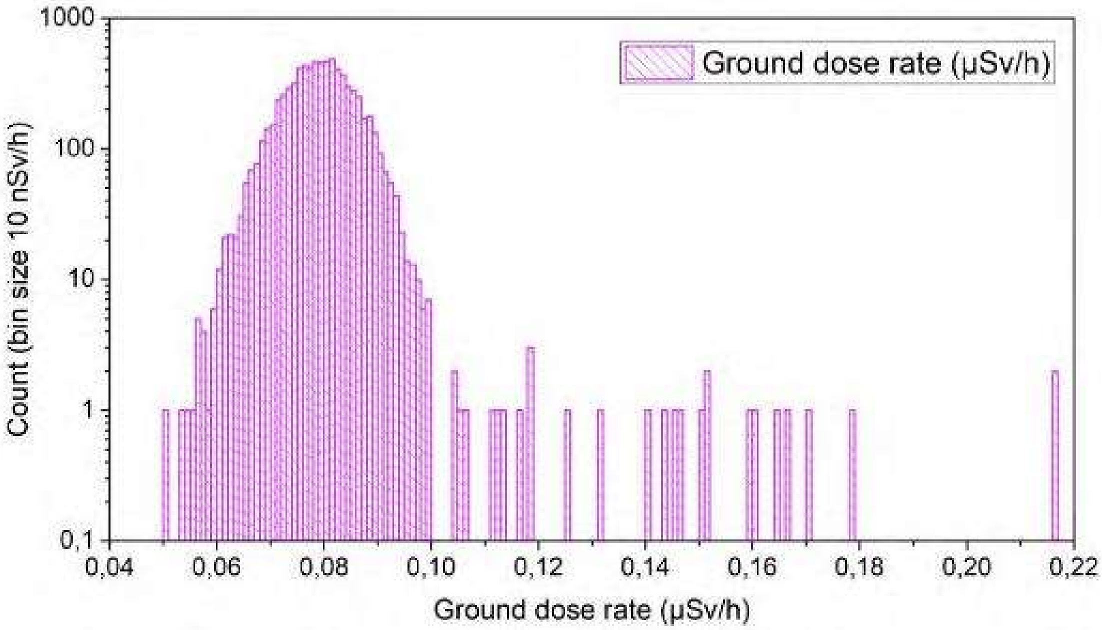

Figure 94: The distribution of the dose rate for all measurements performed above CN Tihange and wider surroundings (7 km x 7 km). Only a very small number of measurements show values above 0.100 µSv/h.

A limited number of measurements above a dose rate of 0.100 µSv/h were recorded. These values were only measured above the CN Tihange site and more specifically above a certain location on the site, i.e. a building belonging to Tihange 2 where radioactive waste is treated (see Figure 95). At this location, the analysis of the energy of the measured radiation (spectroscopy) also clearly indicated that the measured increase was due to artificial radioactivity associated with activities on the CN Tihange site. The increase in dose rate visible when flying over this building, however, is not visible as a clear increase by the TELERAD ring station located a short distance from this building. This means that radiation is very well shielded laterally (for people on the ground), but less shielding is provided upward. Furthermore, it can be observed that over most of the site, including when the reactors fly over, no increase compared to the natural background is measurable, the values over most parts of the site are not higher than the average value outside the site.

Together with the TELERAD measurements, these helicopter measurements show that radioactivity and radiation in the various buildings and on the CN Tihange site are very well shielded from people in the surrounding area. The measured value is also much smaller than the reference value of 10 µGy/h below which the effects on the environment (fauna and flora) are negligible[133] and is also below the range of 3-30 µGy/h reported in ICRP publication 136. Therefore, there are no adverse effects to birds potentially residing on the roof.

[133] J. Garnier-Laplace & R. Gilbin (Eds.), *Derivation of Predicted No Effect Dose Rate values for ecosystems (and their sub-organizational levels) exposed to radioactive substances*, ERICA Deliverable D5, European Commission, 6th Framework, Contract N° FI6RCT-003-508847, 2006.

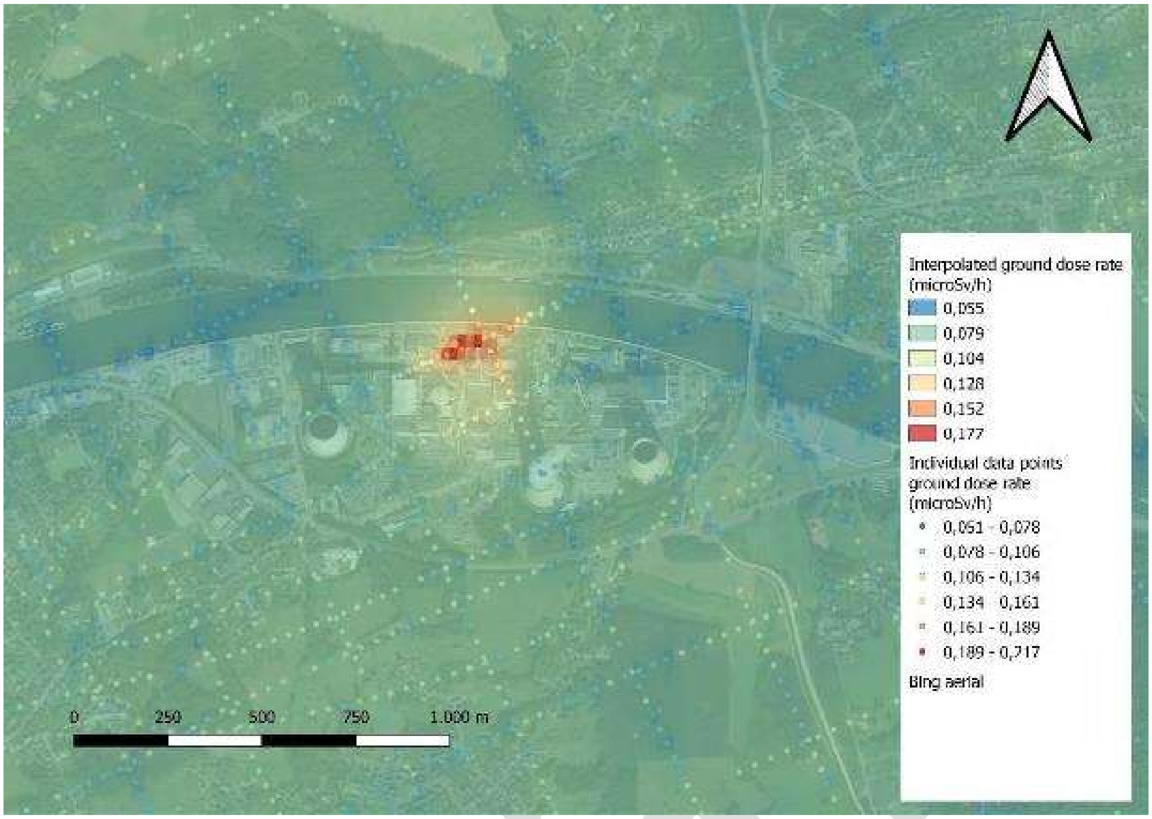

Figure 95: Magnification of helicopter measurements over the CN Tihange site. More explanation: see text, the scale and colors were chosen to make small differences clearly visible.

Atmospheric discharges

Atmospheric discharges originate and/or are attributable to the following processes:

- Gaseous waste (GW)
  - Degasification of the primary circuit is stored in decay tanks of the waste gas treatment system, these are discharged after a period of decay;
- Reactor building or annular space (RGI).
  - Removal of the gas initially transferred by an air purification system from the reactor building or annular space;
- Intermittent discharge (DIS)
  - Intermittent, primarily involuntary or forced discharge that occurs through a nuclear vent outlet. These are scheduled discharges (excluding pilot discharges from I-131). The use of this category is for spikes over continuous discharges whose origin is difficult or impossible to determine;
- Continuous drainage
  - Continuous discharge from various non-controllable sources occurring through nuclear ventilation;

- Iodine Testing
    - Discharges of I-131 during iodine testing. All carbon filters are periodically tested with radioactive iodine, namely I-131.

Table 87 shows the discharge limits for the entire CN Tihange site in annual total activity (being 12 sliding months) for the different groups and/or individual radionuclides. The operator must also submit monthly overviews of discharges to the FANC-AFCN. In addition, there are also specific operating limits for instantaneous concentrations of discharges for the different units.

Table 87: Atmospheric discharge limits for the entire CN Tihange site (CN Tihange operating permit).

Type	Discharge limits technical specifications
Noble Gases	2,220 TBq
I-131	14.8 GBq
Aerosols (beta gamma and alpha)	111 GBq
Tritium	55.5 TBq

It should be noted that discharges of carbon-14 (^{14}C) and argon-41 (^{41}Ar) are not monitored because they are difficult to measure, and are conservatively determined based on reactor power. Nevertheless, only iodine-131 is monitored and reported, other iodine isotopes, particularly iodine-133 (^{133}I) are calculated from the iodine-131 measurements.

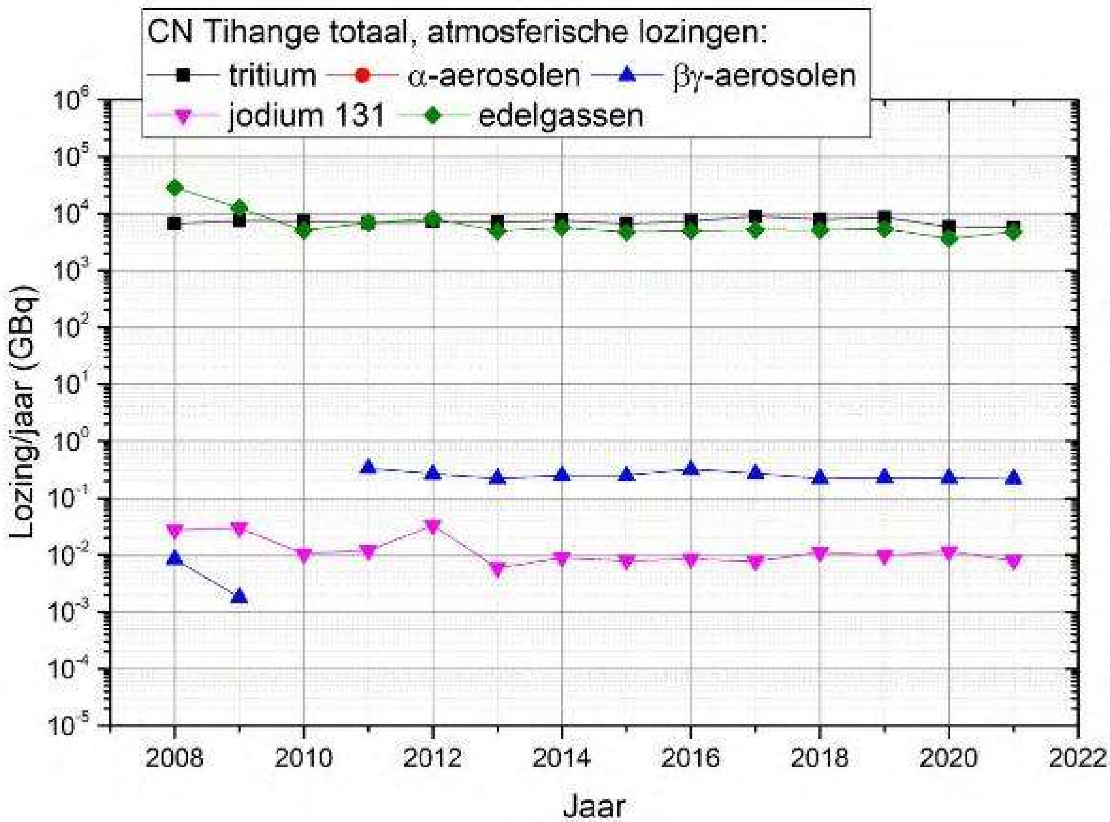

Figure 96: Gaseous discharges per year for the total CN Tihange[134] site.

The atmospheric discharges per year for the different groups of radionuclides as reported to the authorities and also found, among others, in the RADD database of the European Commission (https://europa.eu/radd/) for the years 2008-2021 are shown in Figure 96. These discharges are the atmospheric discharges for the entire CN Tihange site. They are plotted on a logarithmic scale given the significant differences in discharges between the different groups of radionuclides. The apparent increased values from 2011 of beta-gamma aerosols are due to a new guideline regarding reporting[lxxxii]. Any discharged activity less than the detection limit of the measurement chains is conservatively accounted for 25% of the detection limit in the discharge. The variations (apart from the 2011 jump for beta-gamma aerosols) in atmospheric discharges per year are due to variations in the operating regime of the reactors. The overall trend is for discharges to be constant over an extended period.

These atmospheric real discharges can be compared with the discharge limits according to CN Tihange's operating permit (as given in Table 87). The results of this comparison are shown in Figure 97 as a percentage of the discharge limit per group and this for the period from 2012-2021. The actual atmospheric discharges are only a fraction of the discharge limits. For most radionuclide groups, this is well below 1% of the discharge limits. For tritium it is about 13 % of the discharge limits.

[134] All information on discharges from Class 1 facilities including KC Doel can be found on the FANC- AFCN website: https://fanc.fgov.be/nl/professionals/nucleaire-inrichtingen-klasse-i/toezicht-van-radioactieve-lozingen-van-klasse-i

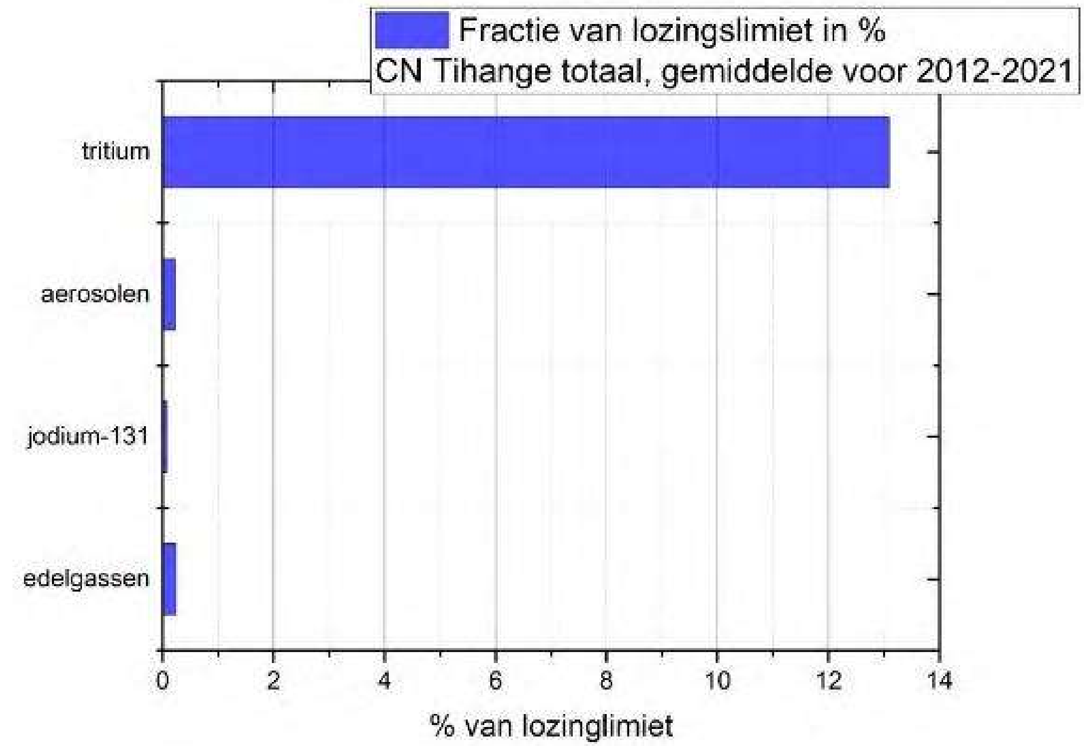

Figure 97: Discharges as a percentage of the discharge limit for different categories of gaseous discharges for the entire CN Tihange site, averaged over 10 years from 2012-2021.

The impact (dose load) of the gaseous discharges will be analyzed later along with that of the liquid discharges. However, Figure 98 shows the importance of carbon 14 (C-14) for the dose in the whole of the atmospheric discharges for the CN Tihange site. Carbon 14, also a natural radionuclide, accounts for more than 90% of the dose load due to the atmospheric discharges and this for all age categories.

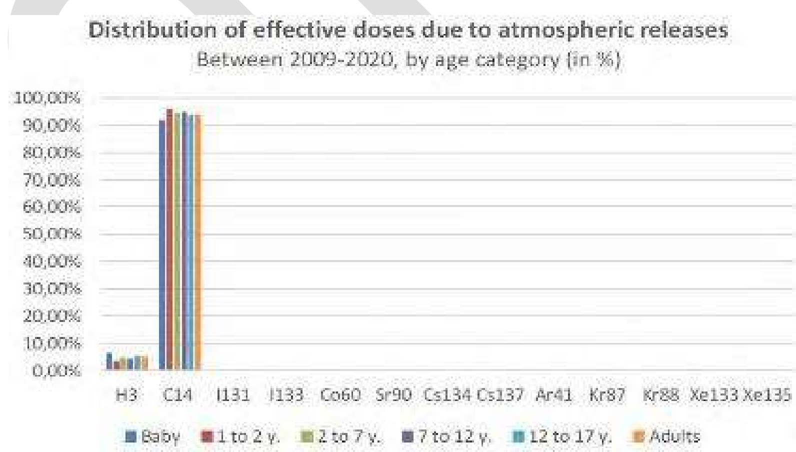

Figure 98: Distribution of effective dose in percent for the total dose impact of gaseous discharges by age group and by radionuclide discharged for the period 2009-2020[lxxxiii].

Liquid discharges

As for Doel 4, the liquid radioactive effluents come mainly from the process circuits, e.g. the circuits for the treatment of primary cooling water in the nuclear power plants, and to a lesser extent come from all kinds of wastewater generated, among other things, during decontamination of floors, material in the nuclear zone.

The main radionuclides in the liquid effluents are the same as for Doel, especially tritium under the form of tritiated water, beta, gamma emitters especially ^{58Co}, ^{60Co}, ^{89Sr}, ^{90Sr}, ^{134Cs}, ^{137Cs}, 110mAg and alpha emitters mainly ^{241Am}.

The potential impact of the discharges on humans and the environment are evaluated by FANC-AFCN by regularly taking samples of the water, sediment, aquatic plants, fish and crustaceans and measuring the levels of radioactivity (reports are on https://fanc.fgov.be/nl/publicaties/verslagen-van-het-radiologisch- monitoring-belgium). Complementary to the FANC-AFCN surveillance program, since 2012 the Tihange nuclear power plant also has a limited monitoring program focusing on bioindicators such as aquatic plants and mosses. Soil and sediment samples are also taken as these can accumulate radionuclides.

Discharges for CN Tihange are much lower than the discharge limits shown in Table 88. During the 2014-2021 period, beta and gamma emitters discharged less than 3% of the annual limit from the site (Figure 97). The tritium discharges were also below the annual limit and averaged 25% of the annual limit during the 2014-2021 period. For the alpha emitters, discharges were less than 0.2% of the discharge limit during that period.

Discharges of tritium and beta-gamma emitters to the Meuse remain almost stable over the period 2004-2021, while discharges of alpha emitters increase by a factor of 400 over the period 2011-2012 before stabilizing again (Figure 96). The tritium discharges represent 99.9% of the discharged activity (Table 88) and are the main contributor to the dose (Figure 97). For the Tihange site, primary liquid discharges are the most radioactive. However, these effluents are diluted with "cold" effluents from technical rooms and premises, as well as with condensed water recovered from cooling towers. Also, through pretreatment, radioactivity is reduced. Based on these results, no radiological problems can be reported.

Table 88: Liquid effluent discharge limits for the total CN Tihange site.

Radionuclide category	
Tritium	147 TBq/year
Beta and gamma, (excluding tritium and dissolved noble gases)	0.89 TBq/year
Alpha emitters	2.2 GBq/year

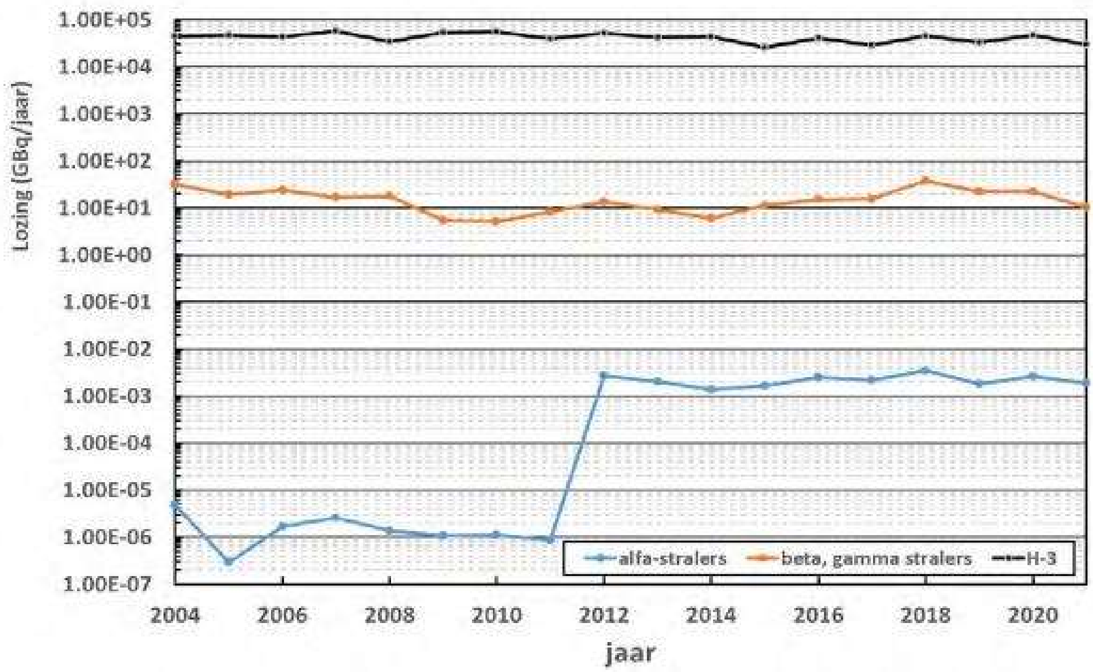

Figure 99: Evolution of liquid discharges from Tihange Nuclear Power Plant into the Meuse River for the period 2004-2021.[lxvii].

For calculating the dose to the representative person due to discharges into the Meuse River, the following exposure pathways are considered:

- Internal radiation by:
  - consumption of river water as drinking water;
  - consumption of fish.
- External exposure by staying on banks, by shipping, by staying on soil contaminated with dredged bed sediment.
- Use of river water for irrigation of food crops, grass and for watering livestock.

The dose for the representative person was also calculated for the 6 age classes, taking into account the consumption values mentioned in the directive of FANC-AFCNi. As for the calculation of the dose due to atmospheric discharges, a critical person is assumed to be permanently present at the site of maximum dose load and to obtain his food from an area where the deposition of discharged radionuclides is maximum.

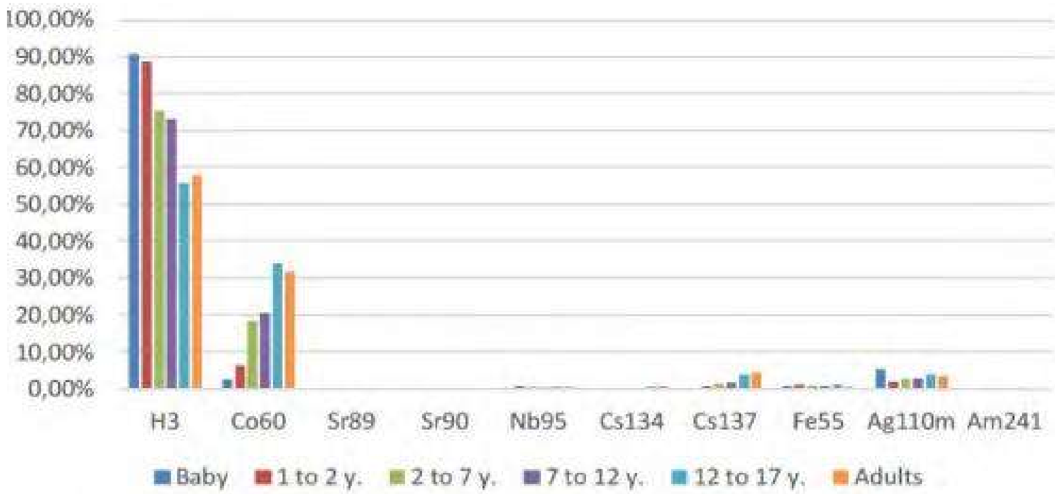

Figure 100: Distribution of effective dose by radionuclide and age category due to liquid discharges into the Meuse River.

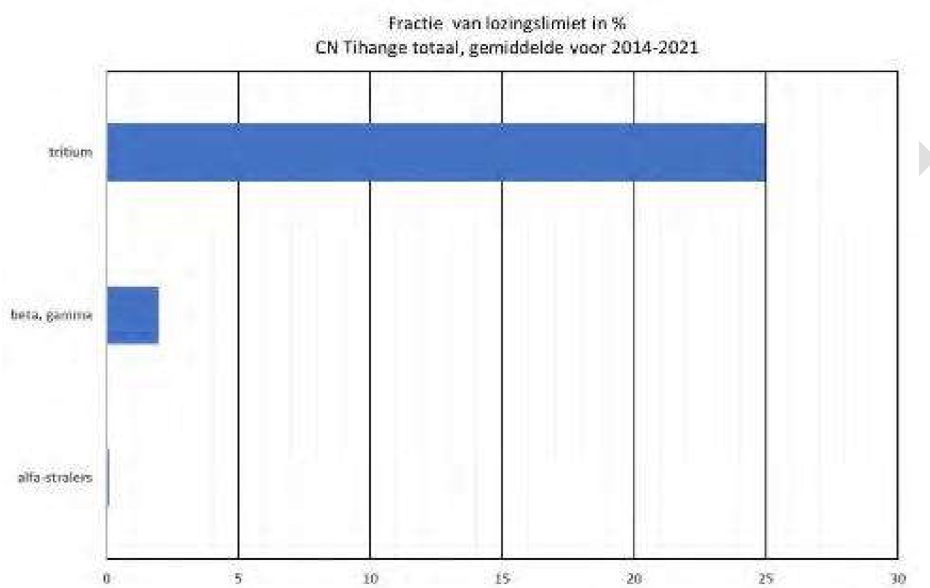

Figure 101: Liquid discharges in % of the discharge limit for liquid discharges to the Meuse River.

Measurements in the environment

The measurements in the environment consist of the monitoring program organized by the FANC-AFCN and a specific monitoring program by the operator. In addition, ad hoc measurements are also available, which are carried out in the context of scientific research and/or during emergency preparedness exercises. The monitoring program for the Belgian territory organized by the FANC-AFCN, which is similar for the Doel and Tihange environment has already been discussed in part methodology. The results of the continuous measurements (TELERAD) and helicopter measurements were already given in the description of the current situation concerning direct radiation exposure in the vicinity of CN Tihange.

The discontinuous measurements (sampling and analysis in laboratories) around CN Tihange determine the radioactivity levels of particulate matter in air, deposition in deposition basins (dry and wet deposition), soil and grass, water and sediments, aquatic plants, moss and mussels near CN Tihange (downstream). Samples are taken as comparators upstream of Tihange at Andenne (and thus not impacted by the discharges) and downstream at Ampsin and Lixhe (border of Belgium and the Netherlands). A detailed description of this program (samples taken, frequency, radionuclides analyzed, ...) can be found in the annual synthesis reports to be found on the FANC-AFCN website from the year 1996[lxxxiv]. Details of the FANC-AFCN monitoring program linked to CN Tihange can be found in Table 89. Samples are taken upstream and downstream. The water of the Meuse after treatment is used as drinking water by a considerable part of the Belgian and Dutch population, therefore sampling and analysis of radionuclides is quite extensive.

Table 89: FANC-AFCN surveillance program in the vicinity of CN Tihange.

Compartment	Type of measurement	Frequency
Atmosphere - radioactive dust particle in the air	Gamma spectrometry: 7Be, 134-137Cs, 141-144Ce, 103-106Ru, 95Zr, 95Nb Beta total on paper filters after 5 days of decay	every 4 weeks daily
Atmosphere - surface deposition (dry and via precipitation)	Gamma spectrometry (untreated water): 7Be, 134-137Cs, 141-144Ce, 103-106Ru, 95Zr, 95Nb, 131I Beta total, alpha total, 3H, 90Sr (filtered water) Beta total and alpha total (filter precipitate)	every 4 weeks
Soil - soil and grass	Gamma spectrometry: 7Be, 134-137Cs, (57)-58-60Co, 54Mn, 65Zn, 110mAg, 40K, 226-228Ra,228Th	annual
Meuse - water	Gamma spectrometry: 7Be, 134-137Cs, 141-144Ce, 103-106Ru, 95Zr, 95Nb, 226Ra, 131I Beta total, alpha total, 3H, 40K, 90Sr	every two weeks
Meuse - sediments	Gamma spectrometry: 7Be, 134-137Cs, (57)-58-60Co, 54Mn, 65Zn, 110mAg, 40K, 226-228Ra,228Th	every 4 weeks
Meuse downstream - aquatic plants, mosses, mussels (Andenne, Ampsin, Lixhe) -.	Gamma spectrometry: 7Be, 134-137Cs, (57)-58-60Co, 54Mn, 65Zn, 110mAg, 40K, 226-228Ra,228Th organic 3H	quarterly
Effluents (liquid discharges) from the nuclear site.	Gamma spectrometry: 7Be, 51Cr, 55Fe, 95Nb, 95Zr, 101-106Ru, 141-144Ce, 131I, 113Sn, 123mTe, 124-125Sb, 134-137Cs, (57)-58-60Co, 54Mn, 65Zn, 110mAg Beta spectrometry: 3H	every two weeks

In addition to the monitoring program of the territory carried out by FANC-AFCN, the operator of CN Tihange organizes its own monitoring program consisting of:

- Dose measurements using 18 Thermo Luminescence Detectors (TLDs) placed at the perimeter of the site (one per 20° sector). They give the integrated dose due to external radiation;
- A monitoring program complementary to the FANC-AFCN monitoring program in which samples are taken and analyzed once a year. For CN Tihange, this has started since 2012. This program has a

limited frequency compared to the sampling program, but the focus is entirely on artificial radionuclides potentially linked to the operation of CN Tihange and on specific samples such as those of bio-indicators, i.e. organisms that concentrate certain radionuclides in particular and thus make it possible to monitor possible evolutions over time. This program is shown in Table 90 for the year 2021. The program has been expanded somewhat over the years with additional sites and some additional sediment sampling. Sediment is now also sampled at the discharge point (O1 on the map below).

Table 90: Operator monitoring program.

Specific sampling	Location and frequency	Measurement specifications
Bioindicator: crust (moss) Soil Grass	Annually at 2 sites (S1 and S2) in dominant wind direction and 1 reference site (Ref T)	Gamma spectroscopy ($^{134,\ 137Cs}$, ^{131I}, ^{60Co}, ^{95Nb}, ^{110mAg}), ^{3H}, 14C (grass, moss)
Aquatic bioindicator (moss, algae).	Annually at 2 sites S1, S4 (watermoss) and S5 (algae) downstream and 1 reference site (Ref A) upstream	Gamma spectroscopy (134Cs-and $^{137Cs-}$, ^{131I}, ^{60Co}, $^{95Nb-}$, ^{110mAg}), ^{3H}, 14C
Sediment	Twice a year at 3 location (O1, S1, S5) downstream	Gamma spectroscopy (134Cs-and $^{137Cs-}$, ^{131I}, ^{60Co}, $^{95Nb-}$, ^{110mAg}),

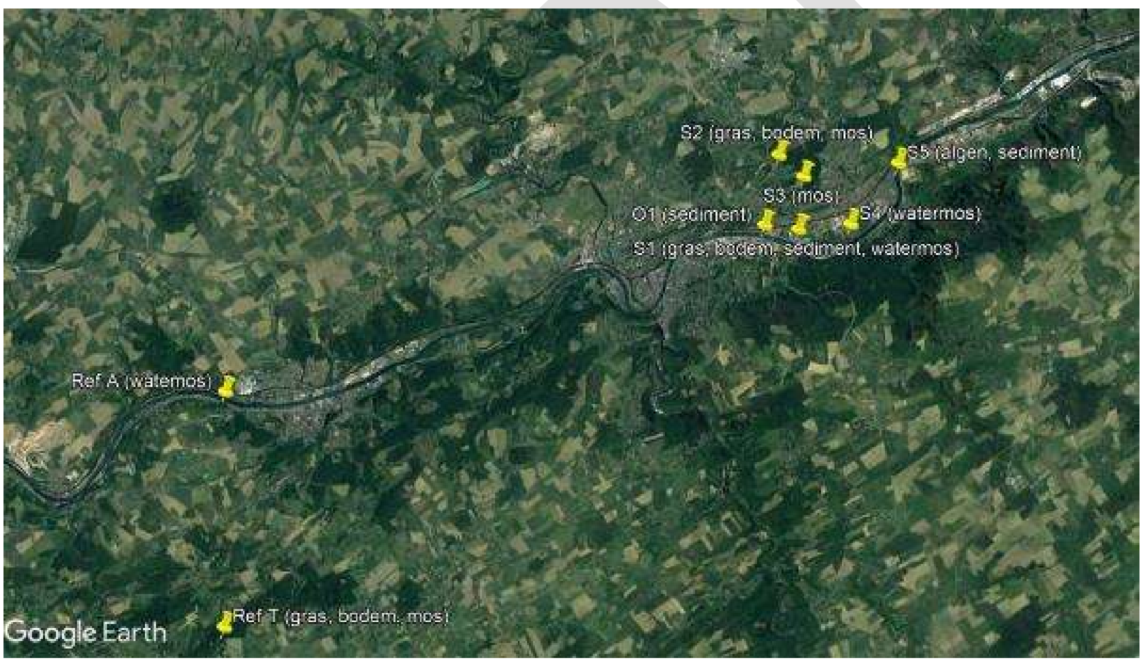

Figure 102: Locations of sampling for additional program performed by the operator of CN Tihange (designations see Table 90, background map: Google Earth Map).

The discontinuous program that has higher sensitivity via sampling and lab analysis to detect potential artificial radionuclides around CN Tihange shows, as for Doel:

- first and foremost, the broad predominance of natural radioactivity (mainly ^{40K});

- As for artificial radioactivity, traces of Cs-137 can be measured in the soil (3.8 Bq/kg in [2021lxxxv135]) almost entirely due to the Chernobyl accident and to the fallout of nuclear tests in the atmosphere (which peaked in the 1960s). The concentrations measured near Tihange are average for those in Belgium. Due to differences in meteorological conditions (rain) when the radioactive cloud passed over after the Chernobyl accident, spatial differences can be observed in Belgium;
- That the artificial transuranic alpha emitters (Pu and Am) on their part are not measurable.

In conclusion, the Tihange nuclear power plant does not have a significant measurable radiological impact on the environment through atmospheric discharges, nor does it have a significant measurable radiological impact on the Meuse River. An analysis of measurement results in the vicinity of CN Tihange is always representative of all activities at the site. The impact of the Tihange 3 reactor will be smaller. This means that the conclusions for the entire site are therefore particularly valid for the operation of Tihange 3.

Impact on humans

The current radiological status and impact of the CN Tihange site activities has been very well characterized through the combination of discharge monitoring coupled with dose impact calculations and monitoring of radioactivity and radiation in the vicinity of CN Tihange.

On the one hand, we can look at the radiological impact of the licensed discharge limits for CN Tihange as a whole (3 reactor [units136] and all ancillary infrastructure) for the gaseous and liquid discharges. The conservatively estimated dose according to the methodology described in §2.3.3.3 is given in Table 91. It is the effective dose per year for a representative person by age group. Here we recall that a representative person, is the most exposed person, someone who, among other things, stays constantly (the whole year) near the site boundary where the impact is highest and consumes only food produced near the nuclear power plant. The maximum effective dose per year from gaseous and liquid discharges corresponding to the discharge limits per year is about 0.22 mSv for the critical individual, especially the representative person of the age group receiving the highest dose. This value is for teenagers; a lower effective dose is found for all other age categories. This is well below the effective dose limit for the public of 1 mSv/year. We see that for the discharge limits there is a particularly large variation in the effective dose by age group due to liquid discharges, this is mainly due to diet.

Table 91: Effective dose per year to the critical individual by age group of person due to gaseous, liquid and total discharges corresponding to the current discharge limits for the total CN Tihange site.

Effective dose in mSv/year for the gaseous and liquid discharge limits; site CN Tihange for the different age categories, The maximum total effective dose is shown in bold,						
	Baby	1 to 2 years	2 to 7 years	7 to 12 years	Teen (12-17 j)	Adult (>17)
Atmospheric	0,134	0,185	0,145	0,132	0,143	0,130
Liquid	0,014	0,017	0,050	0,042	0,077	0,081
Total	0,148	0,202	0,195	0,174	**0,220**	0,211

[135] Surveillance radiologique de l'environnement proche de la centrale nucléaire de Tihange. Résultats de la campagne de surveillance de 2021. IRE report, 2021.

[136] Since three reactors were operational at the CN Tihange site until Jan. 31, 2023, and we only have data available from before the final shutdown of Tihange 2, we consider here CN Tihange with 3 operational units.

As we described earlier, the real gaseous and liquid discharges are well below the discharge limits and the real dose received by a critical individual due to the operation of the entire CN Tihange site is much smaller. The effective dose per year (averaged over the years 2012-2021) for a critical individual of the different age categories for the real gaseous and liquid discharges can be found in Table 92. The highest effective dose found for the real discharges is about 0.045 mSv/year, the critical individual is now in the age category 1 to 2 years. We see that the dose is mainly due to atmospheric discharges. For the period 2009 to 2020, the total effective dose is largely, more than 90%, from carbon-14 discharges.

Table 92: Effective dose CN Tihange in mSv/year for the real gaseous and liquid discharges.

Effective dose CN Tihange in mSv/year for the real gaseous and liquid discharges for the period 2009-2020 for the different age categories. The total is also given and the maximum effective dose is indicated in bold.						
	Baby	1 to 2 years	2 to 7 years	7 to 12 years	Teen	Adult
Atmospheric	0,0125	0,0427	0,0283	0,0224	0,0219	0,0209
Liquid	0,0011	0,0022	0,0017	0,0014	0,0016	0,0016
Total	0,0136	**0,0449**	0,0300	0,0238	0,0235	0,0225

Looking at the evolution of the effective dose to the critical individual due to gaseous and liquid discharges, as reported to the FANC-AFCN, we see that it remains fairly constant around the aforementioned value of 0.045 mSv/year (Figure 103). In 2020 and 2021, however, we see a significant decrease. This is due to the fact that since 2019, carbon-14 is directly measured using a molecular sieve directly at the chimney of Tihange 2, in which the carbon-14 is stepped. Measured values are significantly lower than those estimated from calculations. Therefore, in the analyses from 2020, the measured values for carbon-14 were used for Tihange 2 and Tihange 3 (similar to Tihange 2), while for Tihange 1 the calculated (and thus higher) values are still used. Thus, by using the real measured values for carbon-14, the effective doses in 2020 and 2021 are significantly lower, and somewhat less conservative compared to the past. Starting in 2019, measurements of gaseous tritium were also made at Tihange 2. Measurements also seemed to give significantly lower values than previously conservatively determined values. For 2020 and 2021, the results of these measurements of tritium were also used in the determination of the effective dose for Tihange 2 and Tihange 3, for Tihange 1, as in the analysis for carbon 14, conservatively calculated values were assumed. However, tritium has and much smaller impact on the total effective dose compared to carbon 14.

Calculations based on monitoring discharges thus show a maximum impact, i.e., an effective dose burden for the critical individual of about 0.045 mSv/yearlxxxvi if we consider conservatively calculated values for carbon 14 and rather of around or below 0.030 mSv/year if we use measured values for carbon-14 discharges for Tihange 2 and Tihange 3 units. This conservatively calculated effective dose for the most exposed person is at least 4.8 to 7.3 (depending on value carbon 14 used) times smaller than the dose according to the discharge limits for CN Tihange and 22 to 33 times smaller than the dose limit for the public which is 1 mSv/year. This also illustrates that the concept of dose optimization for public exposure, one of the pillars in radiation protection and discussed in
§2.3.2, is applied to the operation of CN Tihange.

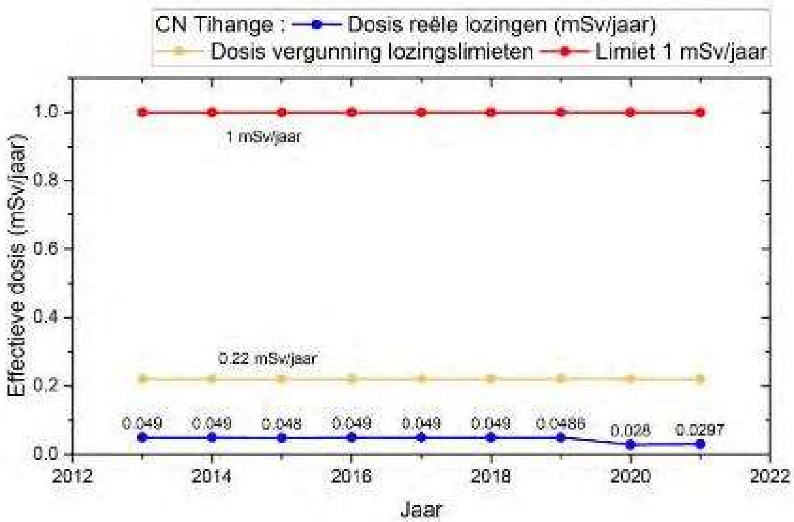

Figure 103: Effective dose for most critical individual in the vicinity of CN Tihange calculated from reported real dischargeslxxxvii. For comparison, the dose limit for the public is shown and the dose corresponding to the discharge limits.

Environmental monitoring also shows that CN Tihange has no measurable radiological impact on its surroundings. Therefore, exposure in the Tihange environment is completely dominated by exposure to natural radioactivity as in other parts of the country. Consequently, the exposure from radioactive discharges is also much smaller than the local spatial variations in natural radioactivity and exposure. The very limited contribution of artificial or man-made radioactivity in the vicinity of CN Tihange still comes mainly from radioactive fallout from the above-ground atomic bomb tests (1950-60) and the Chernobyl accident (1986).

Impact on biodiversity (fauna and flora)

Of the radionuclides, specifically ^{60Co}, ^{95Nb}, ^{110mAg}, ^{131I}, ^{134Cs}, ^{137Cs} considered for the river sediment in the additional monitoring campaign of Electrabel nv, only the ^{60Co}, ^{110mAg} and ^{137Cs} concentrations are above the detection limit. The measured concentrations for the river sediment are low. For ^{137Cs,} the concentration in the river sediment is 7.4 Bq/kg dw (dry weight)-and is comparable to the average value of the monitoring program of FANC-AFCN, i.e. 9.4 Bq/kg dw. For ^{60Co} and ^{110mAg}, respectively, the concentration in sediment is 18.1 Bq/kg dw and 6.6 Bq/kg dw, respectively, in river sediment in 2019. For the flora (grasses and mosses), the concentrations of radionuclides 3H and 14C are additionally measured. Only 14C and 137Cs are measurable in these plants (concentrations above the detection limit). The concentrations in mosses (bioindicator) are higher than these in grass. For ^{137Cs,} the maximum concentration is 10.1 Bq/kg dw and for ^{14C} it is 0.82 Bq/kg dw in 2018. The ^{137Cs} concentration is also measurable in soils and amounts to a maximum of 28 Bq/kg dw in 2018.

In 2013, a comprehensive environmental risk assessment was conducted to estimate the impact of atmospheric and liquid discharges on fauna and flora. For the Tihange site, common reference organisms were selected and the impact of actual discharges and discharge limits on these organisms was calculated using the ERICA assessment tool. It was shown that even for the discharge limits, the dose rates are much lower than the threshold value of 10 µGy/h, below which no adverse effects occur. Thus, based on the results, it can be concluded that the current discharge limits for the considered Belgian nuclear power plants do not lead to harmful effects for the environment. The measurement results of the monitoring program of FANC-AFCN and the operator in the vicinity of KC Doel also lead to the same conclusions.

2.1.2 Effects in case of non-renewal of Tihange 3

The Tihange 3 unit is currently licensed for industrial electricity production until September 1, 2025 at the latest. In case of non-renewal (deactivation, definitive shutdown), according to the current calendar, only unit Tihange 1 will still be in operation on the CN Tihange site for industrial electricity production until October 1, 2025 at the latest (one month later). Tihange 2 was finally shut down during the night of January 31 and February 1, 2023 and will thus already be in the post-operational phase for 2 years in 2025. Consequently, in case of non-renewal of Tihange 3, we can consider the situation after 2025 where all reactors are in the post-operational phase. The discharges directly linked to reactor operation (such as carbon 14 production) will disappear, carbon 14 also has the main contribution to the dose for the gaseous and liquid discharges. On the other hand, certain gaseous and liquid discharges will continue in the post-operational phase. Relatively little information is available on quantities and impact on dose. On the one hand, we can look at what can theoretically be expected:

- Liquid tritium: tritium production is linked to nuclear power generation, a theoretical decrease to practically zero is possible, but given long half-life, residual discharges are possible; -
- Liquid beta-gamma radionuclides: theoretically, a reduction in discharges can be expected, with residual discharges from the POP various facilities may exist; -
- Noble gases: a theoretical decrease to practically zero can be expected since noble gases are fission products that will no longer be produced. Historical data show a slight decrease in noble gas emissions in the years when less power is produced (MWh deficit);
- Iodine: theoretical decrease to practically zero after the production stop, but this decrease is partially offset by iodine residues in the fuel bath and there are also the tests of the filters. In short, a decrease can be expected; -
- Aerosols: no clear impact is expected; based on past reported values, it is clear that reported values are mainly based on detection limits and not purely on real releases; because of these detection limits, the order of magnitude of releases will remain the same. A limited increase, depending on POP activities, cannot be completely ruled out; -
- Tritium (gas): a decrease is expected;
- Carbon-14: dependent on production, therefore there should be a decrease in carbon-14 produced to practically zero.

On the other hand, effective experience with the post operational phase abroad can be considered (however, this is rather limited). Based on experience in Germany, it can be estimated that the dose due to gaseous and liquid discharges as a consequence of the shutdown of 1 reactor unit in the first year after shutdown drops to 25% of the level at operation and further drops to about 10% in the following years (data available up to 7 years after final shutdown). On the basis of this information, it can be conservatively estimated that the effective dose due to gaseous and liquid discharges for the whole CN Tihange site in the case of non-renewal of Tihange 3, and thus with no more reactors in operation, will decrease to a level **below 0.01 mSv /year** and in the years thereafter -we consider a period of 10 years) **will further decrease to below 0.005 mSv/year**.

2.1.3 Effects if Tihange 3 is extended for 10 years beyond 2025 (The Project)

The gaseous and liquid discharges related to the operation of Tihange 3 will continue at the same level as today, as we assume that the reactor will be operated at the same power and that all gaseous and liquid effluents will be treated in the same way when Tihange 3 is extended. A conservative estimate of the effective dose from operation of Tihange 3 gives **0.01 mSv/year and this constant over the 10 years of extended operation**. This is still mainly due to the carbon-14 gaseous discharges, which are directly related to the power of the reactor (Tihange 3). For the entire CN Tihange site, in addition to the operation of Tihange 3, we must now include the discharges in the post-operational phase as we estimated in the previous section concerning the null alternative, i.e., the non-extension have. Table 93 shows the effective dose from operation of Tihange 3 and for the entire CN Tihange site at renewal and non-renewal.

Table 93: Effective dose due to gaseous and liquid discharges conservatively estimated for critical individual at normal operation for the project. The range given in the effective dose for the entire site is the evolution as a function of time over a 10-year period based on experience with the post-operational phase at reactors in Germany.

	Conservatively estimated effective dose critical individual gaseous and liquid discharges
Releasing Tihange 3	0.010 mSv/year
Whole of site CN Tihange at extension Tihange 3	0.020-0.015 mSv/year
Whole of site CN Tihange in case of non-renewal Tihange 3 (all reactors out of service)	0.010-0.005 mSv/year*
Difference of project vs. null alternative	0.010 mSv/year for 10 years

*This dose range is also representative as a conservative estimate of the effective dose due to gaseous and liquid discharges for the whole site in the post-operational phase of Tihange 3 after 10 years of extension.

Consequently, the estimated effective dose of the project is well below the current operating permit and also well (factor of 100) below the legal limit of 1 mSv/year. To put this dose into perspective, we can compare it to a natural exposure. An effective dose of 0.01 mSv corresponds to the additional dose received by an individual from increased cosmic radiation on a 5-hour line flight (10 km altitude). Consequently, the effective dose in normal operation of the project provides a trivial impact.

2.2 Accidental discharges

Given the similar nature of the accidents considered for Doel 4 and Tihange 3, a description of these accidents and the methodology for calculating the impact is given in full in Chapter 2. Here we present the results of the impact assessment and discuss the results.

2.2.1 Draft accident

The radiological impact of the two design basis accidents considered, namely a LOCA and FHA was assessed based on the general data under Article 37 of the Euratom Treaty and the Tihange 3 safety file. In addition, an analysis was also performed based on a Tractebel study[137] in the framework of the 2017 FANC-AFCN/Bel-V guidelines for new Class 1 installations. The latter analysis is strictly not applicable for Tihange 3, as it concerns the lifetime extension of an existing Class 1 plant. In addition to the consequences during atmospheric discharges resulting from the accidents considered for Tihange 3, this analysis also allows to assess the longer-term consequences to humans, food chain and environment. We also use the amounts of radioactivity discharged to the atmosphere from this analysis, the so-called source term, to calculate the impact on neighboring countries.

In the LOCA accident, 25% of the nuclear inventory of iodine and 100% of noble gases are assumed to be released to the reactor building, 91% of the iodine is present in elemental (molecular) form, 5% in aerosol form and the remaining 4% in elemental form. The noble gas concentration is determined by radioactive decay and the reactor building leak rate. The iodine concentration is also determined by radioactive decay and the leak rate, but also by safety injection (sprinkling) and recirculation for cooling (see §2.3.4.1).

[137] CNT3: S2 - Radiological consequences of a Loss Of Coolant Accident and a Fuel handling Accident, 2020 CNT-KCD/4NT/0029611/000/01 Tractebel Engineering S.A.

Limited amounts of beta(-gamma) aerosols are discharged in this scenario. Discharge to the environment is considered for 30 days.

In the **FHA accident, it** is assumed that 30% of the activity of Kr-85 in the space between casing and spent fuel pellets and 10% of the other radionuclides is released from the fuel elements, with 99.75% of the iodine present in the elemental form and 0.25% in the organic form. Furthermore, a decontamination factor of 133 for molecular iodine and 1 for organically bound iodine from the fuel pool (water) to the building is considered. For discharge to the atmosphere along the chimney, it is assumed that the filters are working and an efficiency of 90% for molecular iodine and 70% for organic iodine. A discharge time of 2 hours is assumed.

Despite being very similar reactors, there are differences in release of radioactivity to the environment between Doel 4 and Tihange 3. These are related to design differences. The reactor building of Tihange 3 is larger and the leak rate of the primary envelope is also greater. There are also differences in discharge characteristics, including the chimney heights for both reactors.

The results of both analyses for the effects during the considered accidents are given in Table 94. Both analyses give the effective dose due to the passage of the radioactive cloud, including the associated inhalation of radioactivity and the equivalent thyroid dose due to inhalation of radioactive iodine for the critical individual.

Table 94: Maximum effective dose and equivalent thyroid dose outside the site boundary of CN Tihange resulting from the occurrence of a LOCA and FHA for Tihange 3, compared with the dose limits described in the general data under Article 37 of the Euratom Treaty, which are part of the license, in mSv. Also added for information are the results of an impact analysis according to the guidelines for new Class 1 installations.

	Tihange 3 safety file		Analysis according to guidelines for new Class 1 installations	
	Dose	Limit	Dose	Criterion
Effective dose				
LOCA	5 mSv	5.8 mSv	0.89 mSv	5 mSv
FHA	1.16 mSv	5.8 mSv	0.35 mSv	5 mSv
Equivalent thyroid dose				
LOCA	4.91 mSv	85.5 mSv	1.45 mSv	10 mSv
FHA	22.5 mSv	85.5 mSv	4.95 mSv	10 mSv

The above table shows that the **effective doses and equivalent thyroid doses resulting from both reference design basis accidents for Tihange 3 are within the set limits.** The analysis according to the guidelines for new Class 1 installations shows lower effective doses and equivalent thyroid doses, this is due to the fact that a conservative analysis was used for estimating these in the safety case and a less, but still conservative, estimate in this one for new Class 1 installations. Also, all doses calculated according to the new guidelines for Class 1 installations are below the dose criterion defined for this purpose. This information is included for informational purposes. The estimated doses are lower than these for Doel 4, in part because of the higher chimney height where the maximum concentration of radionuclides at ground level is at a greater distance from the point of discharge. Thus, according to the analysis, the values in the table above are for new Class 1 plants for a distance of 1000 m, because there the effective dose from the passing cloud, including inhalation, gives higher values than at the perimeter of the site (200 m). Consequently, according to the recent analysis, direct protective measures such as sheltering (5 mSv effective dose in 24 hours) or the intake of stable iodine (10 mSv equivalent thyroid dose for children and pregnant women) would not be necessary. See also Table 16 in §2.3.4.3 in this regard.

Food chain measures, as for Doel 4, may be necessary in both accident scenarios, depending on the exact circumstances of the accident. For example, maximum concentrations of about 20 500 $^{Bq/m2}$ I-131 for the LOCA accident and 65 000 $^{Bq/m2}$ I-131 for the FHA accident are found. These clearly exceed the derived value for food measures (milk, meat, vegetables). Even higher values for I-133 deposition are found for the LOCA accident, but due to the limited half-life (20.83 h), it will only be able to be significant during the accident and in the days following the accident. Also for I-131, with a half-life of 8.02 days, the contamination will be limited in time and will no longer have any impact on the harvest of the year after the accident. The long-lived Cs-137 is also limitedly discharged and deposited in the LOCA accident, with a maximum estimated value according to the accident scenario of about 23 $^{Bq/m2}$. This is well below the derived value for food chain measures for Cs-137.

Lifetime effective dose from exposure during the event and in subsequent years (for 50 years for adults and up to 70 years for children) is again at most a few mSv, well below the 1 Sv limit.

2.2.2 Draft expansion accident

The radiological impact of the enveloping design expansion accident for Tihange 3, namely a CSBO was assessed based on the analysis performed by Tractebel[138] in the framework of the 2017 FANC-AFCN/Bel-V guidelines for new Class 1 installations. The results are given in Table 95 and concern the effective dose from the passing radioactive cloud, including inhalation and external radiation exposure from deposition of radioactivity on the ground and the equivalent thyroid dose from inhalation of radioactive iodine, both for the critical individual.

Table 95: Effective dose and the equivalent thyroid dose at the site boundary of CN Tihange due to the occurrence of a CSBO for Tihange 3 (most critical individual).

Tihange-3 CSBO		
	Dose	Permit Limit
Effective dose	4.29 mSv	-
Equivalent thyroid dose	0.033 mSv	-

The effective dose comes almost exclusively from direct exposure to radiation from the passing radioactive cloud due to the various controlled vents. The filtering system (CFVS) releases mainly the noble gases to the atmosphere; other groups of radionuclides are largely retained. The amount of iodine released is limited, providing a limited equivalent thyroid dose. The radioactivity deposited on the soil is also limited (noble gases do not deposit) resulting in a very limited contribution to the effective dose from exposure to external radiation from contamination soil. For design expansion accidents, there are no limits specified in the permit. The

138 DEC B: RC-1.4 - T3 - Radiological consequences off-site - Assessments (DEC/4NT/0606802/140/04), Tractebel Engineering

effective dose and equivalent thyroid dose, both calculated for the critical individual, is below all guidelines defined in the nuclear emergency plan (see §9.2.1) for immediate countermeasures to protect the population such as sheltering, evacuation or administration of stable iodine.

2.2.3 Impact of considered accidents on biodiversity

The reference organisms discussed in Vandenhove et al, 2013 (see KC Purpose) for routine discharges were also used to calculate the impact of accidental discharges to the environment due to a LOCA and FHA.

The calculations with the environmental risk tool ERICA show that the radiological doses to fauna and flora for the LOCA accident range from 0.3 to 8 µGy/h for the maximum deposition of the discharged radionuclides on the soil, with the most exposed organisms (8 µGy/h) being the small mammals and grass being the least exposed. The main radionuclides deposited are short-lived. This means that the radioactivity in the soil and therefore the dose rates to which the fauna and flora are exposed will decrease rapidly and there is no chronic exposure. Over the first month after the accidental discharge, the average dose rates decrease to less than 0.3 µGy/h and after 1 year to less than 0.02 µGy/h for all fauna and flora. It follows that there will be no adverse effects on the environment.

The radiological doses to fauna and flora for the FHA range from 0.13 to 11 µGy/h, with the most exposed organisms being the arthropod detritivorous invertebrates, ringworms, small mammals and mice (> 7 µGy/h) and for the rest, the dose rate is below 6.5 µGy/h. The external dose dominates the internal dose. However, dose rates decrease rapidly because the discharged iodine isotopes are short-lived (half-lives from 2 hours to 8 days). Over 1 month, the average dose rate ranges from 0.04 to 3.2 µGy/h and the contribution of ^{131I} is more than 97% of the dose rate, after 1 year, these average dose rates are down to less than
0.3 µGy/h redirected.

Therefore, since the dose rates decrease rapidly and the organisms are not chronically exposed to significant dose rates, we can conclude that the environment does not experience harmful effects from such an exposure situation.

For the CSBO, it can be expected based on the radionuclides discharged and depositions in analogy to the design basis accidents that the harmful chronic effects on flora and fauna are also negligible.

2.2.4 Discussion of accidental discharges

If no lifetime extension takes place, Tihange 3 will be permanently shut down (DSZ). To remove the heat caused by radioactive decay, the fuel elements will still need to be cooled, initially with the reactor cooling circuit. The reactors will be permanently discharged. The fuel elements will be transferred to the fuel basin and cooled with the cooling circuits of this basin. This transition phase -the post operational phase- until the start of decommissioning will take place under both the Zero Alternative (no Project) and the Project. However, the amount of radioactivity in the core will decrease rapidly (decay of short-lived radionuclides), requiring less cooling, and the inventory of radioactive material that can be released in these accidents also decreases rapidly with time after decommissioning, so the impact of an accident if it were to occur also decreases. It is clear that the risk (risk = probability x impact), which is already small with extension (because of small probability of accident and limited radiological impact) is even smaller with non-extension given that at least the impact is smaller. Thus, the project involves a limited risk related to accident (both design basis - and design extension accident). However, for the whole CN Tihange site, the risk will decrease anyway as according to the current calendar in the period of the project (period of 10 years after 2025) only Tihange 3 will be exploited for industrial electricity production.

2.3 Operational radioactive waste

2.3.1 Waste treatment at the site

Treatment of liquid waste from the entire site is done in Unit 2. After treatment, wastewater is stored in storage tanks in Units 2 and 3 pending reuse or discharge to the [riverlxxxviii]. The corresponding solid wastes (spent resins, evaporative concentrates, flocculants and filters from the treatment plant) are also treated in Unit 2.

The only solid waste generated in Unit 3 is used resin from auxiliary circuits, residues from the magnetic filtration of the steam generator discharge, filters from auxiliary circuits and miscellaneous solid waste. These wastes, except miscellaneous solid wastes, are transported in suitable containers to Unit 2 for treatment or processed in Unit 3 by a company specializing in waste conditioning. Miscellaneous solid waste is processed in the Tihange [3lxxxix] unit. After sorting and conditioning in 400L drums, low- and intermediate-level waste is temporarily stored at the Tihange site, and transported to Belgoprocess on a regular basis.

2.3.2 Quantities of low- and intermediate-level waste

The quantities of low- and intermediate-level waste produced annually at the Tihange nuclear power plant are shown in the second column of Table 96. These data were compiled from CN Tihange's environmental statement, which is updated [annuallyxc]. No distinction is made here between category A or category B waste. Column 3 expresses the volume of conditioned waste per TWh of net electricity produced at CN Tihange in the corresponding year, resulting in a long-term average of **5.54 m3/TWh of low- and medium-active conditioned waste**. Taking into account the share of the Tihange 3 reactor in this electricity production, we arrive at a long-term average of **40.5** ^{m3} ^{of} **low- and intermediate-active conditioned waste** per year for Tihange 3 (column 4). Here, the actual share of Tihange 3 relative to total electricity production at the site fluctuated around 41% in the period 2011- 2020. This is slightly higher than the ratio based on power (35 %), as other reactors (mainly Tihange 2 in the period 2014-2015) had some prolonged shutdowns.

Table 96: Annual volumes of low- and intermediate-level waste produced at the Tihange site, and specifically for Tihange 3 reactor unit. GA: conditioned waste.

	Volume (^{m3}) of low and intermediate level waste (GA)	**Volume of low- and intermediate-level waste (GA) per net electricity generated at KCT ($^{m3/TWh}$)**	**Volume of low- and intermediate-level waste for Tihange 3 (^{m3})**
2011	121,0	5,24	47,1
2012	95,0	4,69	37,4
2013	97,0	4,87	39,4
2014	100,7	5,58	49,1
2015	98,0	7,18	52,7
2016	96,0	4,97	39,0
2017	110,0	5,64	50,6
2018	92,9	6,06	13,5
2019	75,6	3,68	32,9
2020	100,8	7,46	43,6
Long-term average	**99**	**5,54**	**40,5**

2.3.3 Effects of LTO and implications for waste management.

Based on Table 96, delayed deactivation of Tihange 3 nuclear reactor is expected to give rise to an additional amount of low and medium level waste of about **405 ^{m3}** for a 10-year production period. This is mainly Category A waste, with only a limited amount of Category B waste, which may include certain resins and filters. Compared to the ~50,000 $^{m3\ of}$ category A waste currently included as a source term in the surface disposal safety [filexci] this represents a marginal increase (<1 %).

Assuming negligible Category B waste, the additional volume of waste corresponds to approximately **253 monoliths** or **0.27 modules** in the repository for Category A waste. The (volumetric) capacity of the repository is 34 [modulesxcii], based on:

- estimates of 2013 quantities of existing and future category A waste (thus not taking into account a possible LTO of reactor units at Doel and Tihange): 28.6 modules;
- a reserve of ~20 % (5.4 modules), of which a decision to extend the operation of Tihange 3 (among other decisions already taken) thus consumes 0.27 modules or ~5.0 %.

It is assumed that this waste meets the acceptance criteria established by ONDRAF/NIRAS, which among other things take into account the conformity criteria from the safety report. The latter concern radiological criteria (criteria for fissile materials and criticality, as well as activity concentration limits at radionuclide level) and a number of requirements for physicochemical conformity. As it concerns the extension of an existing activity, no (additional) impact on the (short- and long-term) safety of the repository for category A waste is thus expected, beyond the effects related to the installation of this repository in any case.

2.4 Spent fuel

When the spent fuel assemblies are removed from the reactor after being in the core for approximately 54 months, in 18-month cycles, they are held under water in a deactivation basin specific to the unit. Storage in the deactivation pool allows the spent fuel to lose much of its activity and cool. These assemblies still release thermal energy through the decay of primarily the fuel fission products; this thermal release decreases over time. After a cooling period of at least 2 years, the fuel assemblies are transferred in shielded and sealed containers to the intermediate spent fuel storage building (DE building) for temporary storage in one of the 8 pools. The DE Building is common to all three units and is located close to the Unit 3 buildings. As mentioned above (§2.3.7.3), additional storage capacity is provided through the recently licensed [SF2 projectl]. More detailed information surrounding the [SF2] project can be found in the relevant EIA report. The new storage building would be commissioned during 2023.

2.4.1 Quantities

Unlike the environmental statements of KC Doel, those of CN Tihange do not contain data on the number of fuel elements discharged annually per unit. According to information obtained from Elektrabel in the course of the project, an average of 63 fuel elements are discharged per 18-month cycle. This corresponds to 42 elements, or 22.7 tHM of fuel per year.

2.4.2 Effects of LTO and implications for waste management.

Based on the above, we thus expect that the extended 10-year operation of Tihange 3 will generate about 420 additional spent fuel elements. This represents an increase of 3.8% compared to the entire Belgian fuel inventory in case of final shutdown. This also concerns UOX 14ft assemblies with an initial U mass of 0.541 tHM/assembly, which are not expected to differ in characteristics from the fuel elements already produced at Tihange 3. The waste management implications are similar to what was mentioned in §4.4.2.

Storage

Together, the existing and planned storage capacities should allow the processing of all spent fuel from the 3 units' deactivation basins after their final closure. The postponement of deactivation of Tihange 3 will spread the disconnection from the grid of the 3 units more, where otherwise it would be very condensed in a few years.

Storage

Under the assumption that disposal will occur in little hardened clay, with supercontainers as primary packing, the above additional consumption would correspond to **105 additional supercontainers** (Type SC-4) and an additional required disposal gallery length of approximately 650 m.

2.5 Decommissioning

Analogous to Doel 4 (for more info, see §4.5), activation calculations were made at different locations in the Tihange 3 reactor vessel using the activation code ALEPH2.

2.5.1 Input data

As inputs to the calculations, data related to *(i)* neutron flux, *(ii)* neutron spectrum, *(iii)* irradiation history, and *(iv)* material composition are needed.

i) A constant energy-integrated neutron flux of $1.^{4\times 1011}$ [n/cm²s] was used, based on the maximum design reactor vessel fluence of Doel 4 and Tihange 3 corresponding to average values at the level of the monitoring capsules[139] after 40 years of operation.

ii) Since the actual spectra of Doel 4 and Tihange 3 are not given, a typical normalized neutron spectrum for thermal light water reactors[xciii] was used, 'PWR-RPV' in Figure 76. Since this spectrum shows a significant contribution of fission neutrons (with higher energy), it is assumed to be representative of the inside of the reactor vessel. To evaluate sensitivity to the shape of the spectrum, another spectrum 'BR1 Y3' was also considered, calculated for channel Y3 in the BR1 reactor of SCK CEN, and for which the location is rather representative of the outside of the reactor vessel.

iii) To calculate activation, on the one hand, the actual irradiation history of Tihange 3[xciv] was assumed, with data from 1986 to 2021. This history consists of alternating periods of irradiation (assumed at full power) and periods of shutdown during which decay of produced radionuclides may occur. On this basis, an average annual load factor of 88% was estimated for Tihange 3, which was extrapolated for the LTO period. Thus, from 2022, the model considers annual cycles of 322 days of irradiation, and 43 days of decay. On the other hand, continuous irradiation without periods of shutdown is also applied to obtain conservative estimates of activity.

iv) Material composition relies on data provided for the guard capsules[xcv], and specified for the core jacket, transition ring and weld for the Tihange 3 reactor vessel. The chemical composition by weight percent of the major elements (except iron) is given in Table 97.

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[139] Surveillance capsules (surveillance capsules) are small steel samples with the same material composition as the reactor vessel, placed slightly closer to the core so that they are subject to a slightly higher neutron flux than the vessel sample. Analysis of these samples conservatively provides insights into material aging processes.

Table 97: Composition of major elements of parts of the reactor vessel of Tihange 3 (in weight%).

Unit	Material	C	S	P	Si	Mn	Ni	Cr	Cu	Mo	V
Tihange 3	core jacket	0,20	0,006	0,008	0,27	1,39	0,765	-	0,04	0,485	<0,01
	transition ring	0,185	0,006	0,006	0,23	1,41	0,765	-	0,04	0,505	<0,01
	read	0,062	0,006	0,015	0,15	1,11	0,8	0,075	0,093	0,480	

2.5.2 Results

Figure 104 shows a conservative estimate of activity in the 3 material types of the Tihange 3 reactor vessel, based on continuous irradiation for a total operating time of 60 years. The highest activity is located at the level of the transition ring. Therefore, it is interesting to compare the conservative estimate for this material type with more realistic estimates that take into account cycles of irradiation and decay. This is shown in Figure 105, as well as a combination case with cycles up to 2021 followed by continuous irradiation from 2022 to 2045.

It follows from this figure that:

- an extension based on realistic irradiation cycles causes only a very limited increase in overall activity: maximum +0.05% for an extension of operation from 40 years to 50 years; and
- overall activity would increase by 4% based on continuous irradiation, which is not a realistic assumption.

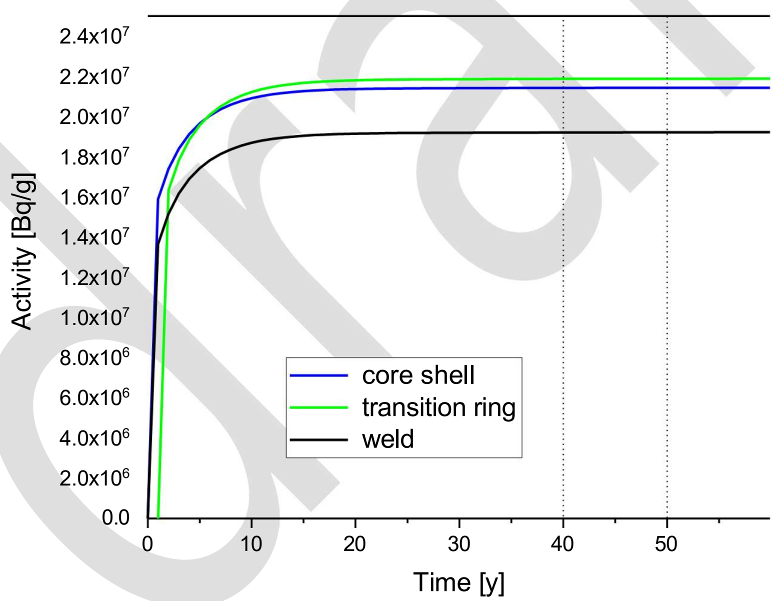

Figure 104: Time evolution of conservative estimates of activity per mass for the 3 material types of the Tihange 3 reactor vessel.

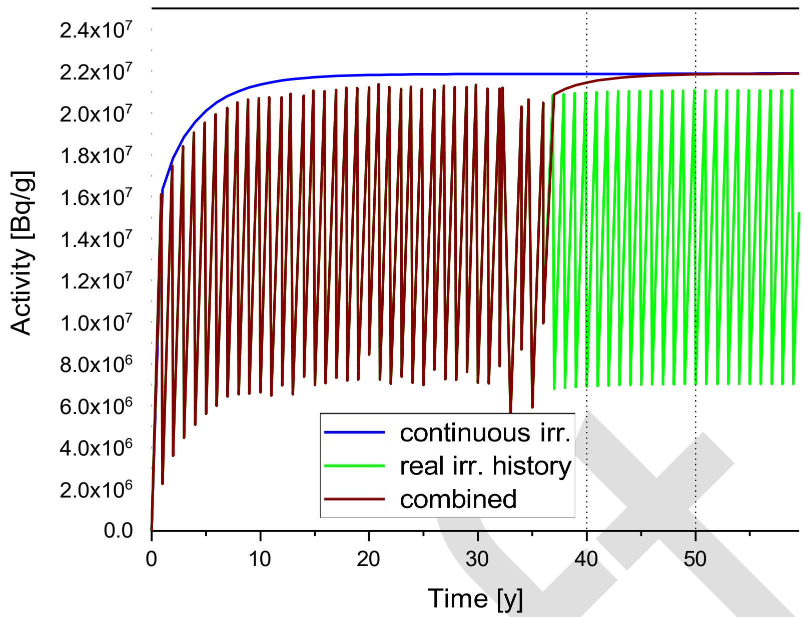

Figure 105: Time evolution of activity per mass for the transition ring of the Tihange 3 reactor vessel: comparison between continuous irradiation, realistic irradiation in cycles, and a combination case.

The evolution of the major activation products before the LTO period and decay thereafter is shown in Figure 106. The highest activity is due to the very short-lived ^{56}Mn ($_{T1/2=2}$.58 hours), which rapidly disappears after cessation. Other isotopes with significant contributions are ^{55}Fe ($_{T1/2=2}$.74 years) and ^{54}Mn (T1/2=312 days). These determine the activity after 20 years. Longer-term activity is determined by ^{63}Ni ($_{T1/2=101}$ years), ^{59}Ni ($_{T1/2=7}$.60 x 10^4 years), ^{93}Mo ($_{T1/2=4}$.00 x 10^3 years) and ^{93m}Nb ($_{T1/2=16}$.13 years).

For long-lived nuclides, since their half-lives are longer than the reactor lifetime, no equilibrium is reached. The activity of these nuclides[140], which are important for long-term safety, increases by 21-25 %. However, their contribution to the total activity at shutdown is limited (<0.25%).

[140] i.e. ^{14}C ($T_{1/2}$ = 5.7 x 10^3 years), ^{36}Cl ($T_{1/2}$ = 3.01 x 10^5 years), ^{41}Ca ($T_{1/2}$ = 1.03 x 10^5 years), ^{59}Ni ($T_{1/2}$ = 7.60 x 10^4 years), ^{63}Ni ($T_{1/2}$ = 101 years), ^{93}Zr ($T_{1/2}$ = 1.61 x 10^6 years), ^{94}Nb ($T_{1/2}$ = 2.00 x 10^4 years), ^{93}Mo ($T_{1/2}$ = 4 x 10^3 years), ^{99}Tc ($T_{1/2}$ = 2.14 x 10^5 years).

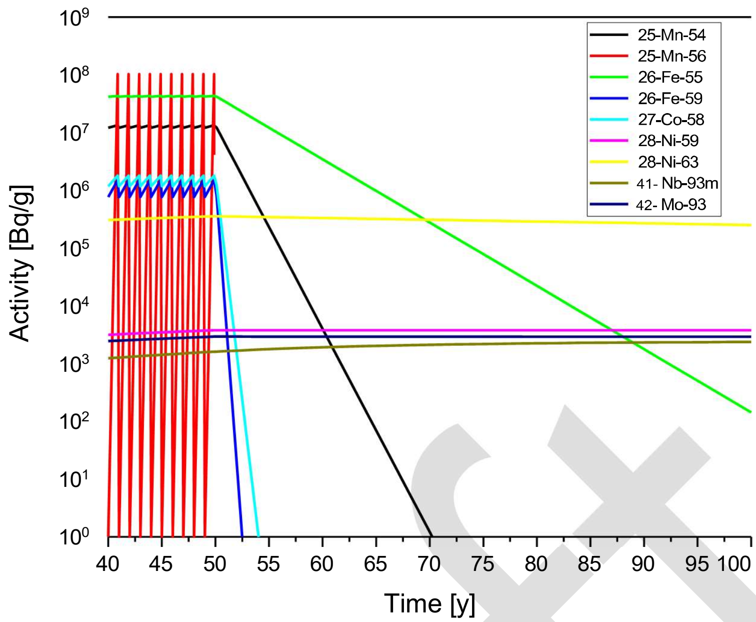

Figure 106: Time evolution of the main activation products during the LTO period and their decay in the period after cessation.

The contributions of the activation products are compared for the different reactor vessel material types in Table 98. As can be seen, these contributions are similar for the different material compositions.

Table 98: Main contributing nuclides (in %) to the activity in the different parts of the reactor vessel after 50 years of irradiation.

Nuclide	Core mantle	Transition ring	Las
54Mn	8,5	8,3	9,5
56Mn	57,7	58,8	52,0
55Fe	28,1	27,5	31,5
59Fe	0,9	0,9	1,0
58Co	1,0	1,0	1,2
63Ni	0,2	0,2	0,3
Other	3,6	3,3	4,5

As a final part of the calculations, the sensitivity to the shape of the neutron spectrum was evaluated. For this purpose, the previous results based on the PWR RPV spectrum were compared with results for the alternative spectrum BR1 Y3 from Figure 76. The calculated activity evolution for both spectra is shown in Figure 107.

Application of the BR1 Y3 spectrum results in an increase in activity by almost one order of magnitude. This is a consequence of the increased thermal flux and hence neutron capture, creating ^{56Mn} and ^{55Fe}, which are the main contributors to the activity at the end of irradiation. Their proportion increases significantly increase in the BR1 Y3 spectrum to 59.3 % and 38.2 %, respectively. On the other hand, the contribution of 54Mn falls below 1 %, which means it is produced via the ^{55Mn}(n,2n) reaction in the fast energy region.

It should be noted that the same integrated neutron flux value $1.^{4\times1011}$ [n/cm²s] was used in both cases, although in reality the thermal flux cannot increase because the absorption probability increases with the deceleration of fast neutrons. Thus, the results in this section are intended only to confirm that extending the irradiation time does not lead to an increase in activity in any spectrum because no long-lived nuclides with half-lives greater than 10 years are produced in large quantities.

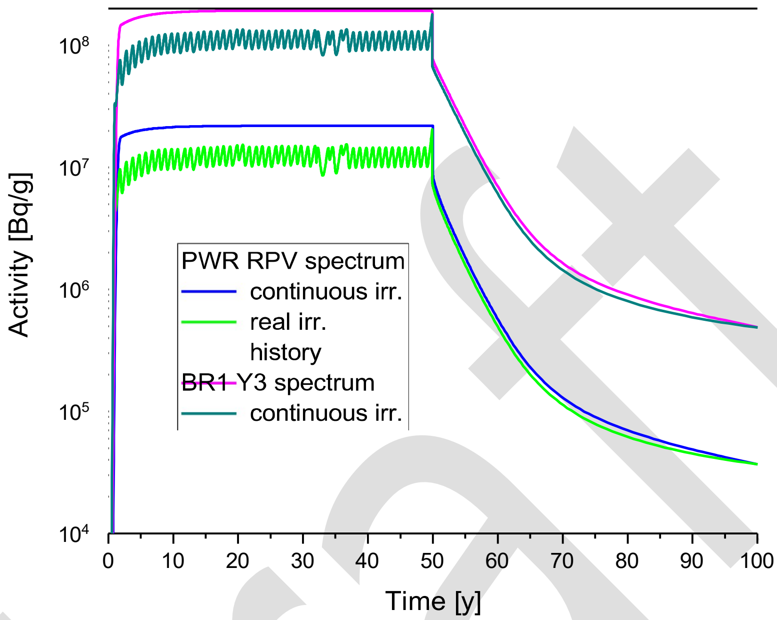

Figure 107: Comparison of calculated activities at the transition ring level with different neutron spectra.

2.5.3 Conclusions

It can be concluded from this model calculation that a 40-50 year lifetime extension will have little to no effect on the total radioactivity caused by activation of elements present in the structural elements of the reactor, since most of these activation isotopes have only short lifetimes. However, there is a significant increase in the number of long-lived isotopes in these structural elements, a proportion of the total neutron flux to which these elements will be subject during the lifetime extension. Thus, assuming the same regime as in the past 40 years, this means an increase of (maximum) 25% at a lifetime of 50 years.

However, the effect on the total amount of waste of different categories (unconditional release, conditional release, category A, category B) is difficult to estimate at this time because detailed data on the amount of trace elements in the structural elements of the plants are missing (or unknown to us). The 25% increase in most long-lived isotopes could shift the transition zone from Category A to Category B, increasing the volume of Category B waste. Since the neutron flux in the extremities of the reactor vessel can be smoothly 10 orders of magnitude smaller compared to that in the center of the reactor vessel, it is assumed that the - rather limited - activity increase due to the LTO will have little or no impact on the delineation of the transition zone. Therefore, no significant shifts are expected with respect to the volumes of B waste.

2.6 Cross-border effects

2.6.1 Normal operation

CN Tihange is located at shortest distances of 38 km and 58 km from the Dutch and German borders, respectively. However, given the negligible and unobservable radiological impact (order 0.044 mSv/year from gaseous and liquid discharges and possibly limited dose from direct radiation, but within local variations of natural radiation) in the operation of all units of CN Tihange for the most exposed person is located on Belgian territory just outside the site of CN Tihange and the fact that the impact only decreases with distance (dilution for discharges and inverse square law for any direct radiation coming from CN Tihange), it can be stated that there are no transboundary effects on humans and the environment during normal operation of KC Tihange, m.i.e. also not with the extension of Tihange 3 for 10 years.

2.6.2 Accidents

To assess the transboundary impacts under the two overarching design basis accident scenarios (LOCA and FHA) and the outer design accident scenario (CSBO), we use the Flexpart methodology, as discussed in the methodology section §2.3.4.

The discharges to the environment assumed in these scenarios are given in Table 99Table 99: Discharged activity of the different groups of radionuclides important to the impact.

Table 99: Discharged activity of the different groups of radionuclides important for impact.

Tihange 3	Draft baseline scenarios		Expansion design scenario
	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 the CSBO accident

Given the greater distance (several tens of kilometers), the use of the Flexpart model is preferable to a static Gaussian dispersion model that is very suitable for local impacts (as used for off-site maximum impact assessment).

The estimates are otherwise very conservative:

- For example, for the Flexpart calculations, the source term for the LOCA (duration of discharge: 720 hours) is considered as a 1-hour discharge (less dispersion), for the FHA 2 hours (which is the real duration of the discharge) and for the CSBO 6 hours (discharges during several vents and continuous discharge over 10 days).
- all iodine is assumed to occur in the elemental form (I_2)
- the maximum air concentrations and deposition levels are used that were obtained for a series of simulations with the start of the discharge at each hour of a full year (meteorological data ECMWF 2020 - see methodology) in the countries concerned for the considered duration of the discharge (6 hours, 2 hours or 1 hour depending on scenario) and considered groups of radionuclides (other deposition). This means that for each country the least favorable weather condition over an entire year (the year 2020) is used to make the estimate.

In addition to the impacts in different countries, maximum values at sea were also determined. Based on these air concentrations and depositions, the total effective and equivalent thyroid dose were then determined for the different age categories. The maximum across all age categories was tabulated.

Table 100: Maximum effective dose and thyroid dose for critical individual and deposition value for the different accident scenarios and for different neighboring countries (Flexpart methodology).

Tihange 3	LOCA			FHA			CSBO		
	TED (mSv)	Shielding dose (mSv).	Dep. I131 (Bq/m2)	TED (mSv)	Thyroid dose (mSv).	Dep. I131 (Bq/m2)	TED (mSv)	Thyroid dose (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 considered for Tihange 3 have a particularly small impact. The doses are such that no immediate countermeasures such as sheltering or administration of stable iodine are required. It is very unlikely but not completely excluded that the deposition of iodine isotopes (such as I-131) for a short period of time would require countermeasures for the food chain in the Netherlands and/or Germany. The maximum values found are just above the derived value for soil contamination. Deposition of long-lived radionuclides is very limited. Consequently, the radiological impact remains very small for these accidents.

2.7 Mitigating measures: contingency planning

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

2.8 Gaps in knowledge

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

2.9 Recommendations

In the context of radiological impact assessment, we hereby wish to make a number of recommendations upon implementation of the Project:

1. The dose due to gaseous and liquid discharges during operation of Tihange 3 is largely determined by carbon-14, a radionuclide that also occurs naturally. The discharge was fairly recently based on measurements for Tihange 2 (similar reactor). Here it was found that real discharges of carbon-14 at Tihange 2 are lower than the (conservatively) calculated values. In this context, when renewing Tihange 3, it is appropriate to quantify the discharges of carbon 14 on the basis of measurements at Tihange 3 in order to maintain as realistic an estimate as possible of the doses under normal operation;
2. If Tihange 3 is extended for 10 years beyond 2025, the operation will coincide with the post-operational and possibly decommissioning phase of the other reactors and some auxiliary buildings on the CN Tihange site. It seems recommended that the radiological exposures potentially arising from decommissioning and those from operation for further electricity production of Doel 4 be distinguished to the extent possible and reported separately publicly.

3 Synthesis and decision site Tihange - Tihange 3

3.1 Synthesis of effects

3.1.1 Non-radiological effects

If Tihange 3 remains in operation for another 10 years, this means that for 10 years (treated) domestic wastewater, treated industrial wastewater and (heated) cooling water will be discharged. Since the discharge standards for the various parameters are well met and the calculated contribution to the increase in concentration is negligible (locally), there is no reason to fear a deterioration of the ecological status of the Meuse as a result of the extension of Tihange 3's activity by another 10 years, provided that special attention continues to be paid to monitoring and the implementation of corrective measures within a reasonable timeframe.

Given the limited effects of the NPP on water quality and the ongoing efforts that will be made to further reduce the effects in the period 2025-2037, it can be said that the project will not jeopardize the achievement of the good ecological potential of surface waters. The efforts made and to be made to meet the discharge standards will not change the quality of the Meuse water. There is no reason to fear that the current (admittedly) unsatisfactory status of the Meuse will deteriorate as a result of the continued operation of Tihange 3 for another ten years. Deactivation (base case) will obviously make a positive contribution, but it is not certain that this will be sufficient to change the unsatisfactory status of the Meuse to a good status.

Regarding flood risk, there are no problems in the current situation and no problems are expected in the short or medium term. The nuclear power plant is not located in a flood prone area and is also sufficiently protected from possible future flood risks due to more intense rainfall (as a result of climate change). There is also no indication that the plant will cause or maintain undesirable flood risks downstream. Therefore, keeping Tihange 3 open longer will not significantly contribute to reducing or causing flood risks.

Water abstraction from the Meuse River and cooling water discharges are identified as the most impactful activities for local species. However, thanks to the measures taken by the operator based on the conditions of the applicable environmental permit, the impacts of these activities can be drastically reduced.

Several conservation areas are located in the area of the Tihange power plant. These areas are protected by law to achieve conservation objectives. These objectives, established in Walloon legislation, aim to protect internationally protected species and habitats. It is therefore necessary to verify that the expansion of the Tihange 3 reactor does not interfere with the pursuit of these conservation objectives.

It was determined that the project could affect these species and habitats through pumping of water into the Meuse River, discharge of cooling water and changes in the quality of the Meuse River, noise and light pollution, indirect effects of acid rain, and the fact that the site occupies land that could potentially be used for conservation purposes.

The various analyses led to the conclusion that the effects of the project on the aquatic environments are not such as to jeopardize the conservation strategies of these ecosystems, given the measures taken voluntarily by the plant operator or under the standards imposed on it by the environmental permit (control of discharges, drainage system, etc.). Since the river on which the power plant is located does not have a high ecological value (ubiquitous species) and in the coming years only one of the three reactors will be maintained, no negative evolution of the environment is expected.

The nuisance associated with the presence of people (noise, lighting, etc.) should not be significant, since the plant is located in an already highly urbanized area and the operator has also taken measures taken to reduce its acoustic effects. In addition, biodiversity facilities have been installed on the site.

Finally, the contribution of the Tihange 3 expansion to acid rain will not be significant. Moreover, the project seems to have a positive impact since the electricity that will be produced by the reactor will not have to be produced by the high-speed power plants, which emit significantly more combustion gases responsible for the increase in acid deposition.

Taking into account all the above elements, it can be said that the expansion of the Tihange 3 reactor does not appear incompatible with the conservation objectives of the Walloon legislation, which itself transposes the European objectives for the protection of species and habitats of interest.

Over the entire period, postponing the deactivation of Tihange 3 avoids emissions of about 12,417 kton $_{CO_2eq}$. This is equivalent to an annual savings of nearly 10% of emissions in the "production of electricity and heat" sector in Belgium in the year 2021 (12.8 Mton). The emissions attributable to the maintenance of the Tihange 3 unit amount to 16,760 tons of $_{CO_2eq}$, representing 0.13% of the avoided emissions. Therefore, the project contributes to the achievement of this objective and the score is positive.

Over the 10-year baseline period, the project will have no additional impact on environmental resilience to climate change impacts. The analysis presented in this EIA also clearly demonstrates the area's resilience to climate change impacts well beyond what is expected in 2025. Whether or not Tihange 3 operates in the reference period 2025-2037 does not change this. The assessment is therefore neutral.

The relevant and overriding objective for this topic is to ensure the safety of the population. Since the Tihange plant is a Seveso facility and is therefore subject to strict regulations, particularly in the areas of fire prevention, prevention of major accidents and related domino effects, and annual inspections, it is assumed that the continuation of operations for a period of 10 years will not impede the achievement of the main political objective of this topic. Nor are psychosomatic effects expected. However, one can speak of a positive health effect of keeping Tihange 3 open longer, to the extent that the probability of a blackout and the potential health effects associated with it are significantly reduced.

3.1.2 Radiological effects

The potential radiation exposure during normal operation of the plant is related for humans and the environment to direct radiation from radioactivity present at the site, and from the gaseous and liquid discharges containing certain concentrations of radioactivity.

Measurements from the TELERAD network operated by the FANC-AFCN show that the dose from external radiation in the vicinity of CN Tihange is much smaller than the legal limit of 1 mSv/year, and indistinguishable from local variations in the natural background.

Measurements taken during a helicopter flight over CN Tihange confirm this picture. An increase in dose rate is visible above one of the buildings where radioactive waste is treated and stored and amounts to about 2x the background value. However, the radiation is laterally shielded and therefore only measurable above the building and also much smaller than the reference value of 10 µGy/h below which the effects on the environment (fauna and flora) are negligible (e.g. on birds).

In the current situation, the Tihange nuclear power plant does not have a significant measurable radiological impact on the environment through atmospheric discharges, nor does it have a significant measurable radiological impact on the Meuse River. This conclusion obviously holds even if only the operation of Tihange 3 is taken into account.

A calculation based on current discharge limits shows that even for (hypothetical) "most exposed person," the dose due to atmospheric and liquid discharges is well below the effective dose limit for the public of 1 mSv per year. Since in practice actual discharges are only a fraction of the licensed limits, the actual dose (for the entire CN Tihange site) is obviously even smaller; it amounts (at most) to only about 4.5% of the dose limit.

The shutdown of Tihange 3 gives rise to the elimination of part of the radioactive gaseous and liquid discharges to the environment. The discharges directly linked to the operation of the reactors (and which also have the main contribution to the dose resulting from the gaseous and liquid discharges) will disappear. On the other hand, certain gaseous and liquid discharges will continue in the post-operational phase.

Based on experience in Germany, it can be conservatively estimated that the effective dose due to gaseous and liquid discharges in the case of non-renewal of Tihange 3 (i.e., with no reactor left in service at the Tihange site) will decrease to a level below 0.01 mSv /year in the first year after shutdown and will further decrease to below 0.005 mSv/year in the years thereafter.

If the project is implemented and the lifetime of Tihange 3 is thus extended, it can be assumed that the gaseous and liquid discharges related 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 the gaseous and liquid effluents remains unchanged. A conservative estimate of the effective dose from operation of Tihange 3 only gives a value of 0.01 mSv/year, and this constant over the 10 years of extended operation. This is well below the current operating license and also a factor of 100 below the legal limit of 1 mSv/year. An effective dose of 0.01 mSv corresponds to the additional dose an individual receives from increased cosmic radiation on a 5-hour scheduled flight at 10 kilometers altitude. Consequently, the effective dose in normal operation of the project provides a trivial impact.

The present EIR also studied the effects of the project on the dose that would result from two design basis accidents and from a design expansion accident. An analysis based on the Tihange 3 safety file shows that the effective doses and equivalent thyroid doses resulting from both design basis accidents for Tihange 3 remain within the set limits. This is also true if the analysis is done on the basis of the FANC guidelines for new Class 1 installations In a design expansion accident, the effective dose appears to be of the same order as that of both design basis accidents, but the equivalent thyroid dose is lower.

The project thus entails a limited risk related to an accident (both design basis - and design extension accident). However, for the whole CN Tihange site, the risk will decrease, since during the 10-year life extension period only Tihange 3 will still be operated on the site.

It is expected that delayed deactivation of Tihange 3 nuclear reactor will give rise to an additional quantity of low and medium level waste of about 405 ^{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 253 monoliths or 0.27 modules in the repository for Category A waste. The (volumetric) capacity of that repository is 34 modules.

In addition, extending the operation of Tihange 3 for 10 years will generate an additional quantity of about 420 spent fuel elements. This represents an increase of 3.8% compared to the entire Belgian fuel inventory in the event of final shutdown.

A long-term management solution will have to be worked out for these fuel elements, amounting to geological disposal if fissile material is classified as waste. Under the assumption that disposal will take place in little hardened clay, with supercontainers as primary packaging, the above additional consumption would correspond to 105 additional supercontainers (Type SC-4) and an additional required disposal gallery length of about 650 m. An additional quantity of spent fuel to be disposed of will not cause a commensurate increase in estimated dose or risk.

3.2 Synthesis of transboundary impacts

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

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

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

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

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

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