Part II. Environmental impact assessment delayed deactivation of Doel 4 nuclear power plant.

1 Non-radiological effects Doel 4

1.1 General

In the impact description and assessment done in this chapter for the various disciplines, the following structure is used in each case:

Relevant policy objectives

A description of the various policy objectives that will be tested against. Source of these objectives are the various relevant policy documents. These are high-level objectives.

Relevant effects and cause-effect relationships

A description of the impacts relevant to making a judgment about the extent to which the Project contributes or does not contribute to the achievement of policy objectives, and the cause-and-effect relationship to the Project.

Delineation of study area and description of reference situation

The starting point here is, in principle, the situation in 2025, the year in which, according to the nuclear law, Doel 4 would be shut down. We also describe here any (autonomous or controlled) developments that could have the consequence that the situation in 2025 would be (fundamentally) different from the current situation in 2023, and also those that have an impact on the evolution of the reference state over the period of the lifetime extension. If there are such developments we take them into account in the impact description (development scenario or second reference situation).

Description of effects

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

Assessment of impacts against policy objectives.

This is where the assessment occurs (across effects) of the extent to which the achievement of the various policy objectives is or is not supported by the effects.

1.2 Theme Water

1.2.1 Relevant policy objectives

For the Water theme, which is a regional competence for the non-radiological effects on the water system, for the reference period considered in this EIA for the extension of the operation of Doel 4, the Flemish policy ambitions as formulated in the vision documents Vizier 2030 and Vision 2050 are important, the provisions of the European Water Framework Directive (WFD) translated into the Decree Integral Water Policy and the Water Code, the Water Policy Document 2020-2025 and to a lesser extent but related to it, the Blue Deal (2020), the river basin management plans and the advice Resilient Waterland are relevant.

Flemish policy ambitions Vizier 2030 and Vision 2050

For the policy ambitions in the field of water with horizon 2030, reference can be made in the first place to **Vizier** 2030[40], the plan of the Flemish Government to ensure that Flanders makes its contribution to achieving the Sustainable Development Goals (SDGs) from the global Agenda 2030 of the United Nations. The emphasis is on goals on which Flanders has an impact. The objectives of Vizier 2030 are also an intermediate step towards achieving the goals of Vision 2050 (see below), the future plan for Flanders in 2050. Vizier 2030 includes 53 objectives and 111 indicators. The most relevant for the water theme are:

- Objective 44: by 2030, water pollution is further reduced and hydromorphology is restored so that achieving good status in most Flemish watercourses and groundwater aquifers is possible, as a crucial stepping stone to a robust water system and as a contribution to the protection of the marine environment with indicators being the ecological status of Flemish surface water systems and the proportion of groundwater systems in good status (qualitative and quantitative);
- Goal 45: By 2030, water supplies are secured by protecting surface water and groundwater resources and providing sufficient space and storage for water on the one hand, and avoiding waste, maximizing alternative water sources and encouraging water reuse, with groundwater levels as an indicator.

The 2030 objectives from the various sectoral long-term policy plans have been integrated into Vizier 2030; with regard to the Water theme, this concerns the water policy document which is further elaborated in the river basin management plans and instruments such as the Blue Deal (see below). The realization of the Vizier 2030 objectives is an intermediate step towards the Flanders that the Flemish Government wants to achieve in 2050. The **Vision** 2050[41] aims to create prosperity and well-being in a smart, innovative and sustainable way in a social, open, resilient and international Flanders, in which everyone counts.

Vision 2050 indicates that most long-term megatrends are already visible now: the growth of the (world) population, urbanization, aging, climate change, increasing demand for energy and water, digitalization, a diverse and individualized society, inequality in welfare and prosperity, and so on. These themes are already shaping the political and social debate now, as well as in the years to come. The vision of the future shows a globally connected region, which deals smartly with materials and ensures prosperity and well-being with significantly fewer raw materials and materials than today. Flanders will then have a low-carbon, sustainable, reliable and affordable energy system and a robust water system capable of absorbing (climate) shocks.

That robust water system in 2050 protects ecosystems while providing many functions and services. The water system protects against flooding, provides water storage, drinking water, process and cooling water. It provides irrigation and drainage. It features opportunities for recreation and experience, in addition to connections for goods transport and soft mobility. To this end, Flanders relies on a combination of smart technology, robust infrastructure and sufficient space. In this way, Sustainable Development Goal 6: "Ensure the availability and sustainable management of water and sanitation for all" is realized. The basis for the water system is good water quality because this allows risks and costs to be kept under control, both for water supply (drinking water, agriculture, industry, etc.) and in case of flooding. Good water quality also offers more opportunities for recreation and tourism and is part of the environmental quality. Through closed-loop recycling and the use of environmentally friendly materials and production methods, pollution will therefore be prevented as much as possible. In 2050, the sanitation infrastructure has been expanded and measures have been taken for its targeted design and efficient management.

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[40] Flemish Government (2019) VIZIER 2030. A 2030 goals framework for Flanders, VR 2019 0802 DOC.0130/2, 19 p.

[41] Flemish Government (2016) Vision 2050. A long-term strategy for Flanders, 105 p.

A challenge is that the overall global demand for water is still increasing by 55% in the period 2015 - 2050. The risk of water shortages is also increasing in Flanders itself, as climate change reduces summer precipitation and increases water evaporation due to rising temperatures. There is already little water available per person compared to other countries, making partial dependence on other regions. The sense of urgency for water supply, as there is for water nuisance (and water pollution) is still in its infancy in Flanders (cf. initiatives such as the Drought and Water Nuisance Action Plan[42] , the Blue Deal and recently the advice 'Resilient Waterland' (see below). Structurally avoiding waste, saving water in times of abundance and protecting groundwater resources are not yet an automatic reflex at the moment. A specific problem is that the available space in Flanders is limited and already crowded. Moreover, this limited space is needed both to secure water supplies and to control the increasing risk of flooding due to climate change. Solutions must be even more tailored and, above all, faster.

Water Framework Directive, Decree Integral Water Policy and Water Code

The European **Water Framework Directive** (WFD) (2000/60/EC) is the basis for the protection and management of (terrestrial) surface waters, transitional waters, coastal waters and groundwater. It aims to protect and, where necessary, restore the quality of these waters and their associated ecosystems. In doing so, it aims to reduce and prevent pollution of water bodies, promote sustainable water use and reduce the effects of floods and droughts. The WFD is complemented by other legislation that addresses specific aspects of water policy, such as in protected areas[43]. It has two daughter directives: the Groundwater Directive and the Priority Substances Directive. These directives set standards for groundwater and surface water.

The Floods Directive (Directive 2007/60/EC) aims to ensure that member states can better assess the risk of floods and take measures to reduce damage. The directive builds on the structures and plans of the Water Framework Directive. In Flanders, the Water Framework Directive and the Floods Directive were translated into the **Decree Integral Water Policy**[44] and coordinated into the "Water Code" which forms the legal framework for integral water management in Flanders. The Water Framework Directive aims to achieve the 'good status' of designated water systems (surface and groundwater bodies) by 2027. The practical implementation of the WFD is done on the basis of river basin management plans and programs of measures.

Water policy paper 2020-2025

Flanders has formulated three strategic objectives and six lines of force for water policy for the period 2020-2025:

- Pursue the good status of water bodies[45]:
    - By continuing to improve surface water and groundwater quality. This can be done by working towards good water status in stages (with the formulation of adapted, intermediate objectives for water bodies for which the target distance is still large), further tackling the nutrient problem, the ecological restoration of watercourses and riparian zones, working out concrete solutions for (emerging) hazardous substances, fine-tuning water policy

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[42] The Drought and Waterlogging Action Plan (2019-2021) was a short-term action plan, complementing the second river basin management plans 2016-2021 and leading up to the third river basin management plans 2022-2027.

[43] For protected areas such as drinking water abstraction areas, bathing water, nutrient sensitive areas and Natura 2000 areas, the WFD sets additional requirements. It refers to specific regulations, such as the Birds and Habitat Directives, the Nitrates Directive and the Urban Wastewater Treatment Directive. Parts of the port area belong to the Birds Directive area, the Scheldt is a Habitat Directive area (see further biodiversity discipline).

[44] Decree of July 18, 2003 on integrated water policy, coordinated June 15, 2018.

[45] In practice, this amounts to an assessment against the Water Framework Directive (WFD).

align with interactions within the water system and with other environmental compartments and by protecting raw water sources for drinking water production on an area-specific basis.

  - By managing the water chain sustainably. This can be done by working to further expand and optimize the sanitation infrastructure where necessary, to maintain the sanitation infrastructure as a function of efficient and effective operation, to optimize and maintain the drinking water network, to maintain the obligations of private water drainage, and to limit the impact of discharges of company wastewater.

- Pursue multi-layered water security and drought risk management (prevention, protection, preparedness):
  - By sustainably reducing flood risks, mitigating the effects of climate change to the greatest extent possible, raising awareness of flood risks and encouraging citizens and sectors to take action, reducing flood damage, giving water back the space it needs, and reducing surface runoff of water and sediment.
  - By reducing water scarcity and minimizing the effects of drought. This can be done by mitigating the effects of climate change as best as possible, encouraging economical use of water, increasing water availability, distributing water as optimally as possible in cases of water scarcity and drought to limit damage, and ensuring a sustainable water supply.

- Strengthen innovation, funding, collaboration and coordination with other policy areas:
  - By further developing the partner work and operation across policy areas and investing in innovation. This can be done by focusing on better coordination between the water policy and the adjacent policy, by giving water a prominent role as a structuring element that helps determine area-oriented processes, by strengthening the area-oriented operation around water, by involving stakeholders more to help achieve the objectives of the integrated water policy and by making Flanders a testing ground for innovation in integrated water management.
  - By evolving towards a balanced financing of water policy and management. To this end, funding streams will be reoriented, strengthened and expanded as a function of achieving environmental objectives, the affordability of measures will be evaluated and the "polluter pays" and cost-recovery principles will be applied more consistently.

Blue Deal (2020)

In 2020, the Flemish government approved the **Blue Deal** that increases efforts in the fight against drought and water scarcity. In response to climate change and increased public support, the Flemish government chooses to tackle the drought problem in a structural way, with increased deployment of resources and appropriate instruments, with the involvement of industry and farmers as part of the solution and with a clear example role for the Flemish and other governments.

The Blue Deal is committed to six tracks:

- Public boards lead by example and provide appropriate regulation;
- Circular water use as a rule;
- Agriculture and nature as part of the solution;
- Sensitize and encourage individuals to soften;
- Increasing security of supply (related to water);
- Investing together in innovation to make our water system smarter, more robust and sustainable.

With the Blue Deal, Flanders is taking concrete actions towards less surfacing, more humidity and maximum circular water use. The measures from the Blue Deal form the basis of the chapter "Risks of water shortage and

minimize flooding" of the Flemish Climate Adaptation Plan 2021-2030. The deal is also a cornerstone of the water scarcity and drought risk management plan, part of the 2022-2027 river basin management plans.
The Blue Deal puts the focus on an integrated water and drought assessment. The focus should therefore be on structural quality of watercourses, drought, water perception and the like, in addition to flooding. A good water test takes into account the most current regulations including the (recently revised) stormwater ordinance and other water-related provisions in VLAREM.

Resilient Waterland

Following the recent flooding problems in Wallonia and along the Meuse and Demer rivers, the Flemish government appointed a multidisciplinary panel of experts on flood protection in October 2021, which in July 2022 issued a well-founded opinion to improve Flanders' flood protection and to define the desired level of water safety. The **'Weerbaar Waterland' advice** sharpened the adjusted strategy for water security (= water safety and water availability) in Flanders.

The desired level of water safety can only be achieved in Flanders if the natural functioning of the water system is rebuilt in every upstream landscape and valley. If water is not given the space it needs, it will make that space itself, resulting in flooding. That space for water must be present everywhere in Flanders, not just in the valleys. To achieve this, four water yards are put forward: tidal rivers, watercourses, sponge landscapes and cities and villages. This not only limits the damage during exceptional rainfall (water safety), but also aims to replenish water resources to bridge periods of drought (water availability).

The main messages of the advice are clear: create more natural flood plains, work on a thorough softening policy, provide structural financing and, above all, take immediate action. To guarantee fast and decisive implementation, the appointment of a water commissioner is recommended. The advice translates the water security strategy into ten coherent actions and a plan of action. The advice Resilient Waterland is the start of a recalibrated systemic approach to water safety and water security in Flanders.

River basin management plans

In the third river basin management plan **for the Scheldt (2022-2027),** water policy is translated more concretely to specific areas in Flanders. The plans contain measures and actions to improve groundwater and surface water and to protect against flooding and drought. This plan builds on the previous plan for the period 2016-2021.

The Doel nuclear power plant is located in the Scheldt Basin, more specifically in the Lower Scheldt Basin. Based on the current water quality and the distance to the imposed objectives of the Water Framework Directive, a number of priority areas have been designated in the Lower Scheldt basin where good water status must be achieved by 2027. A number of focus areas have also been designated, including the Sea Scheldt and the 'Scheldehaven' area. Focus areas are areas with surface water bodies for which a good ecological status by 2033 is considered feasible (class 4) or for which a significant water quality improvement can be achieved (class 5) if actions included in the current third and (next) fourth river basin management plan are implemented.

The action program for the Sea Scheldt, which together with the Scheldt port area is a class 5 focus area, includes as area-specific action "the further implementation of the Sigma Plan in the Lower Scheldt Basin along the Scheldt. A number of actions are also defined for the Scheldt port area, at the docks and in the port area itself. To achieve good status in this focus area, generic actions are also required from the agricultural, household and business sectors. Actions for the further expansion and optimization of wastewater treatment are part of the generic actions and of the zoning plans and area-wide implementation plans.

Based on the plans and policy objectives described above, the following water system objectives and thus bases for review of the project to keep Doel 4 open for 10 more years can be used:

- Maintain good surface water condition, achieve and avoid deterioration;
- (Maintain good groundwater status, achieve and avoid deterioration);
- Pursue sustainable water chain management;
- Flood risk reduction and drought avoidance;
- Pursuing sustainable water supplies.

As indicated above (scoping, see § 2.2.1.3), based on the analysis of the interventions associated with the LTO works in the period 2015 - 2020 and the absence of additional impact of the plant on the groundwater system (as described in the previously conducted environmental impact studies), the impact on groundwater was scoped out.

The original groundwater condition in the nuclear power plant zone was disturbed prior to the construction and initial commissioning of the Doel 1 and 2 power plants in 1975 and Doel 3 and 4 in 1982 and 1985, respectively. As the site was raised with 4 to 8 m of sandy dredged material, a new phreatic groundwater table developed in that layer. During that period, local groundwater hydrology (flow) has also been disturbed in the deeper aquifer due to the installation of foundations and diaphragm walls into stable Tertiary layers (up to about 15 m depth). Finally, since 1975, groundwater nutrition has been altered by the paving of the site. In the decades that followed, the phreatic groundwater in the uplifted layer became locally contaminated by accidental soil contamination due to the storage and use of contaminants at the site. For several decades, legally required exploratory and descriptive soil investigations have been systematically conducted given the presence of VLAREBO activities46. Based on the evaluations, it appears that the historical contamination of groundwater does not exceed remediation standards and or pose a threat to the environment and health. New contamination has been avoided in recent decades through compliance with the Vlarem regulations for the storage of hazardous substances and through appropriate actions (prevention and remediation) in the event of accidents where the soil or groundwater could be contaminated.

Furthermore, no groundwater will be used during the plant's operation[47] nor will the plant have any further impact on groundwater levels or local (historically) present groundwater contamination. However, the existing sewage and cooling water system is leaking and draining groundwater in a number of places.

The work that took place as part of the modifications for the LTO (extension of) Doel 1 and Doel 2 (2015-2020) had only a limited impact on groundwater. No dewatering took place during the works, the additional paving was limited so no meaningful additional impact on groundwater occurred. For the period 2027-2036 there is a chance that as a result of accidents during normal maintenance work, local contamination of the soil or groundwater may occur. Such accidents will also be dealt with in an appropriate manner, in accordance with the legally applicable regulations, so that no significant pollution of soil and groundwater is expected. No other effects on the groundwater system are expected.

1.2.2 Relevant effects and cause-effect relationships

To make a judgment on the extent to which the project does or does not contribute to the achievement of water system policy objectives and the cause-effect relationship of the project, a

[46] The results of these soil investigations were described in the project EIR for the relicensing (2010) and were supplemented in the EIR for the lifetime extension of Doel 1 and 2 (Arcadis/NRG, 2021).

[47] The groundwater near the Scheldt is salinated and for this reason not suitable as process water.

overview of the most relevant foreseeable effects of the project (the extension or postponement of the deactivation of Doel 4 by 10 years) on the water system.

Next to nuclear fuel, water is possibly the second most important raw material or resource of the nuclear power plant. Indeed, the Doel nuclear power plant is highly dependent on the water system for its operation since the tertiary circuit for cooling the condensers of the second circuit are fed with Scheldt water. For the Doel 1 and 2 units, these are two direct cooling circuits with single use of the cooling water, for the Doel 3[48] and 4 units, these are closed cooling systems with a circulation of the absorbed Scheldt water between the condensers and the cooling towers. The result is that a large amount of surface water is pumped up, warms up and partially evaporates and is then discharged back into the Scheldt at a slightly elevated temperature.

In addition to the temperature effect, the cooling water also has an increased chloride content as a result of adding products (to avoid microbial growth and foaming).

A positive effect of using Scheldt water, which is especially beneficial in summer, is that due to the operation of cooling towers, the discharged cooling water has a higher oxygen content than the water in the Scheldt. Surface water is also sometimes used for the production of process water (demineralization water) that is discharged back into the Scheldt after use and purification.

The nuclear power plant also consumes city water (drinking water) as a source of process water, sanitary facilities and replenishment of cooling ponds (for the Doel 3 and 4 units). Excess process water is discharged back into the Scheldt after physical-chemical treatment. Sanitary wastewater, together with rainwater runoff from the roofs and most of the paving, is treated in five biorotors and discharged into the Scheldt.

The plant has two capture points for Scheldt water, one for the Doel 1 and 2 units and one more on the shore for the Doel 4 unit (and previously Doel 3). Each biorotor for the treatment of sanitary wastewater has a discharge point, operating wastewater and cooling water is discharged into the Scheldt at the same point.

Sanitary wastewater and operational wastewater and cooling water must meet the discharge standards imposed in the environmental permit (2011 base permit, last amended in 2019).

Groundwater is not used in the process, neither is captured rainwater. The plant is not located in flood prone areas (raised area). Also as a result of climate change (with higher water levels and more intense rainfall) no major problems are expected in the future.

At the capture points, fish mortality may occur due to suction in the pumps. This impact and the secondary impact of the (thermal) discharges on aquatic life is discussed and assessed further in the biodiversity theme.

Thus, the main foreseeable impacts on surface water are the quantities of water consumed as a resource (water balance), the impact on flow rate and the impact on temperature and water quality of the Zeeschelde River.

The water discharged into the Scheldt does not come into contact with the primary circuit (the nuclear part of the plant). Thus, there is no risk of radioactive contamination of the Zeeschelde (under normal operating conditions).

Regarding surface water, a further intake of city water and Scheldt water and a discharge of wastewater (sanitary and process) and cooling water must be taken into account during the 10-year extension period. A further impact on the water quality and water quantity of the Scheldt in that respect is to be expected. Since no works are planned at the existing discharge or capture points in the Scheldt, the impact on the structural quality of the Scheldt is not considered relevant.

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[48] Doel 3 has been permanently shut down since September 2022.

1.2.3 Delineation of study area and description of reference situation

The *study area* for the Water discipline includes all surface waters belonging to the public hydrographic network, the quality, quantity and/or structure of which could be affected as a result of delaying the deactivation of Doel 4. The precise delineation of the study area depends on the scope of effects, which is the subject of the study. Specifically, the study area is defined by the Zeeschelde River and, more specifically, by the zone of influence within which effects on water quality due to thermal and wastewater discharges may manifest themselves. In view of the tidal effect, the part of the Zeeschelde up to about 5 km upstream and downstream of the nuclear power plant discharge points can be roughly delineated as the study area.

Translated to the water bodies defined in the River Basin Management Plan, the status of the surface water body Zeeschelde IV is discussed.

The *reference situation* is in principle the situation of the state of the surface water concerned in 2025 We assume that in most cases the situation today (2023) will be a sufficiently good approximation for the situation in 2025. Autonomous or controlled developments would rather give rise to a further improvement of water quality for the Zeeschelde by 2025 (due to the further remediation efforts in the basin, due to the decommissioning of Doel 3 and soon Doel 1 and 2); on the other hand, possible effects due to climate change during that period (temperature effects or changes in flow or tidal range) can also be considered. However, it is unlikely that these evolutions would lead to an observable difference within the aforementioned period.

The environmental impact report related to the works for the extension of the operation and operation of Doel 1 and 2 (Arcadis/NRG, 2021) made a comprehensive overview of the quality of the Zeeschelde, based on VMM's measurement data in the period 2013-2019.

The Zeeschelde, both upstream and downstream of the KC Doel discharge point, does not meet all quality objectives. The most critical parameters are temperature (in summer several days above 25°C), dissolved oxygen (the P10 value of 6 mg O2/L is not always respected), chemical oxygen demand (COD), nitrate + nitrite + ammonium, dissolved boron, arsenic, beryllium, cadmium and uranium. However, based on the Prati index for dissolved oxygen, a gradual improvement in oxygenation is observed at all monitoring points since measurements began in 1994. Overall, the oxygen regime has improved mainly downstream of the NPP, as a result of increased tidal flow in the downstream direction.

For the description and characterization of the surface water quality of the Scheldt in the period 2005-2019, reference can also be made to the state assessment within the framework of the 2nd and 3rd River Basin Management Plan for the Scheldt (Lower Scheldt Basin) according to the Water Framework Directive (Table 19).

The Scheldt near KC Doel is part of the Flemish water body Zeeschelde IV with code VL17_43 (formerly VL08_43). This water body is categorized as transitional water of type brackish macrotidal lowland estuary (O1b) and has the status of a heavily modified water body. The assessment under the 2nd River Basin Management Plan (2016-2021) is based on measurement results from the years 2005-2013, the status assessment under the 3rd River Basin Management Plan (2022-2027) is based on measurement results from the years 2016-2018 and can therefore be considered representative of the current situation 2023 and a starting point for the reference period 2027 - 2036.

Table 19: Assessment status of water body Zeeschelde IV.

Framework: second river basin management plan Measurement results 2005-2013	**Framework: third river basin management plan** Measurement results 2018
The overall assessment of the ecological potential of Zeeschelde IV is generally **inadequate**.	The overall assessment of the ecological potential of Zeeschelde IV is generally **inadequate**.
The evaluation of the biological elements is **inadequate**: - **inadequate** for macrophytes; - **moderate** for macroinvertebrates; - **inadequate** for fish.	The evaluation of the biological elements is **inadequate**: - **inadequate** for macrophytes; - **moderate** for macroinvertebrates; - **good** for fish.
The evaluation of the physicochemical elements that determine the biological elements is generally **poor**. For the evaluation of individual physicochemical elements: - **Poor** rating for nitrate + nitrite + ammonium; - **Good** rating for temperature, dissolved oxygen and pH.	The evaluation of the physicochemical elements that determine the biological elements is generally **poor**. For the evaluation of individual physicochemical elements: - **Poor** rating for nitrate + nitrite + ammonium; - **Good** rating for dissolved oxygen and pH.[49]
The result of the evaluation for the specific pollutants that determine the biological elements is **poor**. There is an exceedance for dissolved arsenic, boron and uranium.	The result of the evaluation for the specific pollutants that determine the biological elements is **not good**. There is an exceedance for dissolved arsenic, boron and uranium.
(The evaluation of hydromorphology is **inadequate**)	Evaluation of hydromorphology is **inadequate**
The assessment of chemical status for the Zeeschelde IV is **poor**. There are exceedances for PAHs and total mercury.	The result of the chemical status assessment for Zeeschelde IV is **not good**. There are exceedances for PAHs, polybrominated diphenyl ether, tributyltin, perfluorooctane sulfonic acid, heptachlor epoxide and total mercury.
The water bottom of the Zeeschelde IV is **contaminated**.	The water bottom of Zeeschelde IV is **slightly contaminated**.

The overall ecological status of the Zeeschelde IV has remained the same (insufficient) during the past decades, although an improvement of the fish stock was observed. For this water body and its runoff zone, according to the assessment in the river basin management plan, the ecological potential will not yet be achieved in 2027.

Figure 31 shows the evolution of the quality of the Zeeschelde at a measuring point in Zandvliet downstream of the nuclear power plant on the basis of oxygen saturation according to the Prati index. Since about 2000,

[49] In the third RBMP, temperature is no longer included as a so-called "guide parameter" for the assessment of physico-chemical status according to the WFD systematics. The environmental quality standard does of course remain (as for other physico-chemical parameters that are not guide parameters) and applicable to all surface water bodies. Temperature is also still included in the monitoring network as before. In the period 2016-2018, temperature was rated as "moderate" for the Sea-Scheldt IV.

the oxygen content of the Zeeschelde improved significantly. Improvements have also occurred for other parameters but the overall status assessment according to the WFD methodology for the Zeeschelde remains inadequate.

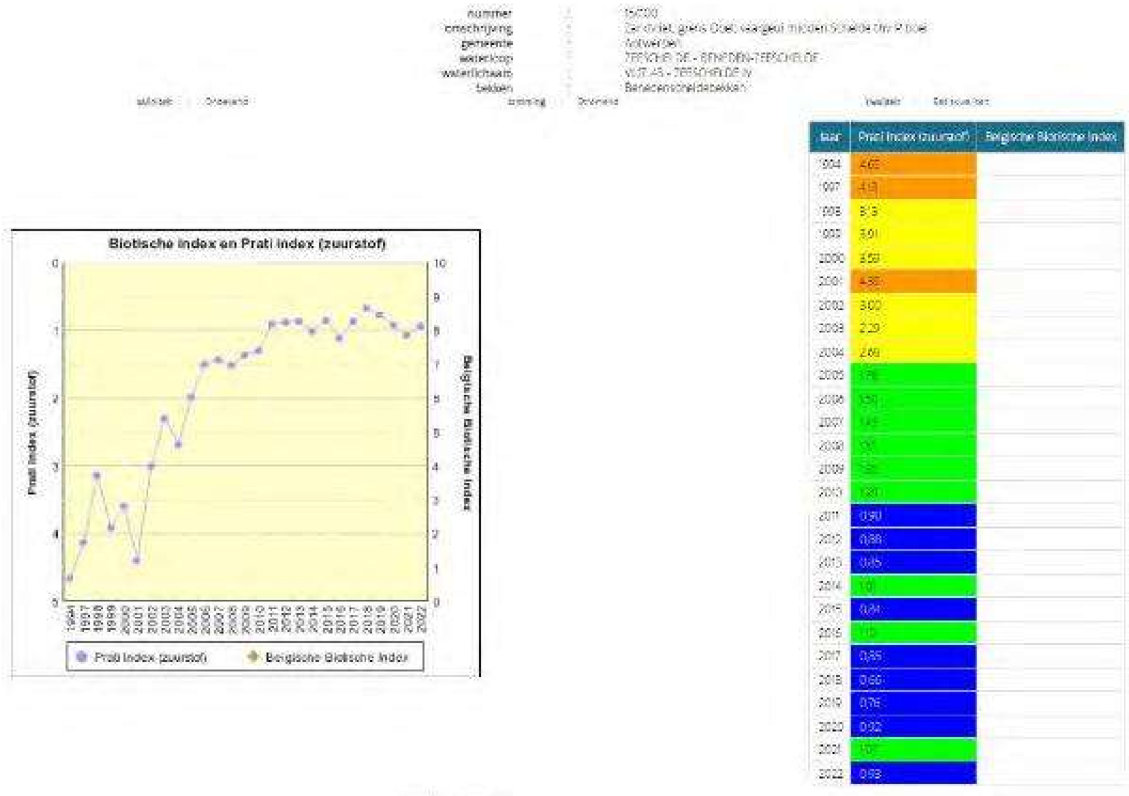

Figure 31: Evolution of oxygen saturation (Prati index) in the Zeeschelde (measuring point 154100) between 1994 - 2022 (source: MM, geoloket water quality).

Since an extension project may have an impact on water quality due to a discharge of industrial wastewater and cooling water, further research must be conducted to determine what the impact may be on the ecological status of the water body in question (Zeeschelde IV - VL17_43). After all, the status must not deteriorate. Hydromorphological changes or an impact on the groundwater body are not applicable in the context of the project.

In the case of a transitional water, dissolved oxygen, (temperature), pH and nitrate + nitrite + ammonium are the physicochemical elements to be assessed. To examine the prediction of effects on the biological elements, the parameters BOD and COD must be examined (without being taken into account for condition assessment).

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

In the environmental impact assessment related to the works for the extension of Doel 1 and 2 in the period 2015 - 2025 (Arcadis/NRG, 2021), the following evaluation was carried out:

- Physicochemical elements that determine biological elements:

For dissolved oxygen, no deterioration is assumed if the standards for biological and chemical oxygen demand are met. If the physico-chemical elements show deterioration, it is assumed that there will also be an effect in the biological quality elements and the condition of the water body will deteriorate.

Discharges are averaged at neutral pH, no changes to pH are expected because of the project.

With regard to the expected impact of the discharge on the temperature of the Scheldt, it is concluded that there is no deterioration in temperature with respect to the entire body of water as a result of the KC Doel thermal discharge.

For the parameters nitrite + nitrate + ammonium, BOD and COD, the impact of the discharge was calculated as negligible; consequently, no change in the status of the water body is expected.

– Specific pollutants that help determine ecological status:

  Uranium is not a relevant parameter because it is not discharged by the Doel site. The calculated impact for the parameters arsenic and boron is negligible; consequently, no deterioration is expected for the "evaluation of the specific pollutants contributing to the ecological status".

– Pollutants that determine chemical status:

  In the current state, the following parameters exceed the basic environmental quality standard: PAHs, polybrominated diphenyl ether, tributyltin, perfluorooctane sulfonic acid, heptachlor epoxide and total mercury.

  For the mercury parameter, the impact of the discharge was calculated. The impact is negligible. The other parameters are not discharged by the KC Doel. Consequently, no deterioration is expected for the pollutants determining chemical status.

– Biological quality elements:

  The impact on biological quality elements cannot be determined quantitatively. Based on the assessments in the Biodiversity discipline of the impact of water capture, cooling water discharge and chemical discharge on aquatic organisms in the Scheldt, no deterioration of biological quality elements is expected in the entire water body.

Based on this assessment, it was not expected that keeping Doel 1 and 2 open longer in the period 2015 - 2025 would lead to a deterioration in status or hypothecate the proposed objectives for the entire water body. The contribution of the nuclear power plant to the pollution of the Zeeschelde is very small. From the analysis made in the EIA for the extension of D1 and D2 it was also deduced that this statement would also be valid in the case Doel 1 and 2 were shut down, as this situation implied that the pollutant load entering the Zeeschelde via the discharges would be smaller than in the case of keeping Doel 1 and 2 open 10 years longer.

The following sections examine the potential impact of extending Doel 4 for a 10-year period (2027 to 2037) on the water system.

1.2.4 Description of effects

The description of the expected impacts is based on available data and information included in the annual environmental statements (dates up to and including 2021) prepared by the operator of the power plant and the various environmental impact assessments prepared in the period 2010 - 2021 (project EIA for the re-licensing of Doel 1, 2, 3 and 4 in 2010, screening note for the LTO works for keeping Doel 1 and 2 open longer in 2015, EIA for the deferral of the deactivation of Doel1 and 2 (KENTER, 2021) and the EIA for the lifetime extension of Doel 1 and Doel 2 (Arcadis/NRG, 2021).

Delaying the deactivation of Doel 4 by 10 years means that water will continue to be consumed and discharged by the Doel 4 plant during this period. The plant uses potable/urban water (as process water, for maintenance and in sanitary installations) and Scheldt water (as cooling water). Groundwater is not used, nor is rainwater. Figure 32 shows the water consumption for the year 2021 (Goal 1, 2, 3 and 4 in operation). Stormwater runoff from roofs and pavements, some of which enters the sanitary sewage system, is not included in the water balance.

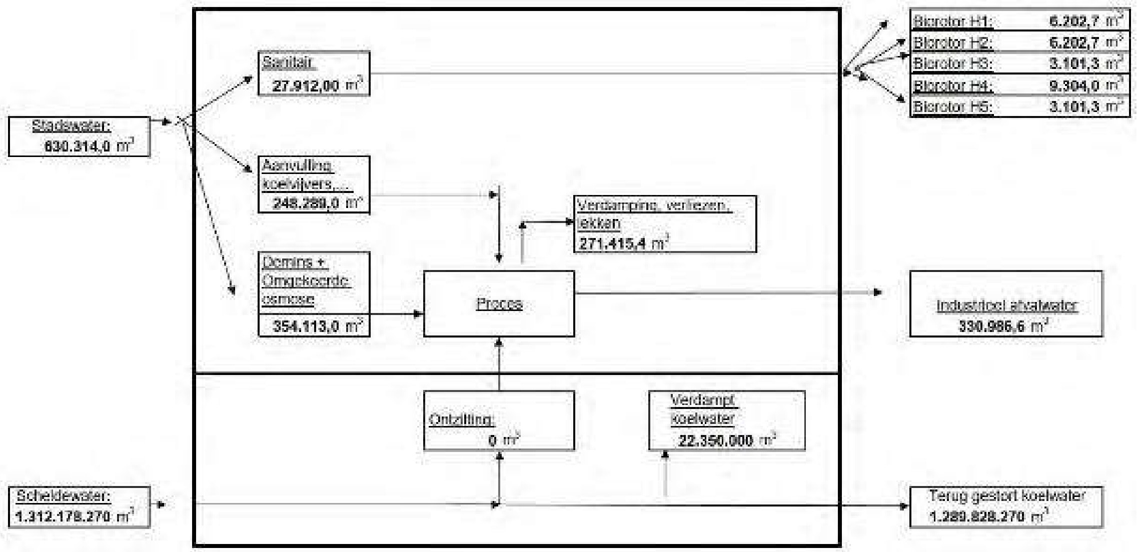

Figure 32: KC Doel water balance for 2021.

City water is mainly used for the production of demineralized water used for steam production in the secondary circuit, for the replenishment of cooling ponds and for sanitary purposes[50].

The *sanitary* wastewater, together with the rainwater (from roofs and pavements), is transported to five biorotors where it is treated before being discharged into the Scheldt (five discharge points). Sanitary wastewater is collected together with rainwater in five collection wells. These sumps are equipped with submersible pumps that pump the water directly to the Scheldt during heavy rainfall. Under normal circumstances, this wastewater is treated in the biorotors before being discharged into the Scheldt. In 2021, the annual flow for domestic wastewater (mixture of sanitary and stormwater) was approximately 27,912 m³.

Operating wastewater consists of effluent from the regeneration of the demineralization units from Doel 1 to Doel 4 and from the water and waste treatment unit, cleaning water (floors) from all units and from the water and waste treatment unit, (non-radioactive) treated wastewater and distillate from the primary circuit from the water treatment unit and ammonia-rich effluents from the vacuum pumps (reverse osmosis unit). The various wastewater streams are neutralized and physico-chemically treated before being discharged.

Operating wastewater contains as most characteristic parameters:

- Chlorides, from the hydrochloric acid used to regenerate the ion exchangers of the demineralization plants;
- Metals, such as molybdenum and chromium used to treat the specific water rings;

[50] City water is also used in specific conditions in the four small auxiliary cooling towers (with forced ventilation) of Doel 1 and 2. These are not in operation under normal conditions. Cooling of the system is normally done by Scheldt water. But for periodic tests and in case of accident, they do operate on city water.

- Boron, derived from the boric acid from the water coming from the primary circuit. (The boric acid is used in controlling the reactivity of the core). If the boric acid cannot be recovered, it is discharged after purification;
- Nitrogen, from nitrogen-containing components in wastewater derived from conditioning agents in the water steam circuits and nitrates/nitrites present in city water. In the secondary circuit, corrosion is controlled by pH regulation and using ammonia and hydrazine hydrate.

In 2021, the annual flow for commercial wastewater was approximately 330,987 m³.

Scheldt water is used exclusively as *cooling water* in the tertiary circuit. The cooling water is withdrawn from the Scheldt at two locations: an open capture point near the Scheldt bank for Doel 3 and 4 and a capture point in the Scheldt itself for Doel 1 and 2. After use, the cooling water is discharged back into the Scheldt via 1 common discharge point. Via a pumping plant, the water is pumped to the Doel 1 and Doel 2 units. The Doel 1 and 2 cooling circuits are direct or open cooling circuits which means that the cooling water sent through the condenser is used once. The Doel 3 and 4 cooling circuits are closed cooling circuits where the cooling water circulates between the cooling towers and the condenser. The part of the cooling water that evaporates or is spilled is replenished. All cooling water and purge water is discharged through 1 discharge point (point K3). Through a distribution system, however, there is the possibility of either bringing the cooling water from Doel 1 and 2 directly to discharge point K3 or pumping it to the cooling towers of Doel 3 and/or Doel 4.

The cooling water used is discharged into the Scheldt together with the effluent and operating wastewater at the same discharge point K3.

In 2021, 1,312,178,270 m³ of cooling water was withdrawn from the Scheldt and approximately 1,289,828,270 m³ was returned. The licensed quantity to be withdrawn is 1,500,000,000 m³.

Figure 33 shows the amount of cooling water discharged over a 10-year period (2027-2036) for the Doel 4 extension project versus the reference period (no extension). The figures up to and including 2021 are based on the discharged flows measured in the period 2013-2021 (source Electrabel nv, water balance data). The average annual volume of Scheldt water withdrawn for this period was approximately 1,169 million m³, the average annual volume of cooling water discharged approximately 1,151 million m³, as approximately 1.5% evaporates. The larger fluctuations in volumes are due to the shutdown of part of the plants (e.g. in 2015 and 2018) or to a lesser extent, due to temperature influences (warmer versus colder years).

For the future situation as of 2023, the volumes must take into account the decommissioning of Doel 3 as of 2023 and the decommissioning of D1 and D2 (as of the year 2026). Based on the average consumptions, a forecast for the coming years was made by Electrabel nv in the framework of the EIA and EIA for the lifetime extension of Doel 1 and Doel 2 (2021) whereby an estimate of the share of the different units was made on the basis of the expected number of operating hours and the average hourly flow rate of the pumps at the intake point for Doel 3 and 4. The future annual Scheldt water consumption for Doel 3 and 4 was thereby estimated at about 704 million m³ (annual quantity), which is estimated to be about 60% of the Scheldt water consumption of the four power plants combined (1,173 million m³). From this, a joint consumption by Doel 1 and 2 of about 469 million m³ per year was derived. It is further assumed that the consumption of Doel 3 is of the same order of magnitude as that of Doel 4 (30 % each).

As of 2023, Doel 3 is no longer in operation in both 'alternatives'. From the end of 2025, in the reference scenario (no extension), Doel 1 and 2 are also no longer in operation, which means that from 2026 the need for cooling water will be greatly reduced (only for Doel 4) to completely eliminated (reference scenario, no extension).

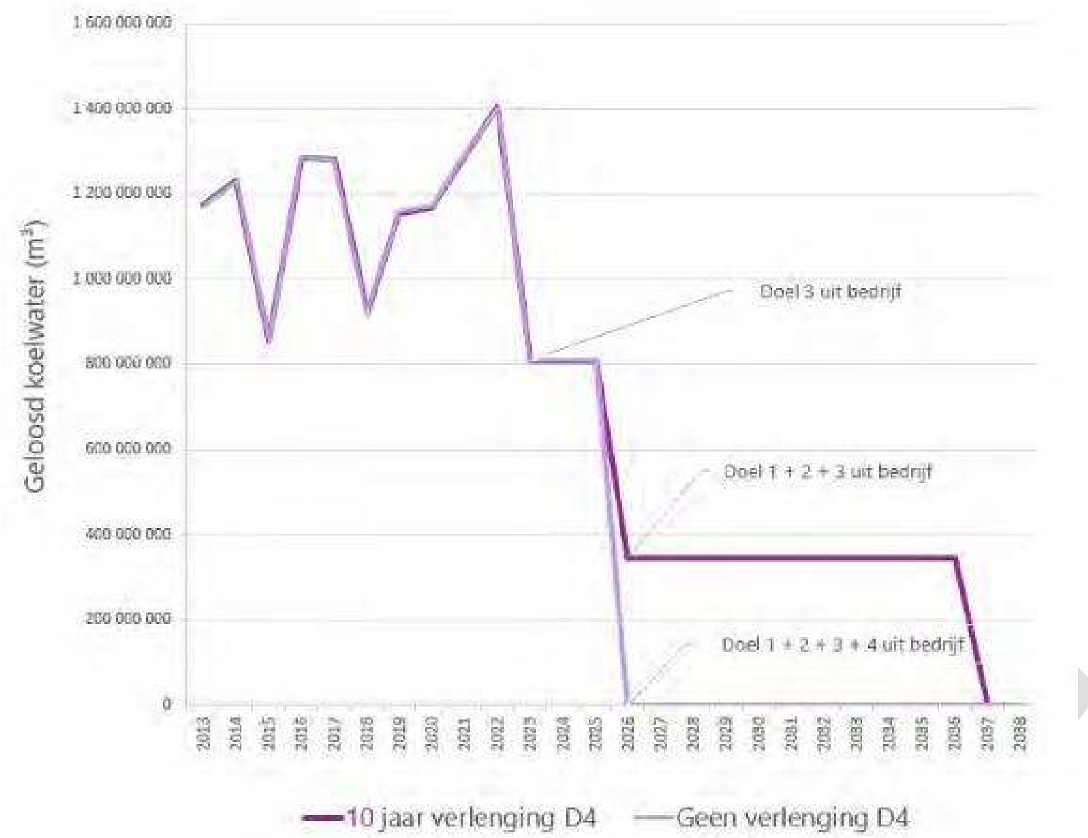

Figure 33: Volume of cooling water (m³) discharged as a result of the 10-year extension of operation of Doel 4 compared to the reference situation (no extension).

Consumption of city water will also decrease in the reference scenario, but it is assumed that it will not decrease drastically due to the decommissioning of Doel 3. This was established by Electrabel nv during periods when certain plants were shut down for maintenance. Only the consumption of city water for the steam cycle is expected to decrease slightly in the period 2023-2026. From the additional decommissioning of Doel 1 and Doel 2 in 2026, the consumption of city water will also decrease to a larger extent, for which an assumption of a 50% decrease was made.

Regarding surface water, a further intake of city water and Scheldt water and a discharge of wastewater (sanitary and process) and cooling water must be taken into account during a 10-year period of extended operation of Doel 4. Table 20 summarizes the differences between the two scenarios in terms of volumes of cooling water and wastewater (sanitary and industrial). During 10 years, approximately 347 million m³ of cooling water, approx. 24,500 m³ of sanitary wastewater and about 140,000 m³ of industrial wastewater are discharged. City water consumption is also included in the table (per year). Over a period of 10 years, in case of extension, this involves a further city water consumption of approx. 2.1 million m² or approx. 211,000 m³ per year. A further impact on city water consumption and the water quality and water quantity of the Scheldt as a result of the discharge of wastewater and cooling water due to the extension of Doel 4 is therefore to be expected. With no extension, there will obviously be no further impact on the Scheldt water system from 2027.

Table 20: Volume of cooling water discharged, wastewater and city water consumed with and without extension.

Discharge		**10 years of velenging**	**Reference scenario (no extension)**
Cooling water	Total quantity	3.47 billion m^3	No discharge
	Average per year	347 million m^3	No discharge
Sanitary wastewater	Total quantity	245.000 m^3	No discharge
	Average per year	24.500 m^3	No discharge
Industrial wastewater	Total quantity	1.4 million m^3	No discharge
	Average per year	140.000 m^3	No discharge
Consumed city water	Total quantity	2.11 million m^3	No consumption
	Average per year	211.000 m^3	No consumption

From the annual environmental statements published by Electrabel nv, the environmental permits and EIRs from 2010 and 2021, and the screening note from 2015, it can be deduced that the main impact of the operation of the nuclear power plant on the water system is the discharge of wastewater and cooling water into the Scheldt. Effects on the quantity (flow rate) and on the quality of the Scheldt are to be expected in this regard, below these effects are discussed in more detail.

Quantity

Under normal circumstances, approximately 180,000 m^3/h of Scheldt water is pumped for cooling in the tertiary circuit. This amounts to 0.71% of the flow rate of the Scheldt, which is approximately 7,000 m^3/s at Doel. This value is the average of a six-hour measurement during the flood phase. Despite the very significant amount of Scheldt water absorbed, the effect on the Scheldt's flow rate can be considered negligible[51].

In 2021, the Doel nuclear power plant used 1,312 million m^3 of Scheldt water (all reactors in operation). About 22 million m^3 evaporated in the cooling towers and 1,290 million m^3 was discharged back into the Scheldt. In 2021, about 27,912 m^3 of sanitary and about 330,987 m^3 of industrial wastewater was discharged. These quantities are a fraction of the cooling water volume withdrawn and compensate a small fraction for the evaporation loss (approx. 1.6%) but, as mentioned above, negligible compared to the cooling water flow rate (which in itself therefore also has no meaningful impact on the flow rate of the Scheldt).

During the period 2013-2022, the quantities of cooling water consumed in proportion to whether or not one or more units were idle fluctuated from a minimum of 867 million m^3 in 2015 to a maximum of 1,427 million m^3 in 2022[52].

For the period 2023-2025, an annual quantity of captured Scheldt water of about 821 million m^3 is still expected after the shutdown of Doel 3 in 2022 and from 2026, after the shutdown of Doel 1 and 2 in 2025 about 352 million m^3 (only Doel 4 still in operation). Even then, the impact on the water system in terms of flow will never be a problem but will obviously be greater than in the reference scenario for the period 2027-2036 in which Doel 3 is stopped as of the end of 2022 and Doel 1 and 2 will be shut down as of 2026 and thus no more cooling water or wastewater will be discharged.

No substantial differences in paving rates are expected in the period 2027-2036, either for the project with extension of Doel 4 or for the reference scenario in which, in addition to Doel 3, Doel 1 and 2 are also out of operation

[51] This also applies, incidentally, to the cumulative effect of all (net) withdrawals on the Zeeschelde downstream of Antwerp. Due to the predominance of tidal action, the available quantities of water here are practically unlimited.

[52] Figure not yet published in an environmental statement, oral communication Electrabel SA, January 2023.

will be taken. The high degree of surfacing (approx. 52%, which amounts to approx. 56 ha of surfacing) and the fact that the runoff rainwater ends up together with the sanitary wastewater in a mixed sewer system that causes frequent overflows from the catchment pits into the Scheldt during (heavy) rainy weather conditions, has in both alternatives an admittedly negligible impact on the flow of the Scheldt, but a negative impact on water quality. After all, the Scheldt does not yet meet the environmental quality standards for N, P and COD.

A question that also needs to be asked in the context of the water assessment (on which a new decree came into force on January 1, 2023[53]) is whether the site of KC Doel is prone to flooding, in its present condition and in the near future (until approx. 2037). In the first instance this can be tested against the water assessment map (Figure 34) and it can be checked whether, as a result of climate change, increased risks of flooding can be expected in the near future, due to more intense rainfall, flooding from watercourses or rising sea levels. The competent water authority is the Flemish Waterway, Region Central Division, Polder of the Land of Waas. The nuclear power plant is sensitive (only) to pluvial flooding but is not located in an area sensitive to flooding from the sea or from rivers/watercourses, nor in a signal area (undeveloped area with a hard regional plan designation). Indeed, the plant is built on highly elevated land (+ 8.86 m TAW) and the Sigmadijk there is locally 12.08 m TAW. For further detailed discussion, please refer to the climate discipline.

Figure 34 shows that in the future, therefore, there may be localized potential for "water on the streets" within the NPP site (around certain buildings) due to heavy rainfall (in winter or summer).

Figure 34: Pluvial flood prone areas (water assessment map, source: waterinfo.be).

The water depth maps for the current climate (Figure 35) and for the future climate[54] (Figure 36) give a view per flood probability where the highest water depths can be expected during a flood event. In implementation of the European Flood Directive, updated flood hazard maps were prepared for three scenarios: small probability (return period 1000 years), medium probability (return period 100 years) and high probability (return period 10 years) of flooding. Flood probabilities are defined as follows:

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[53] Decree of the Flemish Government of November 25, 2022, amending various decrees related to the water test and the information obligation contained in Articles 1.3.1.1 and 1.3.3.3.2 of the Decree of July 18, 2003, on integral water policy, coordinated June 15, 2018, and Circular OMG/2022/1 of December 16, 2022, on guidelines for the application of a climate-proof water test and the safeguarding of water storage capacity in signal areas.

[54] With climate projection 2050.

- Medium flood probability zones are those that have a return period of 100 years or less and correspond by return period to the delineation of former effectively flood-prone areas;
- Minor flooding events are flood events that have a smaller probability than a medium flood probability and are defined in the Flood Directive as an extraordinary event. Taking into account the water bomb in July 2021, however, it should be kept in mind that in exceptional cases, these can be very significant flood events.
- Small flood probability under climate change: this flood event projects the impact of flooding for an extraordinary event to the magnitude in the future under impact of climate change. The 2050 climate horizon was used for the preparation of the maps here and not that of 2100 which is even more extensive.

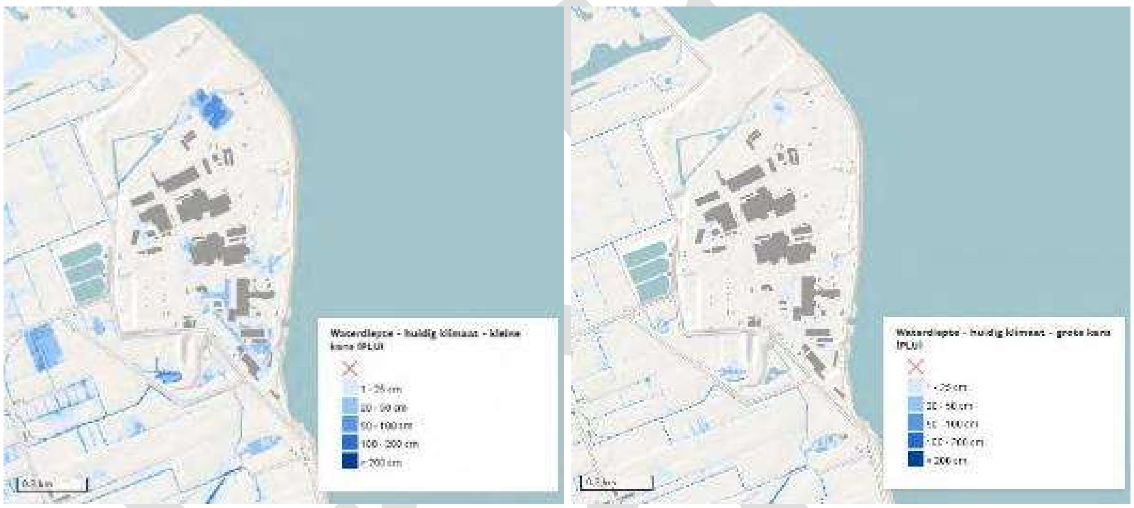

Figure 35: Pluvial flood hazard map for current climate for low and high probability of occurrence (source: waterinfo.be).

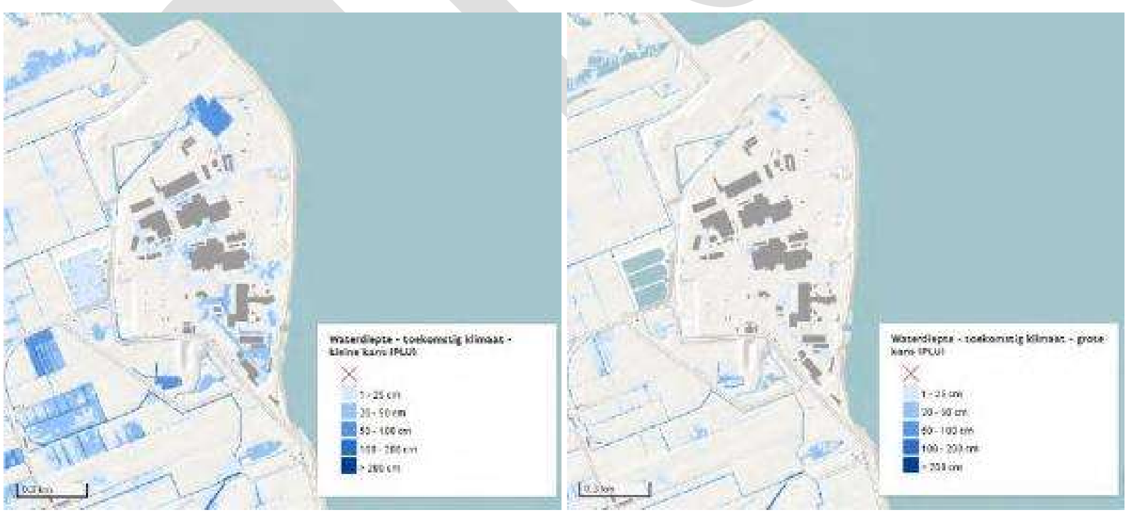

Figure 36: Pluvial flood hazard map for future climate for low and high probability of occurrence (source: waterinfo.be).

The maps indicate that within the site of the nuclear power plant, future attention should certainly be paid to flood-robust (re)construction by focusing on building sufficiently high and, where necessary, compensating space for water (safeguarding water storage capacity) so as not to create new problem areas elsewhere.

Quality

Sanitary wastewater is treated in a biological wastewater treatment plant (5 biorotors) for discharge into the Scheldt. The industrial wastewater is little polluted and is discharged into the Scheldt via a simple pretreatment. Cooling water is also discharged back into the Scheldt after use.

In the mixed sewers for the drainage of rainwater and sanitary wastewater from the nuclear power plant, leaking cooling water from the underground galleries and even groundwater (which naturally contains arsenic) also enters the sewers and sumps via the soil. These leaks of cooling water and to a lesser extent groundwater into the mixed sewers also explain the frequent overflows. For the period 2015-2019 (during the operation of all units), the duration of overflow operation of the sumps varied between 12 and 46 days per year. While keeping Doel 4 open for an additional 10 years will maintain this overflow situation (by maintaining connected pavement), a reduced volume of sanitary sewage will potentially lower the overflow frequency slightly and reduce the load of this sewage, resulting in a smaller impact on water quality than in the current situation. In the reference/zero alternative, the paving rate may not change substantially but no more leaking cooling water will enter the sewer system and the proportion of sanitary wastewater will be further reduced or even eliminated.

With regard to quality, a further distinction must be made between the discharged cooling water, sanitary wastewater and operational wastewater.

The cooling water has a thermal impact on the Scheldt, has an increased chloride content due to dosing of NaOCl to avoid microbial growth, and has an increased oxygen content due to aeration in the cooling towers. Before flowing back into the river, the cooling water is cooled in the cooling towers, where the upward flow of air raises the oxygen concentration in the water and lowers the temperature. Discharge standards dictate that cooling water flowing back into the Scheldt must not be warmer than 33°C. The daily average discharge temperature must be below 32 °C and the 30-day average discharge temperature may not exceed the 30 °C limit. In 2019, despite the heat wave, the legally set limits were respected. In 2020 and 2021, which were also marked by heat wave periods, the standards were also respected. The average instantaneous discharge temperature in 2021 was 24.72 °C, the daily average 24.58 °C and the monthly average 24.60 °C. In 2017 and 2018 (both also very warm years) these standards were also met and it is expected that under similar conditions this could also be achieved in the coming period (2023-2027).

In the EIA of 2010 (Vinçotte) and that of 2021 (Arcadis/NRG), the impact of the wastewater and cooling water on the Scheldt was discussed in detail. The main conclusion is that as far as wastewater is concerned, it can be said that the average calculated concentration increase in the Scheldt due to KC Doel's activities compared to the environmental quality standards (EQS) in the years 2013-2014 was less than 0.1%, which was considered a negligible impact. Given that the effluent quality in the period thereafter 2015-2021 was no worse overall, it can be assumed for that period that no relevant effects on the quality of the Scheldt have been identified either. For the future period (2023-2027), under normal operating conditions, no significant effects on water quality are also expected, especially since the closure of Doel 3 (end 2022) and the planned closure of Doel 1 and 2 (end 2025) will further reduce the impact on water quality. If the quality of the Scheldt water continues to improve in the coming years, the relative contribution of the Doel KC discharge may of course increase slightly but the overall effect will still be negligible. In the reference scenario (without extension of Doel 4), the impact on the Scheldt will disappear completely in the period 2027-2036.

In the period 2013-2017, a problem did arise in connection with an excessive concentration of nitrite in company wastewater. In 2013 the discharge standard (2 mg/l) was exceeded, in 2014 and 2015 the average concentration was below the discharge standard but peak concentrations above the discharge standard were still measured, and in 2016 and 2017 two peaks and 1 peak discharge were observed, respectively. It was suspected that unit shutdowns had an impact on this. The cause of the peaks was due to a confluence of unavoidable conditions that created ideal conditions for the development of biological growth in a wastewater tank. The implementation of appropriate measures (e.g., continuous measurement and faster intervention), plant modification, better operation of the Doel 3 collection facility and procedures in case of unavailability prevented the occurrence of a nitrite peak in 2018. In 2019, the discharge standard for nitrite was temporarily increased from 2 to 8 mg nitrite-N per liter (until the end of 2021) which allowed (for nitrite) to continue operating within the standards and in the meantime solve the bottleneck. The total discharged N load has been under control since 2017 (Figure 37). In 2019-2021, the future standard of 2 mg N-NO2/l was still sporadically exceeded but the concentration was below the standard on average.

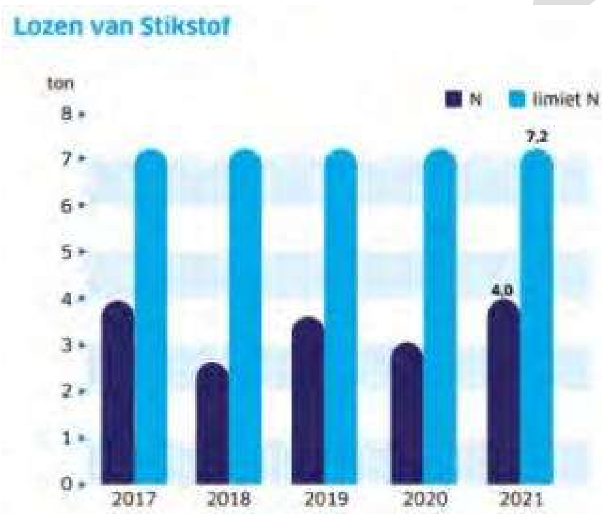

Figure 37: N load in company wastewater in the period 2017-2021 (source: Electrabel nv, environmental statement 2022).

Another problem remaining in 2019 was preventing excessive levels of AOX in sanitary and industrial wastewater and cooling water. NaOCl is added to cooling water as a conditioning agent to prevent fouling in the cooling system. This can cause AOX to form. An optimal conditioning regime can ensure that the extent of NaOCl use and the period during which conditioning must be applied is reduced, which can reduce the formation and discharge of AOX. The most important control parameter appears to be the use of active chlorine. Currently the dosing of NaOCl is done based on the analysis of the excess active chlorine and experience regarding the cooling tower gasket but because the detection limit of the active chlorine measurement is too high, fine control with the goal of lower NaOCl consumption, lower active chlorine levels in the discharged cooling water and less AOX formation is not yet possible.

With regard to the cooling water discharge, a significant temperature increase (higher than 3 °C) due to the cooling water discharge from KC Doel can be observed within the area of the breakwater, up to a maximum distance of ca. 1,050 m from the discharge point. Relevant but acceptable temperature rises between 1 and 3 °C occur at low tide and at the turn of low tide to a maximum distance of ca. 1,300 m from the discharge point, the area still located within the breakwater. At high tide, a relevant temperature rise occurs between 1 and 3 °C outside the breakwater up to a maximum of 500 m from the discharge point in an easterly direction and up to a maximum of 800 m upstream of the discharge point in a southerly direction. The area within the breakwater forms a heat barrier for certain aquatic organisms. For this area, the environmental quality standards regarding temperature for the Scheldt due to the cooling water discharge from KC Doel. The channel of the Scheldt east of the breakwater does remain passable for aquatic organisms. The average cross-sectional area of the area within the breakwater does not appear to exceed 25% of the cross-sectional area of the Scheldt. The channel of the Scheldt east of the breakwater is considered to be passable for aquatic organisms at all times. For further assessment of this effect, reference is made to the biodiversity discipline. Since the amount of cooling water in the period 2027-2036 will be smaller than the amount needed until 2022 (before the closure of Doel 3), it can be concluded that the effects on thermal pollution (size of the thermal plume, temperature increase) will be smaller during the extension of Doel 4. However, the (smaller) effect is extended over an additional period of 10 years.

In the longer term, climate change may have a negative impact on the cooling capacity of the Scheldt water. Indeed, with an increase in the temperature of the Scheldt due to climate change, the temperature of the discharged cooling water will increase proportionally, with the possibility of a more frequent limitation of the maximum thermal loads to be discharged on a daily basis (cf. the permit conditions), especially in summer. In addition, in the longer term, more negative effects in this area can also be expected if a significant drop in river flow should begin to occur as a result of climate change. However, given the predicted rise in sea level (and the already noticeable increase in tidal range), this does not seem likely to cause immediate problems for the tidal river Scheldt at this location, neither within the next 5 years, nor for the period 2027-2036. No measurable increase in the temperature of the Zeeschelde due to recent climate change has yet been observed. The water in the Zeeschelde did become slightly warmer in the 1970s and 1980s, but it seems plausible that earlier discharges of cooling water contributed to this[55][lxi]. Regarding the effect of climate change on surface water temperature, INBO (2015)[56] indicates for "surface water in general" that an increase of 0.5 to 0.6 °C per 10 years should be taken into account. In the period (2022 - 2036) this would theoretically mean that the water temperature of the Scheldt could thus rise by 0.75 to 0.9 °C. However, assuming that this should possibly be considered as a maximum for the tidal Zeeschelde river, this loss of cooling capacity should probably not cause any major problems (an increase in the thermal load, an exceeding of the discharge norms, a larger heat barrier in the summer and this during the most sensitive period - tidal low water) through better monitoring of the Zeeschelde temperature and an adapted control of the available cooling capacity. Moreover, from 2023 Doel 3 will go out of operation which will already reduce the thermal load by then and from 2026 the same applies to Doel 1 and 2.

Keeping Doel 4 open 10 years longer from 2027 to 2037 therefore means that during 10 years a smaller amount of wastewater (see above) of similar composition and with similar concentrations and a smaller annual total pollutant load as assessed in the years 2013-2014 (concentration increase of less than 0.1%) will be discharged and this will also have a negligible impact on the Scheldt. The discharged pollutant load and thermal load of cooling water will decrease by about 70 % in the period 2023-2027. For the coming years, it can also be assumed that the nitrite and AOX problem will remain further under control, as was the case in previous years. Sanitary and industrial wastewater will also decrease significantly during this period.

In the reference scenario (all plants closed) during the period 2027-2036, there will be no impact on the Scheldt (no discharge of cooling water, no discharge of wastewater, no more heat plume in the Scheldt).

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[55] VNSC (2019) System analysis nature Scheldt estuary. Joint fact-finding by stakeholders, experts and the Flemish-Dutch Scheldt Commission, 62 p.

[56] 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.

The water discharged into the Scheldt never comes into contact with the primary circuit (the nuclear part of the plant). Thus, there is no risk of radioactive contamination of the Scheldt under normal conditions.

Rainwater is not used in the process or for sanitary installations. The rainwater that falls down on roofs and most of the paved surfaces is discharged into the Scheldt together with the sanitary wastewater via the biorotors. The water from the parking lots at the company entrance drains into a stream in the nearby polder (Doorloop). Use of rainwater for the production of demineralized water or use as cooling water is in principle possible, but the necessary infrastructure for this is currently not present.

Structure quality

Since no works are planned at the existing discharge or capture points in the Scheldt, the impact on the structural quality of the Scheldt is not considered relevant.

1.2.5 Assessment of impacts against policy objectives.

For the water system, it can then be examined to what extent the effects described above that may occur as a result of keeping Doel 4 open for an additional 10 years will help to achieve, or possibly counteract, the policy objectives considered important for the water system. Relevant policy objectives that come into focus with this project are achieving good surface water status, striving for sustainable management of the water chain, mitigating flood risks and drought, and striving for a sustainable water supply.

Achieve good surface water status

Keeping Doel 4 in operation for 10 more years means that (treated) sanitary wastewater, treated company wastewater and (heated) cooling water will be discharged for 10 more years. For a number of parameters (e.g. AOX, nitrite) the discharge standards were sporadically exceeded in the past (period 2014-2017) due to some peak concentrations. By applying measures, the average discharge standard could be respected in recent years. Given that the set discharge standards can be met and the calculated contribution to the concentration increase is limited (locally) to negligible, this still means residual pollution that ends up in the Zeeschelde for 10 additional years. The part of the Zeeschelde that is discharged is currently still in an "inadequate" ecological condition and does not meet all environmental quality standards (temperature, $O2_{content}$, COD, Nitrite + Nitrate + Ammonium, Boron, Arsenic, Beryllium, Cadmium and Uranium). Water quality has improved significantly in recent decades but the river is still vulnerable to any form of pollution. The nuclear power plant is a significant discharger in terms of total pollution load, even if Doel 1 and 2 are shut down in the future. The self-purifying capacity of the Scheldt has not yet been sufficiently restored. However, a deterioration of the ecological status of the Zeeschelde as a result of keeping Doel 4 open 10 years longer is not to be feared, provided continued attention is paid to monitoring and timely adjustment.

As there are only limited effects of the nuclear power plant on water quality, but efforts will continue to be made to further reduce the effects in the future, it can be assumed that the project does not jeopardize the achievement of the good ecological potential of the surface water. Since the commissioning of the nuclear power plant, the condition of the Zeeschelde has improved, efforts that have been and are being made to meet the discharge standards will also have contributed to this. A deterioration of the present (admittedly) inadequate condition of the Zeeschelde is not to be feared as a result of keeping Doel 4 open 10 years longer. Of course, not extending it (reference scenario) would make a positive contribution, but it is uncertain whether this alone would cause the inadequate condition of the Zeeschelde to evolve further towards a moderate condition.

Given that Doel 1 and 2 together represent about 40% of the water consumption of the entire nuclear power plant and Doel 3 and 4 each represent about 30% of the water consumption, and given that the nature (composition and degree of pollution) of the wastewater and cooling water is similar for all subunits, it can be assumed be that the impact of extending the life of Doel 4 (which is a smaller fraction than Goals 1 and 2 combined) would also not result in a deterioration in status or that extending the operation of Doel 4 would hypothecate the stated objectives for the entire body of water.

Striving for sustainable management of the water chain

Managing the water chain sustainably involves (further) efforts to expand and optimize the sanitation infrastructure. Bottlenecks in current operation are the fact that rainwater is not disconnected from the sanitary wastewater stream with too frequent overflow events of (albeit diluted) sanitary wastewater during intense rainstorms. There is no separate sewage system in place. An additional bottleneck is that cooling water and, to a lesser extent, groundwater are also drained and also end up in the mixed sewer system, thus also contributing to the overflow problem. Since more intense rain showers cannot be avoided as a result of the climate change already observed, this is a bottleneck that deserves attention in the following years of further operation of the nuclear power plant (Doel 4). Such dilution of wastewater streams does not lead to efficient and effective treatment.

Generally, the NPP does meet the imposed discharge standards for sanitary wastewater, operational wastewater and cooling water but for some parameters the discharge standards are not always met (e.g. nitrite, AOX). Efforts are still needed to adjust the sanitation infrastructure for these parameters as well or even better to take source-oriented measures to solve these bottlenecks.

For a number of parameters present in the sanitary effluent, company wastewater or cooling water, the measurements are not always carried out consistently or the detection limit in the measurements is higher than the discharge standard, resulting in uncertainty as to whether or not the discharge standards are met. Specifically for the cooling water, a solution must still be found, for example, for the adequate monitoring of the content of active chlorine in order to be able to reduce AOX formation and obtain an optimal dosage of NaOCl to control microbial growth in the cooling water.

Maximum limitation of thermal loads and optimal use of cooling capacity are also measures that contribute to sustainable management of the water chain, especially in light of climate change. It is recommended that the impact of thermal discharges be more closely aligned with the evolution of the temperature gradient between the Dutch border and Antwerp. Such monitoring and alignment of the cooling capacity of the power plant with the cumulative thermal load on the Zeeschelde can further contribute to a maximum limitation of the magnitude of the thermal discharge.

Keeping Doel 4 open 10 years longer means that the presence of the mixed sewer system and the overflow problem may be perpetuated (possibly to a lesser extent) during that period and that no further efforts will be made to reuse rainwater. The thermal impact on the Zeeschelde will also continue. Without application of the measures mentioned above, it must be concluded that it cannot be concluded that the water chain is already managed in a maximally sustainable way.

Mitigate flood and drought risks

In terms of flood risks, no problems present themselves in the current situation and no problems are expected in the short or medium term in terms of fluvial flooding or flooding from sea level rise. Consequently, keeping Doel 4 open longer does not contribute appreciably further to reducing or causing flood risks from the sea or watercourses. As a result of more intense rainstorms, more flooding (water in the streets) may occur in the future under the current situation and due to climate change. However, there is currently no evidence that the plant is causing or maintaining undesirable downstream (in the low-lying polders) flood risks.

In terms of drought, it is observed that less efforts are currently being made to maximally retain, reuse and locally infiltrate stormwater. Considering that stormwater is largely drained immediately via roofs and pavements, it can be said that the NPPF has a drying effect on surrounding polders. The effect is limited and does not lead to meaningful desiccation in the current condition. In light of the increasing drought phenomena in Flanders and specifically the salinization problem in the area, it seems advisable to give maximum attention to softening and management of rainwater (reuse, infiltration and delayed discharge) during further renovations at the site or adjustments to the sewage system. Extending the operation of Doel 4 for 10 years will perpetuate the (limited) drying effect.

Striving for a sustainable water supply

Here it is evaluated whether keeping Doel 4 open longer contributes to water conservation, the water used is used in a sufficiently circular way and whether softening measures are taken. Minus points in this evaluation are, for example, the fact that rainwater is not used for certain applications (for example, in the sanitary facilities or for maintenance or in certain processes, or, in combination with infiltration and green areas as a cooling element to combat heat stress and the heat island effect in summer,
...), this could lead to significant savings in city water consumption. In this sense, it also seems valuable to maximally avoid the use of city water in the cooling water circuit and as process water. The absence of efforts to introduce more far-reaching forms of circular water use or to realize disconnection or softening projects means that the evaluation for this policy objective must be scored rather negatively. The decommissioning of Doel 3, 1 and 2 will certainly provide opportunities in this respect.

1.2.6 Summary of key findings

The tests against the water system objectives are summarized in Table 21. The plan to extend Doel 4 ten years will not have a negative impact on the ecological potential of the Zeeschelde and will not increase flood risks. In terms of sustainable management of the water chain, drought avoidance and commitment to a more sustainable water supply, optimizations are still possible.

Table 21: Summary of the assessment with respect to the water system.

Objective	Project contribution (extending Doel 4 by 10 years)	Review
Good surface water status	No deterioration of condition and does not mortgage achievement of good ecological potential.	Neutral
Sustainable water chain management	Persistence of a non-optimal state regarding sustainable management	Negative
Flood risk reduction	No appreciable contribution	Neutral
Avoiding drought	Persistence of the limited withering effect	Limited negative
Sustainable water supply	No efforts/plans on more circular water use	Negative

1.2.7 Mitigating measures

Recommendations to further meet the stated strategic goals related to the water system have already been indicated higher in the text and are summarized below:

- Prevent drainage of groundwater and cooling water to the mixed sewer system and disconnection of stormwater (e.g. in new projects or maintenance work) causing dilution of wastewater and frequent overflows;

- Continued optimization of wastewater treatment is appropriate to eliminate former bottlenecks (nitrite, AOX), more consistently measure a number of other parameters so that compliance with discharge standards can be verified;
- Disconnect stormwater from sanitary wastewater and reuse stormwater as sanitary water, avoid urban water use to the maximum extent;
- Softening (infiltration), constructing green roofs or water features (buffering) on the site to reduce the heat island effect, retain and store (rain) water more locally and prevent desiccation and salinization;
- Future conversions and renovations should be sufficiently flood- and climate-robust to cope with the effects of more intense rainstorms in the future and not transfer flooding to the surrounding area;
- Anticipatory fine tuning of cooling capacity based on monitoring the temperature of the Zeeschelde River.
- The shutdown of Doel 3 (2022) and Doel 1 and 2 (2025) can be used as an opportunity to optimize water treatment and (rain) water management for Doel 4.

1.2.8 Gaps in knowledge and monitoring

There are no gaps in knowledge that could prevent the assessment of impacts on the water system from being sufficiently accurate. A gap in information, however, is insight into the exact proportion of wastewater coming from Doel 4 and thus the exact contribution of the operation of Doel 4 to the residual pollution entering the Scheldt during the 10 years of extended operation. To estimate the effects in this environmental assessment, a (worst-case) assumption was used.

Additional monitoring to the existing monitoring program with the exception of monitoring the cumulative thermal load in the Zeeschelde is not considered necessary.

1.3 Topic Biodiversity

1.3.1 Relevant policy objectives

Both the Nature Decree (and various implementing decrees) and the Decree on Integrated Water Policy contain relevant policy objectives against which the policy plan will have to be checked. The Forest Decree also creates a framework for the protection, and in the case of forest loss, the compensation of forest. However, since the plan does not result in the disappearance of forest, this is not a relevant policy objective for this EIA.

From the **nature decree**, two generic concepts are important that apply horizontally in Flanders: the **standstill principle and the duty of care**. This principle states that new developments must not contribute to the deterioration of nature (at the Flemish level). This applies to both surface area and quality. The duty of care means that projects and plans, including the decision on extending the lifetime of Doel 4, must be checked to ensure that they do not cause **avoidable "damage"** (see Nature Decree) to nature.

This includes the protection of existing nature and natural elements, regardless of their use.

The duty of care does not mean that new development is not possible, but it does mean that sufficient research must be done to ensure that any damage can be avoided.

In addition to "horizontal" nature policy, the Nature Decree also sets the lines for defining a
area-specific policies.

For **VEN areas,** specific consideration must be given to ensure that no "**unavoidable and irreparable damage"** may occur because of the plan. Within the VEN, a distinction is made between large units of nature (GEN) and large units of nature under development (GENO). In addition, there is also the integral softening and support network IVON that consists of nature softening areas (NVWG) and nature linking areas

(NVBG). Checking off the risk of unavoidable and irreparable damage in a so-called "sharpened nature assessment" should only be done for the areas of the VEN itself.

In addition, the implementation of the European directives in the Nature Decree ensures that for the **special protection areas, i.e.,** habitat and bird directive areas, it must not only be demonstrated that significant negative effects are avoided compared to the current situation, but that the plan may also not interfere with the achievement of the nature objectives set for these areas. This is examined in an **appropriate assessment**.

The **species decree** ensures the protection of specific species. This implies that there should be no damage to these species or their habitat and also that species protection programs (SBP) can be drawn up in which measures are proposed to ensure that the favorable conservation status can be achieved for specific species. Consideration will need to be given to whether the plan may harm protected species or jeopardize the implementation of an SBP.

A final important policy objective can be found in the **Decree Integral Water Policy** that transposes the European Water Framework Directive into Flemish legislation. A large part of the objectives will be tested in the Water discipline, but objectives for **biological quality elements** are also included for the various water bodies. For the biological quality elements relevant to the water bodies in the vicinity of the plan area (mainly the Zeeschelde), it will have to be determined whether the plan has an impact on the achievement of the water quality objectives. However, this aspect will be assessed in the Water discipline.

The various components of the project will be tested against these policy objectives using the questions below:

- To what extent can the project, be expected to avoid damage to nature (cfr. Nature Decree)?
- To what extent can the project be expected to avoid irreparable and unavoidable damage to VEN areas (cf. Nature Decree)?
- To what extent can it be expected that the project could avoid meaningful impacts with respect to NATURA2000 areas (cf. Nature Decree)?
- To what extent can the project be expected not to cause harm to species protected under the Species Decree?
- To what extent can the implementation of the project be expected not to impede the achievement of objectives formulated in species protection programs (cfr. Species Decree)?

1.3.2 Relevant effects and cause-effect relationships

The project may impact the biodiversity discipline in several ways. The final assessment, as indicated above, is based on the policy objectives, the impact analysis is done from the relevant impact groups. The following sections briefly explain which impact groups are relevant and why.

In the biodiversity discipline, most of the expected effects are indirect effects due to changes discussed in the water, noise or air disciplines. If it is decided in these disciplines that only negligible effects are expected, this is not investigated further in the biodiversity discipline.

Many of the effects that may occur are related to discharges into the Scheldt. Given the designation of the Scheldt as a Habitat Directive area, the possible occurrence of effects here is of great importance. Moreover, there are also the objectives for the Scheldt from the Decree Integral Water Policy and the mudflats and salt marshes are also important for birds from the Birds Directive area and as a habitat from the Habitat Directive.

Effects on the Scheldt may occur in the form of a **change in surface water quality**. The elements of the plan that could potentially affect this are the discharge of the various forms of wastewater and the discharge of cooling water. In addition, the capture of cooling water is also important given that it may give rise to **mortality** for co-absorbed fish, shellfish, crustaceans or other invertebrates. If the section on **nuclear effects** shows that an impact is to be expected on the Scheldt, the impact will also be briefly discussed. In that case, a carry-over of effects to higher trophic levels, such as the birds of the Birds Directive area, will also be estimated. A significant impact on water quality, e.g. due to an increase in temperature, could potentially also give rise to **barrier effects** if a large area becomes unsuitable for the organisms present.

In addition to the effects on the Scheldt, the operation of the power plant could potentially also have an impact in terms of **disturbance**. This may involve noise disturbance, light disturbance or disturbance due to the presence of people. Given the strategic level of the EIA, these disturbance effects will be estimated qualitatively.

The plan could theoretically, because of the heating installation, the emergency generators and the traffic itself, also contribute to effects of **acidification and eutrophication from the air**. This is expected to have only a limited impact, certainly in a broader spatial perspective and including the activities taking place in the Waaslandhaven / Port of Antwerp. However, this aspect will be relevant when discussing avoided impacts. It should be noted, however, that the translation of the latter aspect to biodiversity can only be done in a qualitative way, as the location of any additional nitrogen deposition is not known. If the section on **nuclear effects** shows that an impact is to be expected from deposition from the air, the impact of this will also be discussed.

Effects in terms of **direct land take** can in principle occur as the extension of the plants' operation ensures that the space taken up cannot be used for nature development.

No impacts are expected for groundwater (both **groundwater level** and **groundwater quality**) that could impact biodiversity. Therefore, this is not discussed further in this EIA. Finally, no **modification of the hydrology** of the Scheldt is expected either. Indeed, the captured cooling water is almost completely discharged again so that no impact on e.g. the water level is expected.

It is also important to note that the presence of the high-voltage lines is not part of the EIA. The high voltage lines are owned by Elia and changes to the 380 kV network are not desirable in order to avoid weaknesses in the high voltage network. Moreover, the high-voltage lines remain necessary to provide power to the Port of Antwerp.

1.3.3 Delineation of study area

The study area for the biodiversity discipline is determined by the zone over which impacts may occur, supplemented by zones of concern for nature. The distance over which effects can be expected varies greatly among the different impact groups.

As a minimum, the adjacent nature protection zones (see Figure 38) are included in the study area. Specifically, these are parts of the Special Protection Area of the Habitats Directive (SPA-H) "Scheldt and Durme estuary from the Dutch border to Ghent" (BE2300006), the Special Protection Area of the Birds Directive (SPA-V) "Schorren en polders van de Beneden Schelde" (BE2301336) and the Dutch Protection Area Westerschelde & Saeftinghe (NL9802026) which is both SPA-H and SPA-V. Nearby VEN areas lie within this delineation.

Specifically for the avoided impacts, the study area is extended to include all of Belgium and adjacent areas abroad.

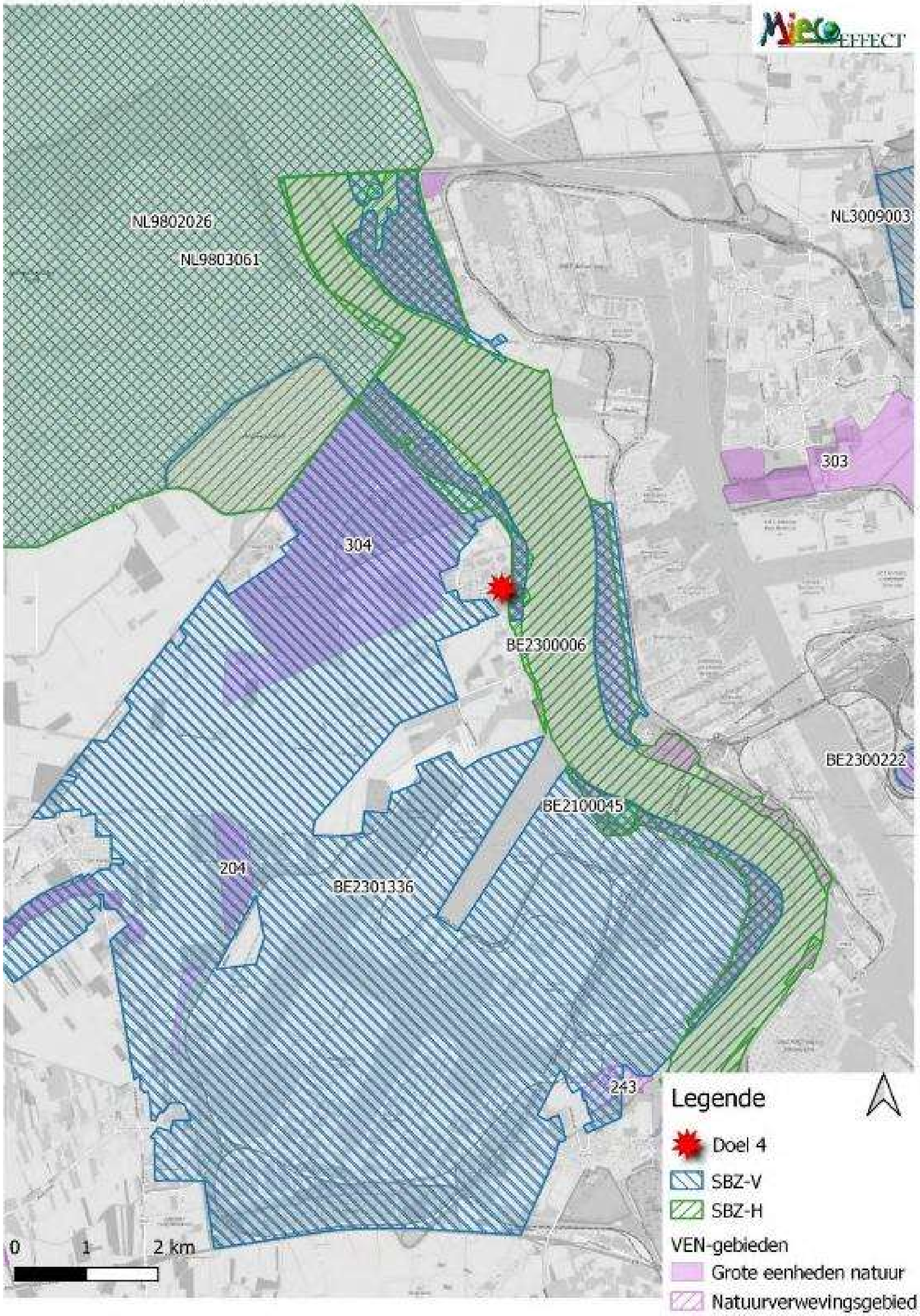

Figure 38: Nature protection zones.

1.3.4 Description of the reference situation

Natura2000 areas

As already described in section 3.3.4, the plan area borders several Special Protection Areas belonging to the Natura 2000 network. The nature objectives established for these areas are therefore an important reference for assessing the effects. Table 22 lists the target species for all these Natura 2000 areas that either overlap with the plan area or are located in the immediate vicinity of the plan area (see Figure 38).

Table 22: Target species for the Natura 2000 sites that overlap with or occur in the immediate vicinity of the plan area. X: species explicitly included as target, (x): species is target for wider area than indicated in heading of column, /: species is not target.

Target species	Salt marshes and polders of the Lower Scheldt	Scheldt and Durme estuary from the Dutch border to Ghent	Westerschelde and Saeftinghe
Birds			
Shelduck	x	x	x
Bluethroat	x	x	x
Hen Harrier	x	/	/
Pied-billed plover	/	/	x
Pied Sandpiper	/	/	x
Marsh harrier	x	x	x
Sanderling	/	/	x
Little Tern	/	/	x
Grebe	/	/	x
Golden plover	x	/	x
Greylag goose	x	/	x
Greenshank	/	/	x
Great tern	/	/	x
Kingfisher	x	x	/
Kestrel	x	/	/
Canoe Sandpiper	/	/	x
Peewit	/	/	x
Little egret	/	/	x
Little swan	x	x	/
Pied Piper	x	x	x
Black-headed Gull	x	x	/
Ferruginous Goose	x	/	x
Gadwall	x	x	x
Quack	/	x	/

Target species	Salt marshes and polders of the Lower Scheldt	Scheldt and Durme estuary from the Dutch border to Ghent	Westerschelde and Saeftinghe
Quail King	/	x	/
Spooner	x	x	x
Middle goosander	/	/	x
Arrowhead	x	x	x
Spotted Crake	x	x	/
Purple Heron	/	x	/
Bittern	x	x	/
Black-tailed godwit	/	/	x
Oystercatcher	/	/	x
Peregrine falcon	/	/	x
Shoveler duck	/	x	x
Wigeon	x	/	x
Stonehenge	/	/	x
Steltkluut	x	/	/
Beach plover	x	/	x
Table Duck	/	x	/
Tureluur	/	/	x
Common tern	x	/	x
Water Warbler	x	x	/
Wild duck	/	/	x
Teal	x	x	x
Little Bittern	/	x	/
Curlew	/	/	x
Bald Eagle	/	/	x
Silver plover	/	/	x
Black rider	/	/	x
Black-headed Gull	x	/	x
Mammals			
Frankenstein	/	x	/
Common dwarf bat	/	x	/
Gated bat	/	x	/
Little dwarf bat	/	x	/
Latent flyer	/	x	/
Lake bat	/	x	/

Target species	**Salt marshes and polders of the Lower Scheldt**	**Scheldt and Durme estuary from the Dutch border to Ghent**	**Westerschelde and Saeftinghe**
Rosy bat	/	x	/
Shaggy dwarf bat	/	x	/
Water bat	/	x	/
Porpoise	/	/	x
Gray seal	/	/	x
Common seal	/	/	x
Beaver	/	x	/
Mollusks			
Closer basket snail	/	/	x
Fish			
Sea lamprey	/	/	x
River lamprey	/	x	x
Fint	/	x	x
Bittern	/	x	/
Amphibians			
Pool frog	/	x	/
Crested newt	/	x	/
Insects			
Spotted whitethroat dragonfly	/	x	/
Vate plants			
Green knotgrass	/	x	x

In addition to species, nature targets for habitat types have also been established. The SPA-H Scheldt and Durme estuary from the Dutch border to Ghent is extensive and not all target habitats are relevant for this EIA. Only the habitats occurring in the section near the NPPs are therefore discussed.

Occurring habitat types are divided into two major landscape types: the estuary and terrestrial wetlands. The goals formulated for those habitat types are twofold:

- On the one hand, these objectives are in function of the conservation objectives of the SPA-H 'BE 2300006 Scheldt and Durme estuary from the Dutch border to Ghent'. In these circumstances, these are rather conservation measures outside the SPA-H that aim to bring the SPA-H to a favorable conservation status.
- On the other hand, those "goals" are required to bring the SPA-V in question to a favorable conservation status because they are important (as habitat) for the bird species of the habitats Nature meadow fresh, Nature meadow saline, Grazed salt marsh, Slikken with islands and Surrogate coast.

Following habitat types occur within estuaries of the Belgian part of the Scheldt estuary:

- Habitat type 1130: estuaries;
- Habitat type 1320: Salt marshes with mudflat vegetation (Spartinion maritimae);

- Habitat type 1330: Atlantic salt marshes (Glauco-Puccinellietalia maritimae).

Next habitat type within terrestrial wetlands occurs:

- Habitat type 1330: Atlantic salt marshes (*Glauco-Puccinellietalia maritimae*), inland salt marsh vegetation subtype.

The entire width of the Scheldt near the plan area is also designated as a provisional search zone for habitat type 1130: estuaries. A search zone is a zone that is safeguarded with a view to the development of additional habitat in case there are still open nature targets.

In the SPA 'Westerschelde and Saeftinghe', the following habitat types are targeted:

- Habitat type 1110B - Permanently flooded sandbanks, North Sea coastal zone subtype
- Habitat type 1130 - Estuaries
- Habitat type 1140B - Mudflats and sandflats.
- Habitat type 1310A - Saline pioneer vegetation, salicornia subtype
- Habitat type 1310B - Saline pioneer vegetation, marine fatwort subtype
- Habitat type 1320 - Siltgrass beds
- Habitat type 1330A - Salt marshes and saline grasslands, outer dike subtype
- Habitat type 1330B - Salt marshes and saline grasslands, inland dike subtype
- Habitat type 2110 - Embryonic dunes
- Habitat type 2120 - White dunes
- Habitat type 2130A - Gray dunes, calcareous subtype
- Habitat type 2160 - Sea buckthorn thickets.
- Habitat type 2190B - Humid dune valleys, calcareous subtype

Future nature development Port area

The Flemish Government has recently approved a decree setting the conservation objectives and priorities for the Special Protection Area "BE 2301336 Schorren en polders van de Beneden-Schelde". The conservation objectives it sets have already been included in the description of the previous paragraph. The decision concerns a modification of an earlier decision that had to be approved because of urgency in relation to the required progress of the complex project Extra Container Capacity Antwerp. This new decision also defines the areas that currently have a necessary role to play in achieving the conservation objectives. Some of these areas have already been established in the past. An overview of these areas is shown in Figure 39. Some of the areas are explicitly foreseen as "temporary nature compensation areas" and will in principle disappear and need to be replaced in case certain port projects are implemented.

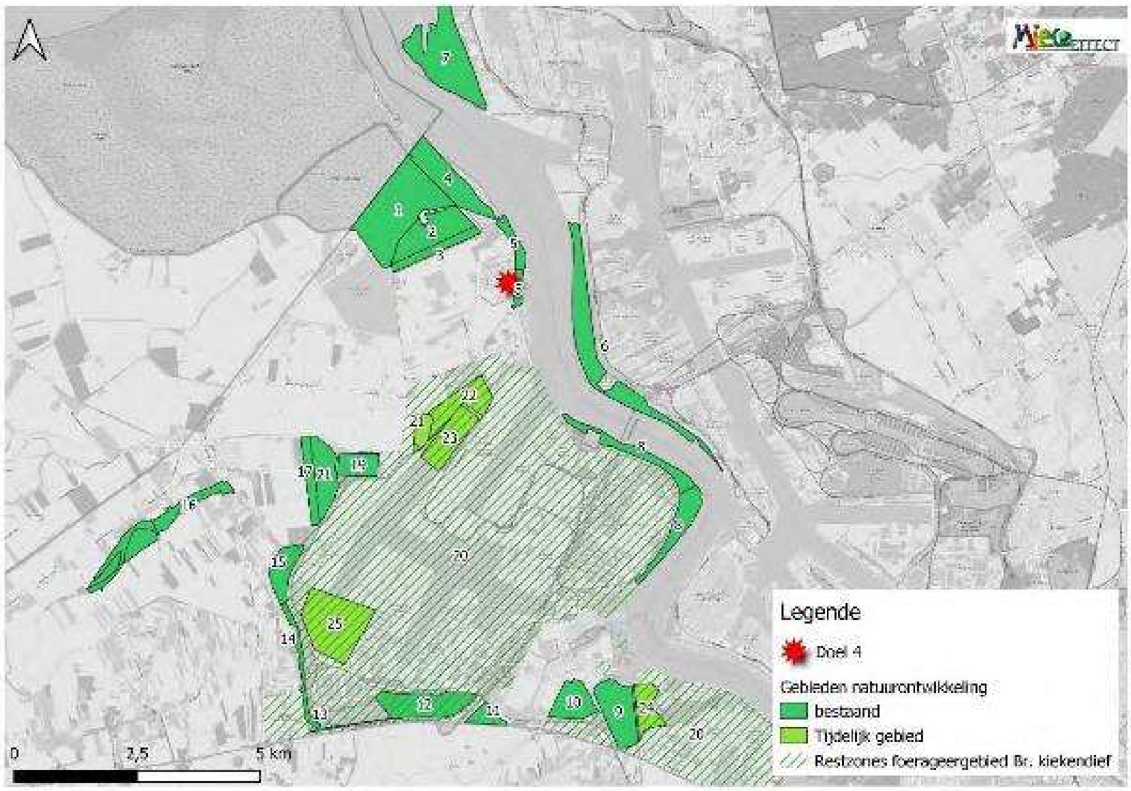

Figure 39: Overview of existing areas of nature development (permanent and temporary).

Table 23: Numbering existing areas of natural development.

No.	Area	No.	Area
1	Prosperpolder North	14	Spanish fortress
2	Target Polder North	15	Drijdijck
3	Brackish Creek	16	Big Gully
4	Schor Ouden goal	17	Freshwater Creek
5	Estuarine nature	18	Wells Meadow
6	Galgenschoor	19	Wells west
7	Large external brace	20	Residual land foraging marsh harrier
8	Ketenissenschor	21	C59
9	Big Rietveld	22	Upgraded MIDAs
10	Rietveld Kallo	23	Dampened target dock
11	R2 triangle	24	Plain of Zwijndrecht
12	Haasop (only permanent part shown)	25	Verrebroek lakes
13	Waterways		

For some of the habitats to be realized, however, there are still outstanding conservation objectives for which additional areas must be created. For example, up to 200 ha of additional areas must be created for the species of the group 'reed and water' in case it would appear that the objectives for this species group are not met with the other areas. In that case, the areas Nieuw Arenbergpolder phase II and Prosperpolder south phase II will be developed. Also for the species of the groups 'Nature meadow fresh/salt' and 'Grazed salt marsh' another 250 ha of additional habitat is needed. For this purpose, (parts of) the areas Prosperpolder Noord and Doelpolder midden will be developed.

In addition to the areas that will be required for the realization of the conservation objectives, it should therefore also be taken into account that areas will still have to be designated and landscaped in case port projects would result in the loss of existing natural values.

As mentioned above, the disappearance of certain temporary nature compensation areas will necessarily lead to a new need for the realization of nature offsets elsewhere. The first case in point is the Extra Container Capacity Antwerp (ECA) project.

There has also recently been an analysis whereby it was mapped out which parts of the port area still have a certain importance with a view to achieving nature objectives (Goovaerts & Indeherberg, 2020). In case of certain port expansion projects, this will necessarily lead to the implementation of appropriate nature compensations.

For most of these projects, however, it is not yet fully clear where these compensations will occur. What is already certain is that the temporary areas Gedempt Doeldok, C59, Opgespoten MIDAs and Vlakte van Zwijndrecht will disappear and that the natural values that occur here for the species of Surrogate Coast will be compensated at Prosperpolder Zuid.

An overview of all currently known new nature areas that will in all likelihood need to be developed, be it to achieve conservation objectives or in the context of nature offsets to be realized, is shown in Figure 40.

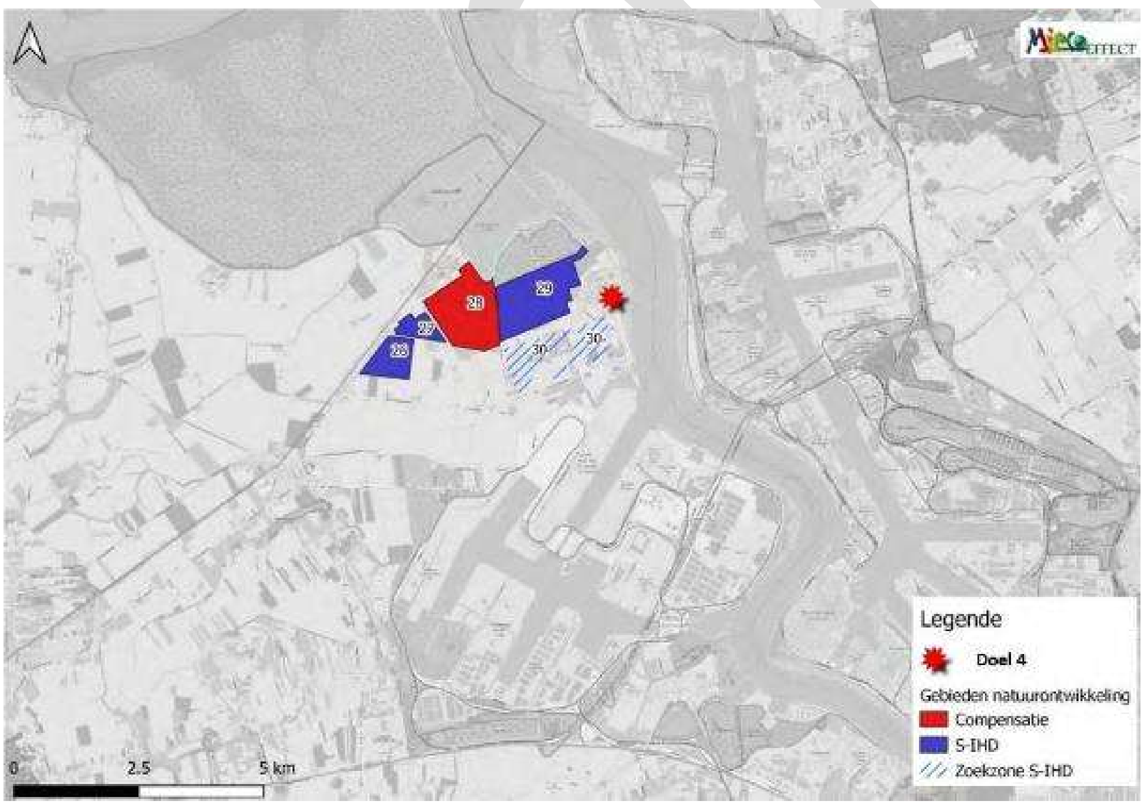

Figure 40: Future areas of nature development.

Table 24: Numbering future areas of nature development.

No.	Area	Reason for development
26	New Arenbergpolder phase II	S-IHD Reed and water
27	Prosperpolder south phase II	S-IHD Reed and water
28	Prosperpolder south phase I	Compensation disappearance of Gedempt Doeldok, MIDAs + C59 and Vlakte van Zwijndrecht for ECA project
29	Target Polder Middle	S-IHD Nature meadow fresh/salt and Grazed salt marsh
30	Target Polder South	Search zone S-IHD foraging area marsh harrier, possibly also compensation foraging area marsh harrier

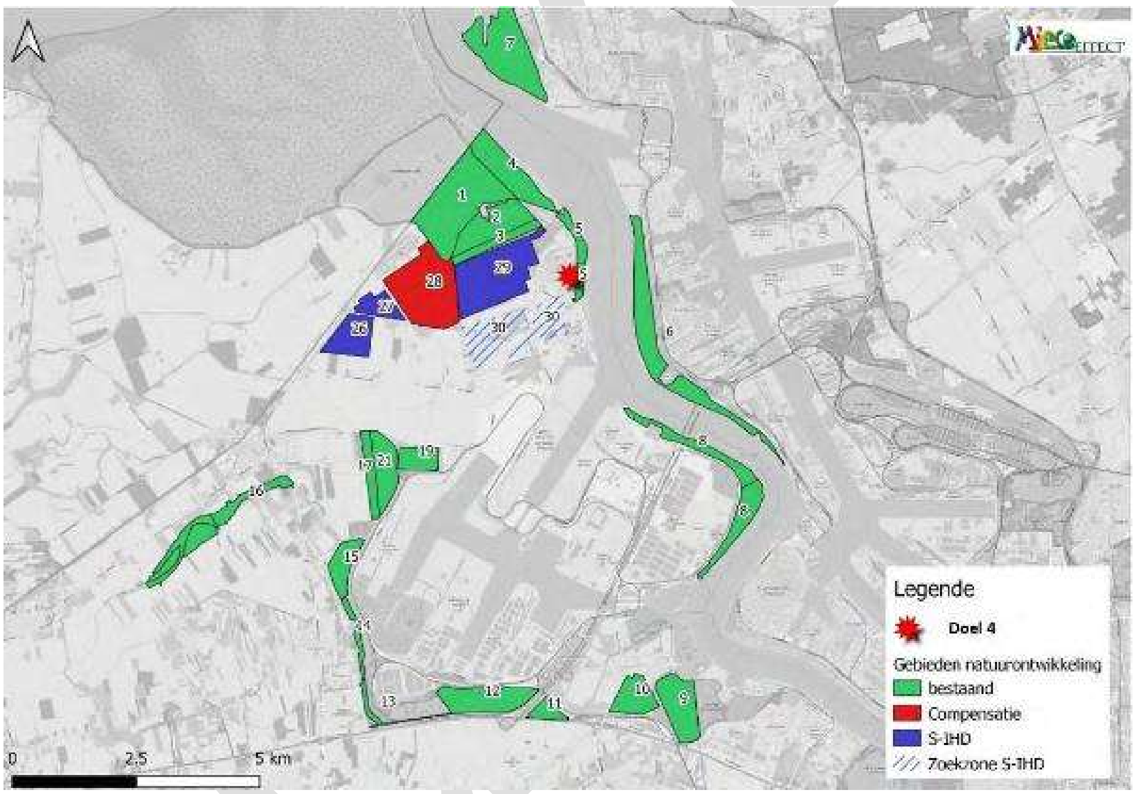

Figure 41: Final picture of nature development as far as known and based on not yet further clarified nature offsets to be realized.

VEN Areas

Parts of the SPA are also additionally designated as a protection zone at the Flemish level and are thus part of the VEN (see also Figure 38). The most relevant VEN areas in the vicinity of the plan area are 'the Wase Scheldt polders' and 'the mudflats and salt marshes along the Scheldt'. Both areas are briefly described below.

The Wase Scheldt polders (Code: 204)

In this area we find different types of creeks, dikes or collars, wheels and an embanked area. The structure-defining elements are two creeks (remnants of an old creek system of marine origin), some wheels (sometimes with formation of floating rills during land accretion, such as the Panneweel), dikes (constructed during reclamation), collars (when restoring a dike after a breach, constructed around the formed wheel), creek ridges, wet lower creek valley grasslands and the complex of the Groot Rietveld.

The two creeks are the fresh creek complex of Saleghem (Grote Geule) and the slightly brackish creek "De Grote Geule" near Kieldrecht. Both are connected via the Kieldrecht waterway. Special plant species in this creek complex are marsh fern, galigane, dotted and dwarf sedge.

The Groot Rietveld is located in the Melselepolder, a raised break-in polder. Here we find a large reed field with pools, grassy and marshy areas. This vegetation and the different transitions (in moisture and salinity) provide a suitable habitat for a large number of rare plants and birds.

We find species of banks and marshes and plants of saline environments such as sea aster and saline rush. The area also provides a link between the mudflats, salt marshes and wet meadows along the Scheldt and the natural cores in the Zand region. Notable breeding bird species include avocet, marsh harrier, bittern, reed bunting, moustache, reed warbler, bearded reedling and bluethroat.

It is an important area for migratory or wintering species such as golden plover, ruff, colgan, gray goose, shelduck and gadwall.

The mudflats and salt marshes along the Scheldt (Code: 304)

The Scheldt waterway and the longitudinal mud flats and salt marshes, with the very dynamic tidal action, have a very high ecological value. The high natural productivity of the ecosystem provides many species, often in large numbers. Important is the salt-bracket-sweet transition in the tidal zone. The occurrence of freshwater salt marshes is unique in Flanders. They are also extremely rare elsewhere in Europe.

Some larger natural areas (Verdronken land van Saeftinghe, Groot Buitenschoor, Galgenschoor) form the nuclei of the natural system. The intermediate - rather narrow - riparian zones form very important connections. Safety (water storage) and transport are compatible with the main function of nature. Recreation is also compatible.

Species worth mentioning are avocet, small mud creeper, river lamprey, crested newt, spindle otter, fragrant agrimony, dwarf flower, bee orchid, round wintergreen, small and large mirrorbell. It is an important area for stopover and wintering species such as golden plover, ruff, reed goose, white-fronted goose, greylag goose, shelduck, gadwall and shoveler.

SBP

The Species Decree provides for the possibility of drawing up a species protection program (SBP). Such a program is drawn up in consultation with the target groups concerned and includes a number of measures aimed at ensuring that a species (or several species) are in a favorable state within Flanders.

A species protection program can be drawn up both for European species to be protected and for other species important to Flanders. Based on a number of criteria, the species for which a species protection program needs to be drawn up are prioritized. Among other things, the red list status and surface needs of species are taken into account, but also the need for ecological connections and whether other species can benefit from the protection measures.

With an MB of May 23, 2014, the "Species Protection Program Antwerp Port" was adopted, which focuses on 90 protected species in the port environment. For a number of 'umbrella species', an individual species protection plan (ISBP) has been worked out in it, which includes a number of provisions and actions. Currently, this SBP is being evaluated in function of a possible sequel in the period 2019-2024. Perhaps better coordination with the other RBMPs at the Flemish level will be sought and more account will also be taken of the conservation objectives for the SPAs at the Flemish level. The objectives for the different animal and plant species will have to be adapted to them even more. However, since this process is still ongoing, the only thing to hold on to is the SBP as it is in force today.

The species protection program for the Port of Antwerp aims to actively protect animal and plant species found in the port area so that their populations are sustainably maintained.

The various conservation measures are hung up on 14 so-called umbrella species. These are chosen so that measures taken for these species are also beneficial for other species, the so-called hitchhiking species.

Most of the SBP are of little relevance to this EIA or the locations of interest in the SBP are already part of a protection zone so the impact will be investigated anyway. Worthy of note is the fact that the cooling tower has had a nesting box for peregrine falcons on it since 1996 in which peregrine falcons regularly breed.

It should be noted that a new version of the Species Protection Program Antwerp Port is currently being approved as a follow-up to the first version of this SBP.

Biological quality elements

The European Water Framework Directive (WFD), translated in Flanders into the Decree Integral Water Policy (DIW), stipulates that surface waters must not only be assessed on the basis of their chemical quality, but also on the basis of their biological quality using so-called biological quality elements. The assessment must be expressed for each (biological) quality element in the form of an Ecological Quality Coefficient (EQC). This can take a value between 0 and 1, where 1 represents very good ecological status and 0 represents very poor ecological status.

The water body Zeeschelde IV (VL17_43), where the nuclear power plant takes in and discharges its cooling water and also discharges wastewater, is a heavily modified water body of type transitional water O1brak (brackish macrotidal lowland estuary). The biological quality elements assessed are macrophytes, macroinvertebrates and fish. The quality elements phytoplankton and phytobenthos are not assessed here.

At the last assessment, in 2018 the water body scored "inadequate" for macrophytes, "moderate" for macroinvertebrates and "good" for fish.

Besides the biological quality elements, the yardstick for hydromorphology is also relevant for the biodiversity discipline. Indeed, the EKC hydromorphology is calculated for the water body Zeeschelde IV on the basis of the so-called physiotope surfaces of mud, salt marsh and shallow water. At the last evaluation, the score for this yardstick was 'insufficient'.

MONEOS

In the Flemish-Dutch Scheldt Commission (VNSC), Flanders and the Netherlands work together for a sustainable and vital Scheldt estuary. Within the research and methodology working group of the VNSC, an agreement was made on a long-term monitoring and research program to support cross-border cooperation in policy and management in the Scheldt estuary: MONEOS. This monitoring program was designed to meet the objectives of various policy frameworks on the one hand, and on the other hand to provide insight into the system functioning of the Scheldt estuary and the effects of interventions/measures in the system. The program builds on existing monitoring activities and strives for integration and coordination across borders.

One of the monitoring points of the MONEOS program (VMM monitoring point 154100) is located just downstream of the nuclear power plant. At this location, both general water quality and macroinvertebrates are monitored. Water bottom quality is also evaluated using the TRIADE methodology. That method integrates the results of chemical, biological and ecotoxicological analyses.

The composition of the macroinvertebrate community in the sludge is very different from that of the other monitoring sites in the MONEOS program. Species not found further upstream are found in this zone and several species reach their highest densities and biomass. The main explanation for this is salinity. Indeed, the monitoring point near Doel is the only monitoring point in the mesohaline zone which allows more species to occur than in the oligohaline zone which is generally rather species-poor (Van de Meutter et al, 2020).

In particular, the TRIADE monitoring shows that the quality of the water bottom has greatly improved since 2007 (Table 25). From very poor quality (score 4), the quality is now poor (score 3) to moderate (score 2). At the last measurement, a good score (1) was achieved.

Table 25: Results of the TRIADE monitoring at VMM monitoring point 154100.

Bye	**Monster Triad Final Class MOW**	Sample Triad Physico Chemistry Final Grade MOW	Sample Triad Ecotoxicology Final Grade MOW	Sample Triad Biology Final Class MOW
01/08/2001	4	3	3	2
14/04/2003	4	3	4	4
18/04/2007	3	2	2	4
28/04/2010	2	2	2	1
08/05/2014	3	3	1	3
07/12/2015				
23/01/2017	2	3	1	1
13/02/2019		1	1	

Vegetations and habitats.

The biological valuation map (2020 version) shows the valuable and less valuable vegetations in the immediate vicinity of the plan area (Figure 42). The valuable vegetations are mainly located at the level of the mud and salt marsh areas of the Scheldt and on the dikes.

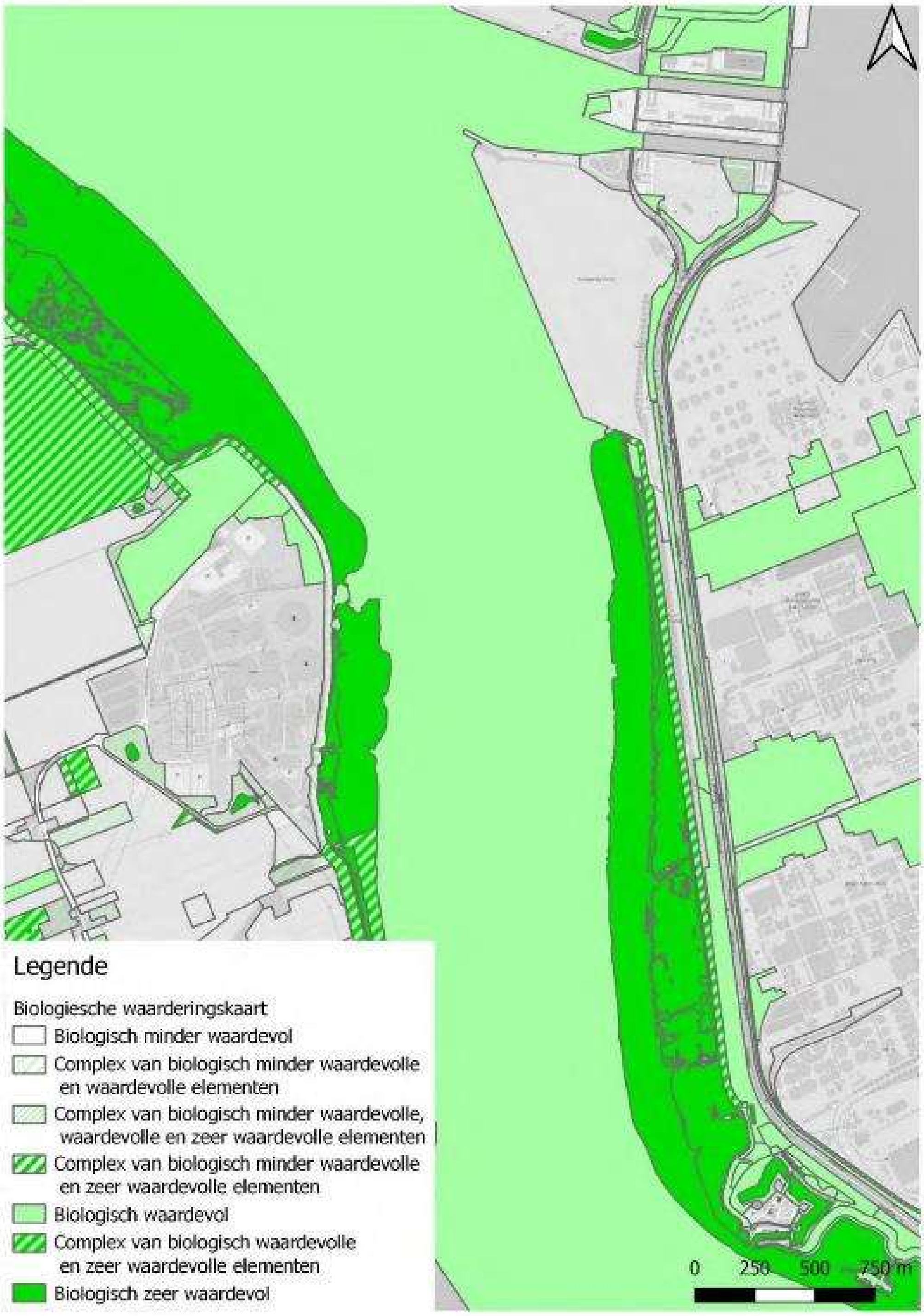

Figure 42: Biological valuation map (2020 version) in the immediate vicinity of the project area.

Many of these valuable vegetations are also designated as European habitat types (Figure 43). The channel of the Scheldt is designated as habitat type 1130 (Estuaries). The salt marsh vegetations are designated as 3130_da (Atlantic salt marshes), the valuable grasslands on the dikes are designated as habitat type 6510 (low-lying sparse hay meadow). The areas close to the site colored on the habitat map as 'partial habitat' concern mainly vegetations of the regionally important biotope 'rbbmr' (reed marsh).

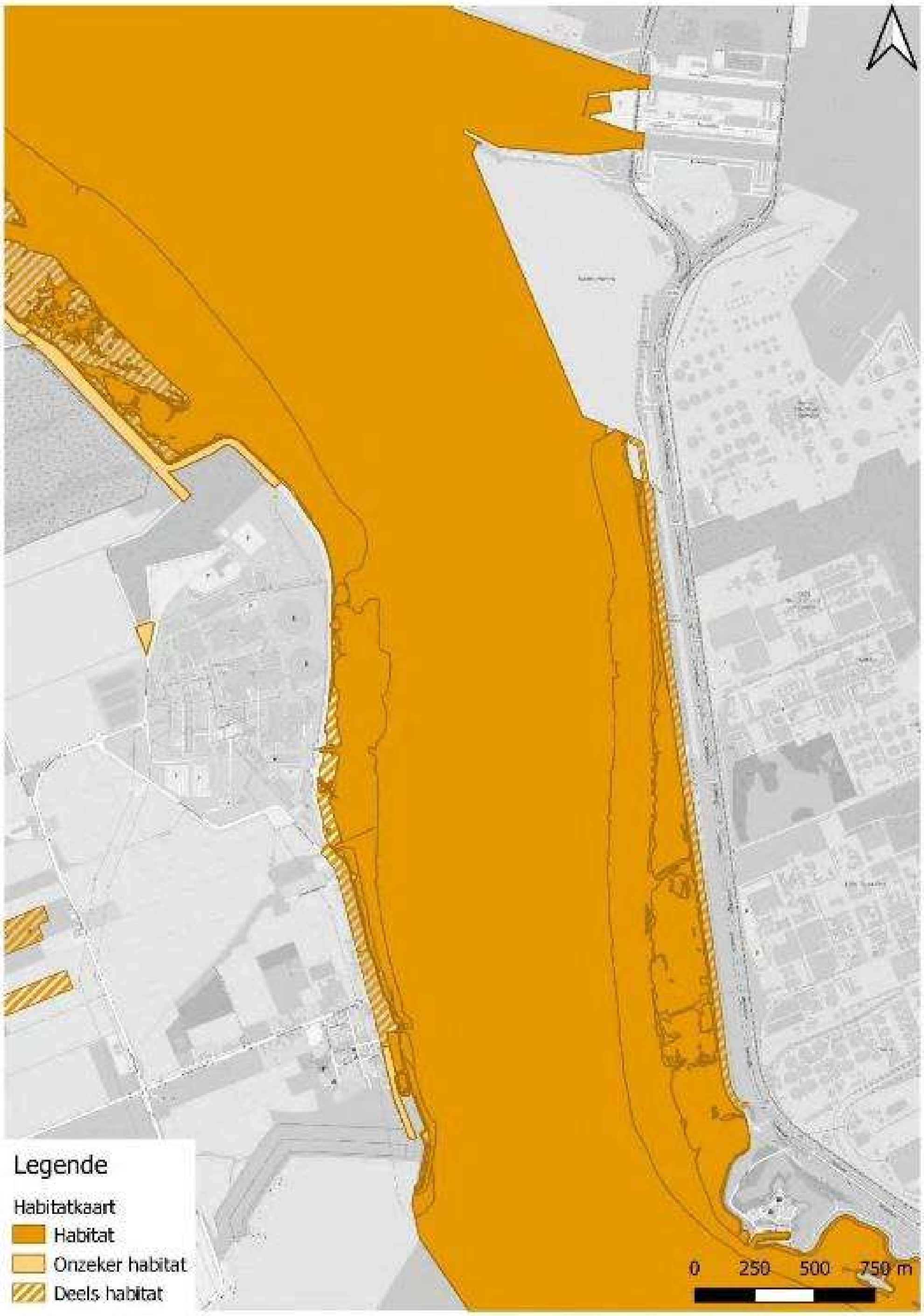

Figure 43: Habitat map in the immediate vicinity of the project area.

In addition to current habitats, preliminary search zones are still of interest. According to the Nature Decree, art. 2 (definitions), 70° is a search zone:

"*A zone indicating, for each European species and habitat to be protected, the perimeter which is safeguarded in order to optimally place the conservation objectives for the special area of conservation in question. The extent of the search zone is determined by the area required for the* *realization of the outstanding balance of the target for the relevant European habitat or European species to be protected.* "

A conservation objective is only "placed" when establishment and management of the plot concerned have been agreed in a nature management plan or an equivalent contractual agreement between the Flemish Government and the manager/owner. As long as part of the target has not been included, the existence of a search zone remains applicable in the area concerned for a habitat where the habitat type has been set as a target.

For the area surrounding the plan area, the entire Scheldt (including salt marshes) is colored as a search zone for habitat type 1130 (Estuaries).

1.3.5 Description of effects

Modification of surface water quality

The operation of nuclear power plants can impact organisms occurring in the Scheldt in different ways. A distinction is made between sanitary wastewater/heath water, industrial wastewater and cooling water. All these discharges are discussed in detail in the project EIA (Arcadis, 2021) and their impact on water quality is also explained in this EIA in the Water discipline.

For most parameters the discharge standard is met. However, for the parameters nitrite and AOX (adsorbable organic halogen compounds), exceedances of the discharge standard were measured which cannot be easily explained by, for example, measurement errors or one-time outliers. When looking at the entire water body, there appears to be no exceedances of the environmental quality standards. Regarding the thermal impact of the cooling water, although the discharge standards were met, the impact on the Scheldt does appear to result locally in the environmental quality standards being exceeded. The main impact of the discharges is anyway limited to the zone within the breakwater.

It should be noted, however, that there is only one discharge point for all four nuclear power plants. This also means that no strict distinction can be made between the discharges from Doel 4 and those from the other plants still in operation at the time of the measurements. The contribution of Doel 4 to the total discharges is estimated at 30% based on the environmental reports.

<u>Eutrophication</u>

The discharge standards for nitrite were not met in 2013-2014 and the values in the 2015-2019 period are similar. However, the contribution to the environmental quality standard for the entire water body is small. However, there is an exceedance for the nutrient parameters nitrate + nitrite + ammonium and orthophosphate for the entire water body. Also for this parameter the contribution of the NPs is on average very small.

However, not only average values are important for these parameters; peak loads can also have a significant impact. Part of the explanation for the higher discharge can be found in a sub-optimal operation of the water treatment plant where too much water enters, causing frequent overflows. Peak load can therefore be expected.

In principle, increased nutrient loading locally, at the level of the zone within the breakwater, may therefore have an impact. At higher nutrient levels, shifts within species communities may occur because fast-growing species are favored. However, this is not clear from, for example, the monitoring results of the MONEOS program where the zone near the nuclear power plants is just very species-rich. However, as indicated above, the reason for this species richness is rather to be found in the salinity level, which is more favorable in this zone than for other parts of the Scheldt.

Moreover, until not so long ago, the Scheldt was very heavily polluted, due in part to the lack of wastewater treatment for Brussels' wastewater. Thus, the water quality is still improving and there is no good reference of the species richness that could be achieved with good water quality (oral communication F. Van de Meutter, INBO). In addition, many other factors have an impact on populations such as the unfavorable hydromorphological condition of the Scheldt.

Due to the complexity of factors impacting populations within the breakwater, it is impossible to know whether the discharges have a significant local impact here. However, a direct toxic impact from elevated nitrite concentrations can be ruled out. For the entire body of water, little impact from the discharges is expected.

<u>AOX</u>

A similar analysis can be made for AOX concentrations. The increased AOX concentrations in the discharged water are a consequence of products added to the cooling water to prevent the growth of organisms in the pipes (bio-fouling). Again, the contribution to the environmental quality standard for the entire body of water is negligible, but there could theoretically be an impact at the level of the zone within the breakwater.

However, given that the TRIADE assessment of the water bottoms downstream the discharge point shows no impact, significant ecotoxicological effects can be excluded. However, even here it is difficult to know if there is no negative impact at all because water quality is still improving and there is no reference to determine true good status.

<u>Temperature</u>

Changes in thermal conditions can impact the ecosystem in several ways. One direct consequence can be mortality due to lethal temperatures. For sensitive species such as sea trout and smelt, the temperature at which mortality occurs is 26-27 °C and 26-29 °C, respectively (Kerkum et al., 2004). Above 33-34 °C, several species of macroinvertebrates (flea lobsters, woodlice), zooplankton, phytoplankton and diatoms also become problematic (Kerkum et al., 2004). Such conditions occur mainly locally. At the regional level, temperature increases also have effects on ecology by causing shifts in the ecosystem: the life cycles of organisms are disrupted, creating a "mismatch" in the timing of life stages. At temperatures above 20 °C, shifts in phytobenthos life communities can already be observed. For a number of fish species (including smelt and pos) a water temperature of <10 °C is necessary during the spawning period (winter/spring). If this temperature is not reached, reproduction stagnates.

Another effect, of both local and regional importance, is the occurrence of exotic species that survive the winter in the warmer parts (especially locally) and then affect the natural life community in the summer (also regionally). Characteristic macroinvertebrate and fish species may be displaced in the process. Finally, less oxygen can dissolve in warmer water, causing faster shortages and the disappearance of critical species (Evers, 2007).

The cooling water plume study (see discipline Water) showed that at a short distance from the discharge point (max. 1050 m), the average temperature of the Scheldt water can increase by more than 3°C. This effect is only observed within the breakwater. Temperature increases between 1 and 3 °C appear to occur at low tide and at the turn of low tide up to a maximum distance of about 1,300 m from the discharge point, the area still within the breakwater. With rising water, a temperature rise of between 1 and 3 °C occurs outside the breakwater to a maximum of 500 m from the discharge point in an easterly direction and a maximum of up to 800 m upstream of the discharge point in a southerly direction. The extent of the heat plume is greatest at the turn of low tide. The zone bounded by a temperature higher than 25 °C is located entirely within the breakwater. It should be emphasized here that no distinction can be made between cooling water from Doel 4 and from the other three nuclear power plants, all of which were still active at the time.

Measurements in the cooling water plume show that there is no oxygen depletion of the Scheldt water as a result of the discharge of hot cooling water, rather a slight enrichment (when the cooling water flows through the cooling process, the water is strongly aerated).

For fish, research was conducted in 2012 and in 2013 by INBO (Breine & Van Thuyne, 2012 and 2013). They examined the fish stock inside the breakwater and outside it. The study showed no difference in terms of the presence of exotics. The major difference between the two areas was that more fish were present within the breakwater. Some species use the heated area within the breakwater as a rearing area.

The survey did reveal an increased abundance of heat-loving native species (bass and sole) within the breakwater. In addition to fish, shrimp and crabs such as the Japanese sturgeon shrimp, sturgeon shrimp, gray shrimp and Chinese mitten crab were also caught. These mainly keep themselves within the breakwater.

Impacts on populations of macroinvertebrates, phytobenthos and phytoplankton were not investigated. Local shifts can be expected to occur within these populations, favoring less sensitive or heat-loving species over other, possibly more typical species. However, most of these effects will occur only locally near the breakwater and will not affect the rest of the river system. Moreover, this zone of the Scheldt, with its varying salinity levels, is very species-poor. Indeed, there are few species that can thrive in those specific conditions. Therefore, the likelihood of significant shifts in species composition is more limited here than in other systems.

However, in their opinion on possible monitoring research near the cooling water plume, Van den Bergh et al. (2012) indicate that for macroinvertebrates, there would be indications that more exotic species occur in the vicinity of the nuclear power plant. Some species were first discovered near the nuclear power plant, others occur only there within the Sea-Scheldt, while some have a wider distribution. Based on these observations, they argue that the presence of these species suggests that thermal pollution may be a local breeding ground for exotic species. Here there is always a risk that species will develop a more invasive character (e.g., through cold adaptation) and spread further from here. Since many species possess planktonic larval stages, this spread can be very rapid and far-reaching. In other overviews of the macroinvertebrate community in the Scheldt (Speybroeck et al., 2014) or of the occurrence of exotic species in general (Adriaens et al., 2020), however, the presence of exotic species is not linked to the presence of the NPP, but to the discharge of ballast water from ships in the harbor and the presence of artificial hard bank substrates.

Given that in the future the discharge will be limited to only the cooling water of Doel 4 and that this comprises only 30% of the former discharge flow, it can be expected that the future impact will in any case be much smaller than it was during the measurement campaigns. Given that the impact of the thermal discharge was previously limited to the zone within the breakwater and that there were no clear effects on the occurrence of exotic species, it is not expected that this will be the case because of the extended operation of Doel 4.

<u>Indirect effects on birds</u>

The impact of the discharges on water quality can potentially also cause indirect effects for the birds of the SPA-V. Indeed, many of these species forage at the level of the mudflats of the Scheldt. A significant impact on macroinvertebrates or fish at the level of the Scheldt or the mud plate behind the breakwater could therefore have consequences for the availability of food for birds.

The dispersion of discharge water in the Scheldt is difficult to model. However, a picture of the expected dispersion can be obtained from the monitoring of the thermal impact. This monitoring shows that the impact is largely limited to the zone within the breakwater. More importantly, however, it is only at low tide that the plume extends downstream of the discharge point. At that time, the mudflats are dry and there is little impact. At the tide and at rising tide, the plume is upstream of the discharge point and thus there is likewise little impact to the mudflat which is submerged at that time. For this reason, the impact of discharges on organisms in the mudflat can therefore be expected to be rather limited.

For fish, which can be important as food for certain (piscivorous) bird species, there would potentially be a more significant impact though. However, monitoring results from INBO indicate that fish are just more abundant inside the breakwater than outside it.

In summary, the impact of discharges on the availability to birds of SPA- V can be expected to be limited.

Barrier effect

A study by Aqua Terra (Kikkert & Beers, 2006) found that stream-loving fish are hindered by water temperature during migration if temperatures exceed 23° C. However, fish appear to be well able to detect and avoid the elevated temperatures.

The study of the cooling water plume (see Water discipline) shows that it is limited to the zone within the breakwater. Thus, a significant part of the river width is not affected, so no barrier is created for migratory fish species.

Also for other effects and species groups, the fact that only part of the width of the Scheldt is affected provides sufficient guarantees that no hard barriers to migration will be created.

Therefore, the plan does not create any barrier effects.

Mortality

The nuclear power plant draws cooling water from the Scheldt via a water capture point that is spatially separated into two separate parts: one for the cooling of the Doel 1 and Doel 2 units and another for the Doel 3 and Doel 4 units. The water is always first passed through a sieve to filter out the objects present in it to prevent obstruction of the pipes. However, this is done differently for the two capture points.

For the capture point for the cooling water of Doel 1 and 2, mechanical purification takes place outside the dike, at the level of the water trap itself, by means of grids on the inlet itself. In this way, fish and crustaceans do not get the chance to enter the cooling water circuit. No mortality of fish or crustaceans is therefore observed at this capture point.

This used to be the case for Doel 3 and 4. For these power plants, a cooling water capture system was opted for, whereby the water was first led gravitationally from the Scheldt to a collection pit on the site itself. In order to study the impact of the plant on fish stocks, samples of fish and crustaceans sucked in by the water pumping station have been taken regularly since 1991. Annually, an average of 100 million fish and shrimp (100 tons) ended up on the plant's belt screens (Maes, 2001[57]). It was mainly juvenile fish and crustaceans that were sucked in. All these fish and shrimp that ended up on the grids were collected in a waste container and incinerated afterwards.

However, many species survive passage through the cooling water system. Various survival tests have shown that the life community of fish and crustaceans can be divided according to their tolerance for passage through the cooling water system. Herring-like fish (sprat, herring, anchovies) are very sensitive fish species that never survive ingestion. They are primitive fish species that contract infections after any kind of contact to which they succumb within three hours. Carpids and smelt also usually die after ingestion. A few fish species, such as the three goby species found in Doel, survive the passage but die in the days following the ingestion by the water trap because of stress or injury. All shrimp, crabs and fish such as eel, stickleback, flatfish and river lamprey almost always survive the intake through the pumping station. Unlike pelagic fish species, the latter are used to contact with the bottom. Therefore, they are also more resistant to contact with the grids and filters.

In order to reduce the number of victims, measures were taken in 1997 aimed at both preventing the intake of sensitive fish species and reintroducing the tolerant fish species into the Scheldt after the intake through the water trap. To achieve these objectives, two systems have recently been used. On the one hand, fish are deterred from the intake point. On the other hand, fish that do end up in the cooling water system are transported to the Scheldt instead of a container.

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[57] Maes, J., 2001. Keeping fish out of cooling water from the Doel nuclear power plant. De levende Natuur 102 (2): 96-97 (2001).

A comparative study (Maes et al., 2004[58]) showed that the deterrent system at the intake point caused an average of about 60% reduction in fish entering the system. Here there were large differences between fish species. Since the system works with acoustic deterrence, it works particularly well for species with better hearing, such as species with a swim bladder. In herring and sprat, for example, the drop was 94.7% and 87.9%, respectively. In contrast, ten-spined and three-spined sticklebacks, river lamprey and dab were hardly deterred by the system. However, as described above, the latter species are species that are less harmed by a passage through the cooling water system. These species are diverted to the Scheldt with a fish-friendly system that can guide the fish to the water quickly and without collateral damage. In this way, the overall impact of the plant on fish and shrimp populations in the Zeeschelde was reduced by 90% (Maes, 2001).
Moreover, given the closure of Doel 3, the required volume of cooling water, and thus the amount of potentially attracted fish and crustaceans, will be halved. It can be concluded that because of the measures applied, the longer operation of Doel 4 will not give rise to a relevant increase in the mortality of fish and crustaceans in the Scheldt. The effect is limited.

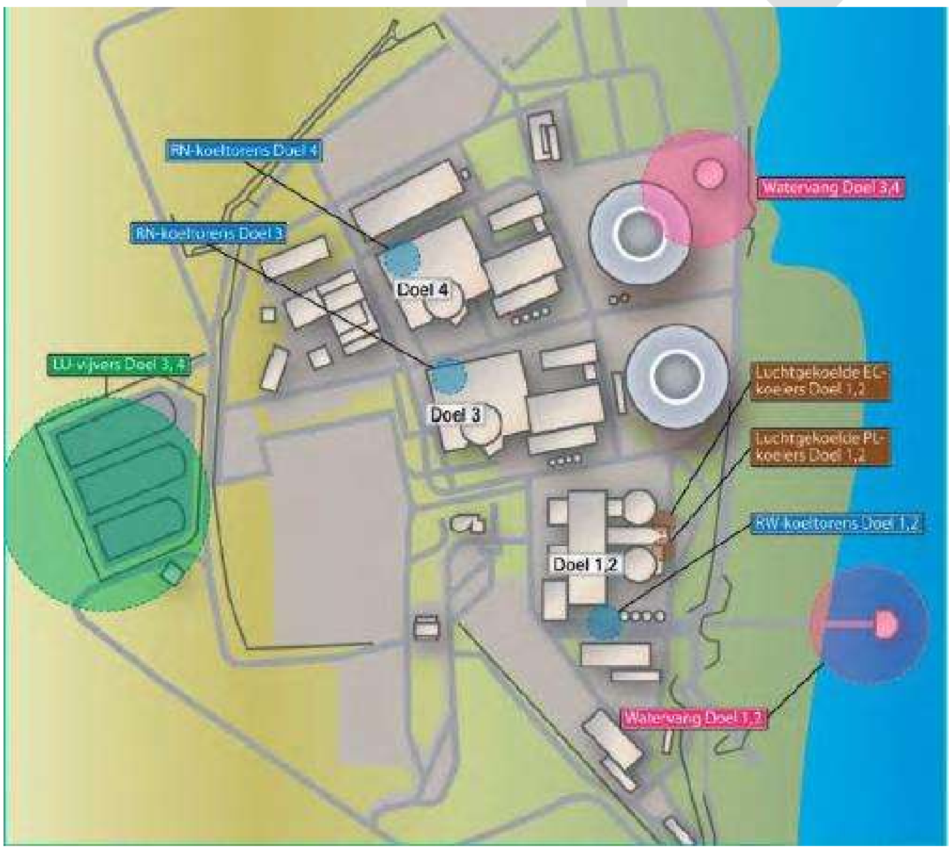

Figure 44: Cooling water principle diagram showing water capture Doel 1&2 and Doel 3&4 (Source: Electrabel nv, 2011).

[58] Maes, J.; Turnpenny, A. W. H.; Lambert, D. R.; Nedwell, J. R.; Parmentier, A. & F. Ollevier, 2004. Field evaluation of a sound system to reduce estuarine fish intake rates at a power plant cooling water inlet. Journal of Fish Biology (2004) 64, 938-946

Disruption

Nuclear power plants can potentially cause disturbance in terms of light, noise and human presence. Many of these factors are difficult to reduce to just the operation of Doel 4.

For noise, there are some sources that can only be linked to Doel 4. However, these were never modeled separately. The draft draft EIR by Arcadis (Arcadis, 2020) did include modeling of all noise sources present. This can therefore be considered an absolute worst-case approach to estimate the impact of Doel 4.

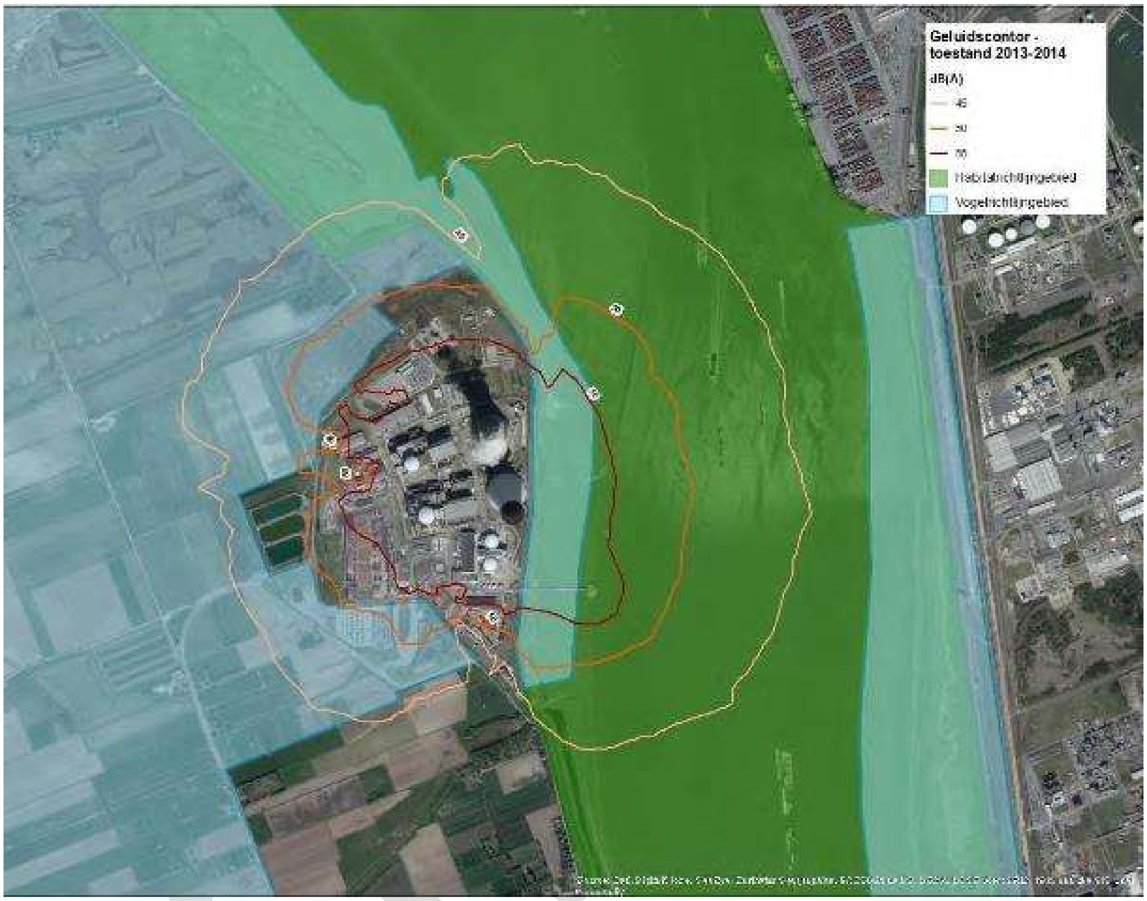

Figure 45: Noise contours of the continuously operating sources during the day, evening, and night periods (Source: EIA Arcadis/NRG, 2021).

The results of the Arcadis/NRG EIA (2021) show that noise contours extend mainly in an easterly direction. The 55 dB(A) contour overlaps with the mudflats and salt marshes located along the power plant itself. The 45 dB(A) contour overlaps with the Scheldt itself, with a limited part of Doelpolder Noord and with part of the future Doelpolder Midden area.

However, this is a continuous sound that is very predictable as a result and is located in a clearly separated area. Therefore, the birds can be expected to be little deterred and, moreover, a significant degree of habituation has already occurred. Passing cars, walkers and for the Scheldt also boats will probably have a greater impact. For this we also refer to the assessment framework nature and recreation (Arcadis, 2009). Moreover, only part of the noise comes from Doel 4.

In addition, simultaneously with extended operation of Doel 4, the decommissioning phase of the Doel1, 2 and 3 nuclear power plants will run. No information is available at this time on how this will occur and what the expected noise levels. However, as it concerns demolition works, the levels can be expected to be considerably higher and, moreover, often involve unpredictable impulse noise which is much more disturbing to birds.

Therefore, the impact of the plan in terms of disturbance can be expected to be negligible.

Airborne acidification and eutrophication

Acidification and eutrophication are a very important factor for habitat quality in Flanders. This is again evident from the description in the most recent Nature Report Flanders (Schneiders et al., 2020):

"*The pressure exerted on biodiversity by fertilizing and acidifying substances via air and water pollution has declined significantly in recent decades. For several years, however, these pressures have continued to fluctuate around a level that is still too high to restore (semi-)natural terrestrial and aquatic ecosystems. The critical threshold of airborne eutrophication is exceeded for all forests, all heathlands and almost half of the species-rich grasslands in Flanders. This means that these habitats are suffering long-term damage. Eutrophication is one of the main reasons why habitats of European importance do not reach the desired status and why their future prospects are also unfavorable. Acidifying air pollution exceeds the critical damage threshold in 28 percent of forests and species-rich grasslands and in 9 percent of heathlands.*"

"Excess hydrogen ions from acidification and excess nutrients from fertilization cause direct damage to organisms. The composition of communities is also changing. Species bound to nutrient-rich environments increase and rare or demanding species from nutrient-poor environments decline. A homogenization occurs."

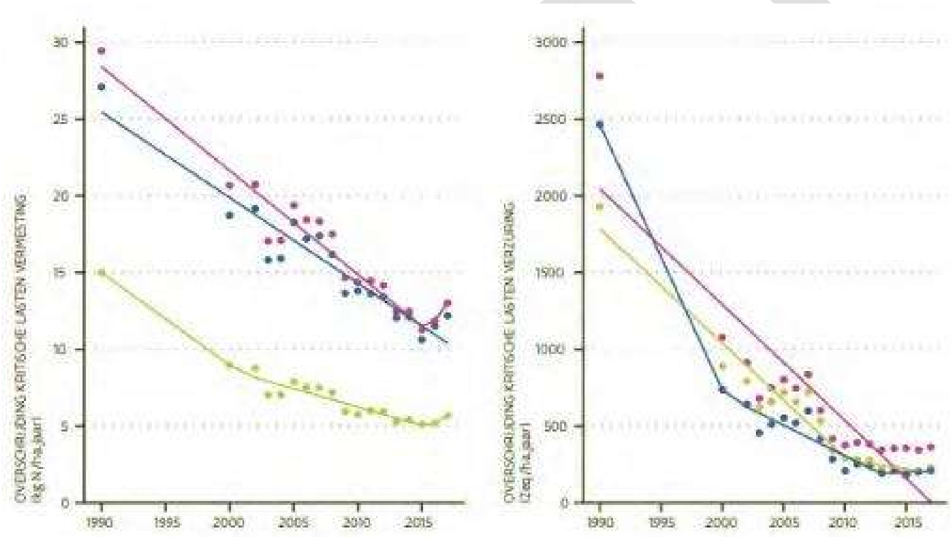

Figure 46: Exceedances of critical loads (modeled and area-weighted) for eutrophication (left) and acidification (right) in forest, species-rich grassland and heathland between 1990 and 2017 (Source: Schneiders et al., 2020).

The Air discipline examines the impact of the operation of the nuclear power plant in terms of air quality. This impact may occur because of the operation of the emergency facilities and the incinerators and because of the traffic to and from the site. The analyses show that, for the assessment framework of the Air discipline, the impact is negligible, certainly in relation to emissions from other sources in the vicinity (mainly in the port). For acidifying and eutrophying deposition, an additional analysis is carried out here with a check against the thresholds relevant to biodiversity.

Total deposition is the sum of dry and wet deposition. Dry deposition is calculated by multiplying the deposition rate for a given pollutant by the air concentration for that pollutant. Wet deposition is determined by precipitation rates and the concentration of a given pollutant in precipitation.

Higher precipitation amounts generally give higher wet depositions because deposition is calculated by multiplying concentration and precipitation amount. However, this increase is not linear because concentration generally decreases with large precipitation amounts.

The parameters (deposition rate, scavenging coefficient, etc.) used per pollutant (nitrogen oxides, ammonia, etc.) to calculate theoretical deposition are set in the IMPACT model[59]. The model calculates the theoretical maximum total nitrogen depositions expressed in kg N/(ha.year) in order to estimate the effects of acidification and eutrophication on vegetations in the environment.

The deposition calculations in the IMPACT model used deposition parameters, as determined in the VLOPS[60] model based on the type of vegetation per kilometer block.

Using the above models, the distribution of nitrogen emissions from the project, was calculated for vegetations in the study area. For vegetations, the Natura2000 typology is used.

The figure below shows current fertilizing deposition in the vicinity of the KCD (VLOPS22, VMM). This deposition includes all sources of fertilizing deposition (agriculture, traffic, industry, households), and thus also emissions from existing farms in operation in the vicinity. Based on these modeling results, it is clear that depositions vary between 15 and 35 kg N/ha.y.

Figure 47: Current fertilizing depositions in kg N/ha.y (VLOPS22).

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[59] IMPACT is a mathematical air model made available by the Flemish government and stands for Immission Prognosis Air Concentration Tool. The tool, launched January 31, 2017, allows to calculate and visualize in a user-friendly way concentrations and depositions of airborne pollutants in the vicinity of an (agro-)industrial source. IMPACT is the successor to IFDM-PC, the software used for such calculations since 1996.

[60] The VLOPS model (Flemish Operational Priority Substances Model) is an atmospheric transport and dispersion model that calculates air quality and depositions based on emission data, land use data and meteorological data. It uses both the detailed Flemish emission data from the VMM's Air Emission Inventory and the available data for sources outside Flanders.

Figure 48 shows the actual acidifying deposition in the vicinity of the KCD (VLOPS22, VMM). Based on these modeling results, it is clear that depositions vary between 1,500 and 3,000 Zeq (= acid equivalent)/ha.y.

Figure 48: Current acidifying depositions in Zeq/ha.j (VLOPS22).

The description and assessment of effects on acidifying and eutrophying deposition is based on overview studies of critical deposition values for acidification and eutrophication (Van Dobben et al. 2012[61], Hens & Neirynck 2013[62] and Bobbinck & Hettelinck 2011[63]). These critical threshold values indicate the level of deposition from which negative effects can be expected for a given habitat type.

Based on the combination of current fertilizing and acidifying depositions with the threshold values for the various habitat types, it can be determined for each habitat patch whether there is an exceedance of the threshold value and how great it is. ANB provides exceedance maps for eutrophication and acidification for this purpose. These are shown in Figure 49 and Figure 50.

Immediately noticeable is that no exceedance is shown at the level of the channel of the Scheldt itself. This is because the habitat type occurring here (1130) is not nitrogen sensitive. However, the salt marshes along the edges are shown and for a large part of them there is currently already an exceedance of the acidifying and

[61] van Dobben H.F., Bobbink R., Bal D. & van Hinsberg A. (2012) Overview of critical deposition values for nitrogen applied to Natura2000 habitat types and habitats. Alterra report 2397. Alterra WUR, Wageningen, The Netherlands.

62 Hens M. & Neirynck J. (2013) Critical deposition values for nitrogen for sustainable conservation of European habitat types in Flanders, INBO, note WBC, based on van Dobben H.F., Bobbink R., Bal D., van Hinsberg A. (2012) Overview of critical deposition values for nitrogen applied to habitat types and habitats of Natura2000. Alterra report 2397. Alterra, WUR, Wageningen, The Netherlands.

[63] Bobbink R, Hettelingh JP, eds. (2011) Review and revision of empirical critical loads and dose response relationships, Coordination Centre for Effects, National Institute for Public Health and the Environment (RIVM), www.rivm.nl/cce.

fertilizing depositions, albeit only to a limited extent. The salt marshes on right banks have a greater excess.

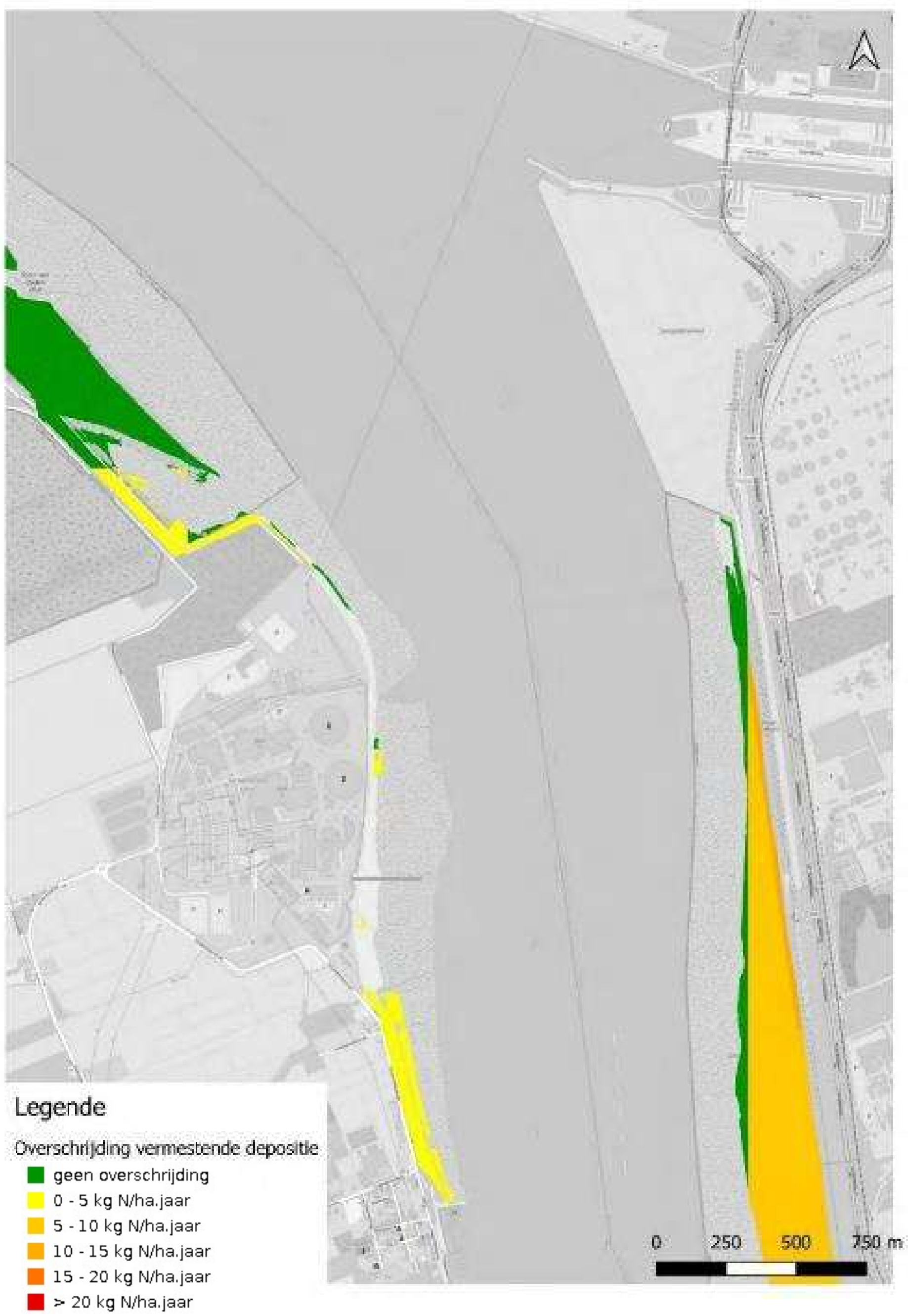

Figure 49: Exceedance map of fertilizing deposition.

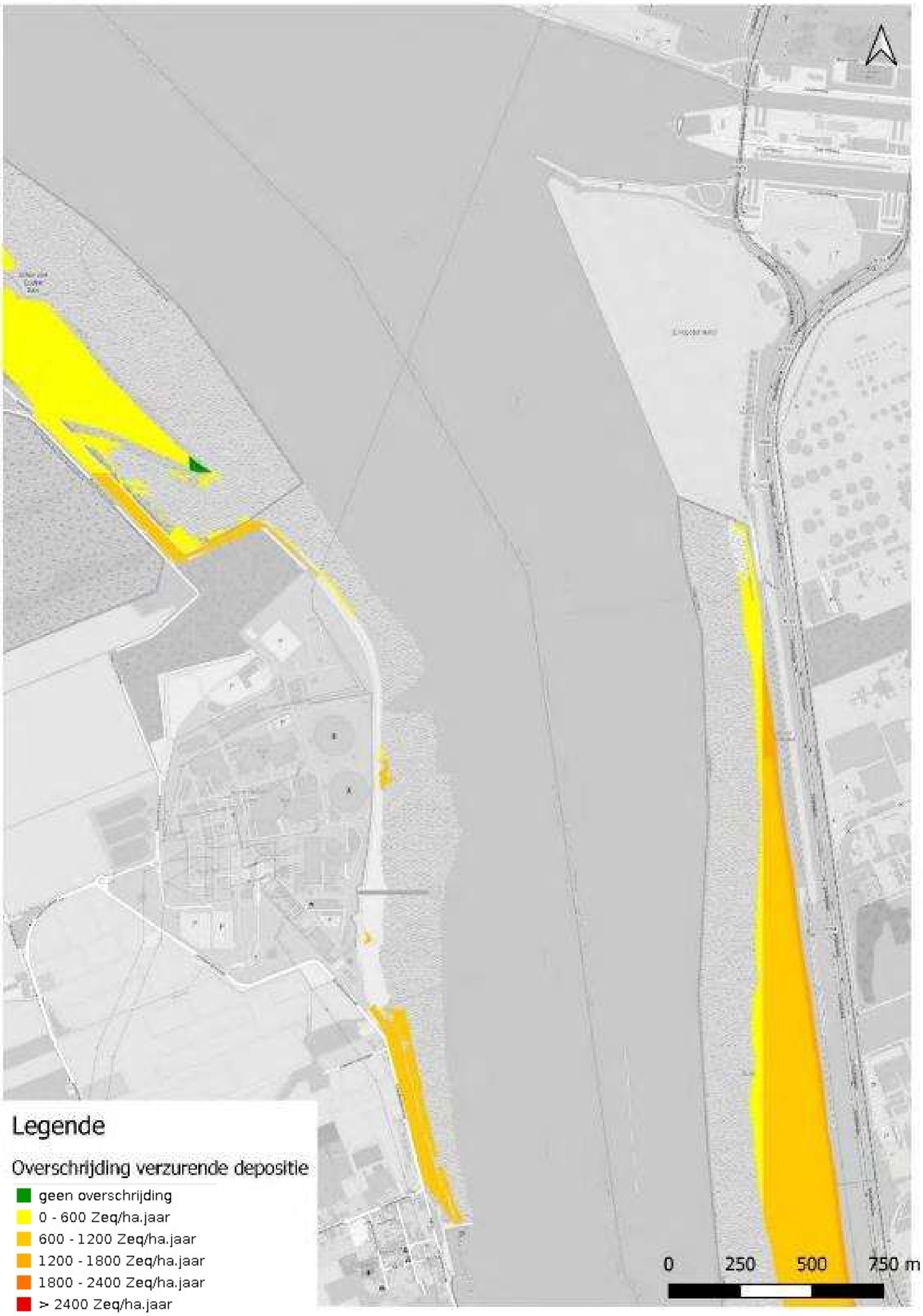

Figure 50: Exceedance map of acidifying deposition.

The plan's contribution to eutrophying and acidifying depositions is calculated based on the assumptions described in the Air discipline. A worst-case approach was chosen, as a result of which the calculated impact may be considered an overestimate.

The calculated fertilizing deposition is shown in Figure 51, the contribution of the plan was shown here starting from 0.06 kg N/ha.year. The highest values are calculated near the site of the nuclear power plant itself with a maximum value of 0.1 kg N/ha.year. Further away, the depositions decrease rapidly. However, there are also depositions at the level of habitats present along the Scheldt. The habitats or rbbs that may experience a fertilizing impact because of the plan are 1330_da, 6510 and rbbmr.

A KDW of 22 kg N/ha.year was determined for habitat type 1330_da. As shown in Figure 49, this value has already been exceeded for part of the area today. The maximum contribution of the plan for this habitat type can be found at the level of the small patch of salt marsh habitat right next to the site itself. The contribution of the plan here is 0.07 kg N/ha.year, or 0.32% of the CDW. Near habitat type 6510 (KDW 20), the maximum contribution is 0.05 kg N/ha.year, or 0.25% of the KDW. For the regionally important biotope, the critical load for eutrophication was determined as 26 kg N/ha.year. The maximum deposition here is 0.09 kg/ha.year, or 0.35% of the RDW.

The calculated acidifying deposition is shown in Figure 50, the contribution of the plan was shown here starting from 5 Zeq/ha.year. Again, the highest patterns are observed near the site itself, with a maximum value of 7.2 Zeq/ha.year. At the level of habitat 3130_da (critical load 1,571 Zeq/ha.year) the maximum deposition is just 5 Zeq/ha.year, at the level of habitat 6510 (critical load 1,429 Zeq/ha.year) the maximum deposition is 5.8 Zeq/ha.year and at the rbbmr (critical load 2,400 Zeq/ha.year) the acidifying deposition is below 5 Zeq/ha.year.

The plan thus causes a slight increase at the level of valuable vegetations and habitats, but the project's contribution remains (well) below 1% of the CDW everywhere.

Moreover, the calculation assumes a worst-case estimate. As described in the Air discipline, because of the shutdown of the other nuclear power plants, it can be expected that systematically fewer and fewer emission sources will be present on the site. The Air discipline assumes a decrease of about 30%.

Given the closure of Doel 1, 2 and 3 nuclear power plants, in practice there will be no increase in depositions, but a decrease at the level of these habitats. Moreover, the extension of Doel 4 only runs over a period of 10 years, which means that the limited depositions that exist will also only take place for 10 years. After that, they will systematically decrease.

Finally, the vegetations for which the highest impact is expected (3130_da and rbbmr) are strongly influenced by the Scheldt water due to the regular floods inherent to this ecosystem. Given the poor assessment of the Scheldt in terms of nitrate + nitrite + ammonium (see Water discipline), the question can be raised whether the limited nitrogen deposition can have a relevant impact on these vegetations.

Therefore, because of the above arguments, it is considered that the plan has no relevant impact in terms of fertilizing and acidifying depositions.

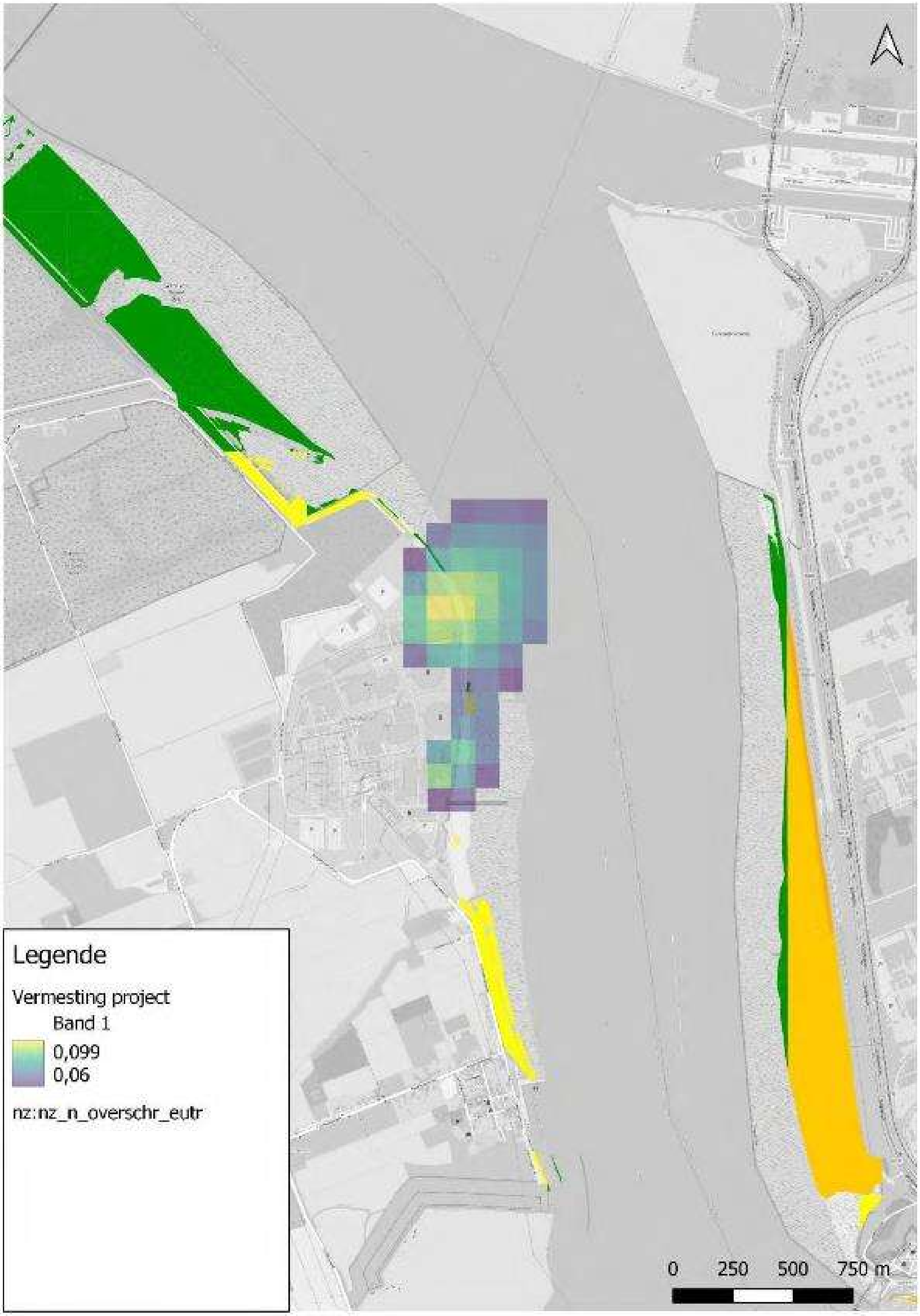

Figure 51: Fertilization, contribution plan.

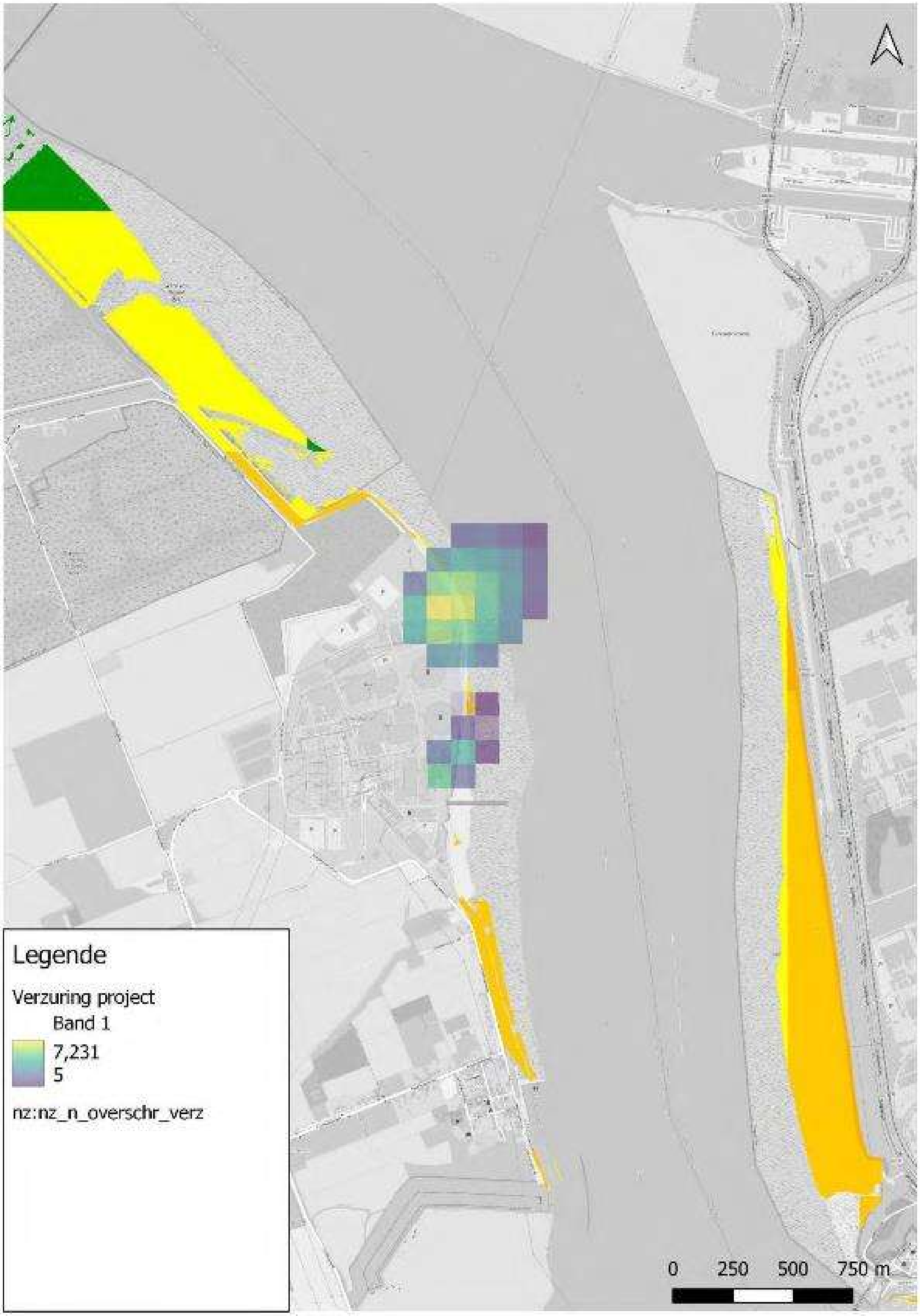

Figure 52: Acidification, contribution plan.

In addition, there will also be avoided emissions because of the plan. These avoided emissions are the emissions that can be expected if electricity production during the period of the plant's extended lifetime would not have been realized by the nuclear power plant, but by other methods of energy production.

As it is not known at which locations the emissions from the installations that would take over the production of Doel 4 could take place, nor is there any insight into e.g. possible permit conditions the installations would have to meet, nor are the inspection characteristics known that could significantly determine the impact on air quality, it is not possible to make a quantitatively substantiated statement of the possible impact that the emissions from these "replacement installations" will have. This is all the more important for any impacts in terms of biodiversity. After all, not all vegetations and species are equally sensitive to nitrogen deposition. And this deposition, besides the emissions themselves, also depends on the distance from the source and other factors such as, for example, the roughness of the landscape.

The exact impact in terms of acidification and eutrophication is therefore impossible to map. However, given the extent to which the critical thresholds for nitrogen deposition are exceeded in Flanders, it can be assumed that additional deposition caused by fossil fuel replacement plants (e.g., gas), even if limited, would be very unfavorable for the conservation status of habitats and species in Flanders. Indeed, it can be assumed that emissions and depositions from these plants will be significantly much larger than those associated with the operation of Doel 4.

Direct space occupation

Theoretically, the decision to keep the Doel 4 nuclear power plant open longer could have a negative impact in terms of land take. After all, if the plant were to disappear, an area would be freed up that is very favorably situated from a nature point of view, given its proximity to the Scheldt and various nature development areas. However, this reasoning needs some qualification.

First, the plants are located in a zoned industrial area. Therefore, after abandonment, there is a real chance that new industrial development would occur, rather than development for nature. Also, the soil quality of the site would severely limit the potential for nature development. The soil here was raised with soil that was contaminated with arsenic.

In summary, the decision to defer deactivation has no impact in terms of direct land take.

1.3.6 Assessment of impacts against policy objectives.

To what extent can the plan, be expected to avoid damage to nature (cfr. Nature Decree)?

The impact analysis examined the plan in terms of alteration of surface water quality, barrier effect, mortality, disturbance, airborne acidification and eutrophication, and direct land take. For barrier effect and direct land take, no effects were found to be expected.

For mortality, there may be an effect due to the intake of cooling water. However, due to the modifications to the system (deterrent system and diversion back towards the Scheldt), the number of victims is strongly reduced, so that only a limited effect is expected.

For disturbance, a limited effect of noise disturbance was potentially expected, but given the continuous and predictable nature of the noise, no real harm is expected.

For acidification and eutrophication from the air, the contribution of the plan itself is negligible and, because of avoided effects, even makes a (limited) positive contribution.

Impacts from wastewater, industrial water and cooling water discharges have negligible impact on the entire water body. Locally, in the zone within the breakwater, impacts could potentially occur, but this is not apparent from monitoring data from the MONEOS program, for example.

Overall, therefore, it can be concluded that the plan will not cause avoidable harm and has a neutral impact for this policy objective.

To what extent can the plan be expected to avoid irreparable and unavoidable damage to VEN areas (cf. Nature Decree)?

The Doel nuclear power plant site is surrounded on several sides by VEN area. These include Doelpolder Noord, Doelpolder Midden and the shoreline zone of the Scheldt near the nuclear power plant itself. The most important natural values here are the mudflats and salt marshes themselves, the birds that occur here and the fish in the Scheldt. The capping of this objective corresponds to answering the questions in an enhanced nature assessment.

A limited effect of noise disturbance was potentially expected for birds in the VEN area, but given the continuous and predictable nature of the noise, no real harm is expected.

For the mudflats and fish in the Scheldt, the impact on surface water quality is a concern. Data in the draft draft EIR by Arcadis (Arcadis, 2020), based on measurements of the discharge plume, show that the thermal impact of the discharges is largely limited to the zone within the breakwater. As the impact on the rest of the Scheldt is limited, no barrier effects are expected for fish in the Scheldt. Also for the other parameters (such as nitrite and AOX), the contribution of the discharges to the environmental quality standard for the whole water body appears negligible.

Locally, in the zone within the breakwater, impacts could potentially occur, but this is not apparent from monitoring data from the MONEOS program, for example.

For airborne acidification and eutrophication, a very limited contribution from the plan is possible at the level of VEN area (Figure 53 and Figure 54).

As described above, the depositions shown must be nuanced to a significant degree:

- First, this is a very limited contribution over a very limited area;
- Second, the calculation assumes a worst-case estimate. As described in the Air discipline, because of the shutdown of the other nuclear power plants, it can be expected that systematically fewer and fewer emission sources will be present on the site. In the Air discipline, a decrease of about 30% is assumed;
- Given the closure of Doel 1, 2 and 3 nuclear power plants, in practice there will be no increase in depositions, but a decrease at the level of these habitats. Moreover, the extension of Doel 4 runs only until 2037. This means that the limited depositions that exist will only take place for 10 years, and then systematically decrease;
- Finally, the parts of the VEN for which the highest impact is expected are strongly influenced by the Scheldt water due to the regular floods inherent to this ecosystem. Given the poor assessment of the Scheldt in terms of nitrate + nitrite + ammonium (see Water discipline), the question then arises whether the limited nitrogen deposition can have a relevant impact on these vegetations.

Moreover, the VEN area that would potentially be affected (Slikken en schorren langs langs de Schelde) is highly designated because of its importance for birds. Although a negative impact on birds has been demonstrated for a number of bird species, this is mainly the case for species of sparse vegetation such as sparse grasslands, heaths or forests on sandy soils. These were mostly indirect effects of, for example, soil acidification (calcium deficiency) or due to changes in naturally sparse vegetation (Vogels et al., 2022[64], Nijssen et al., 2017[65], Stevens et al., 2017[66]). In nutrient-rich systems, significant effects for birds are much less likely.

It can therefore be decided that no damage will occur because of the plan to keep the Doel 4 plant open for 10 more years.

In addition, keeping the plant open longer will have a positive impact because of avoided emissions. However, since the location of the "replacement plants" is not known, it is impossible to determine their impact for the VEN areas.

Overall, therefore, it can be concluded that no avoidable and irreparable harm will occur in the context of the enhanced wildlife assessment and that the plan has a neutral impact for this policy objective.

Figure 53: Fertilizing depositions near VEN area.

[64] Vogels,J., van de Waal, D., van den Burg,A., Wallis de Vries,M., Nijssen, M. & R. Bobbink (2022). The Living Nature | volume 123 | number 6.

[65] Nijssen, M.E., et al, Pathways for the effects of increased nitrogen deposition on fauna, Biological Conservation (2017).

[66] Stevens CJ, David TI, Storkey J. Atmospheric nitrogen deposition in terrestrial ecosystems: Its impact on plant communities and consequences across trophic levels. Funct Ecol. 2018;32:1757-1769.

Figure 54: Acidifying depositions near VEN area.

To what extent can it be expected that the plan could avoid meaningful impacts with respect to NATURA2000 areas (cf. Nature Decree)?

The plan area is surrounded by SPA-V and is also adjacent to SPA-H. The targeted species and habitats for this SPA are described in Section 3.3.4 The deduction of this objective corresponds to answering the questions in an appropriate assessment.

For the habitats in the SPA-H, a possible impact on the mudflats and salt marshes are relevant as well as possible effects on acidifying and eutrophying deposition. In addition, an impact on notified species may be relevant. These include disturbance effects, barrier effects, mortality or effects due to altered surface water quality.

For SPA-V species, there could potentially be an impact because of direct land take of (potential) habitat, because of disturbance, and through an indirect impact of surface water quality that could affect food availability for SPA-V birds.

All these possible effects were examined. The impact analysis concluded that no effects are expected in terms of barrier effects.

For the other impacts, as part of the appropriate assessment, it must be investigated not only whether there is an impact on current habitats and species but also whether the plan will not jeopardize the achievement of nature goals.

The fish species river lamprey, shad and bitterlings are targeted in the SPA-H 'Scheldt and Durme estuary from the Dutch border to Ghent'. For these species, mortality due to the intake of cooling water could be relevant to the nature objectives. Sea lamprey are not registered for this SPA-H, only for the Western Scheldt, so no effect is expected anyway.

Chub and bitterling are species with swim bladders that are effectively deterred by the sound of the deterrent system. River lamprey are mentioned in the study by Maes et al. (2004) as one of the species that do not survive a passage through the cooling water system. This species will be led back towards the Scheldt in the current system. It can therefore be concluded that mortality due to the intake of cooling water will not compromise the nature objectives for these species.

For direct land take, therefore, it was assessed whether the decision to keep Doel 4 in operation longer compromised the development of new habitat. This is not the case as the possibility of developing habitat at this location is not possible anyway given its zoning as an industrial area and historical pollution. In addition, the additional area is not necessary to meet the wildlife goals for SPA-V. As discussed in § 3.3.4, additional areas will be established for the species for which there is currently insufficient habitat. The area of these areas is sufficient to meet the nature goals.

Also for acidifying and eutrophying depositions, the impact must be tested against both current natural values and nature objectives. For the impact of the plan itself, the eutrophying and acidifying impact was calculated. For the appropriate assessment, the impact at the level of current habitat types 3130_da and 6510 is relevant. No assessment is required for the search zones, as only a search zone for habitat type 1130 has been designated in the vicinity of the project area, which is not nitrogen sensitive.

For habitat type 3130_da, the maximum deposition is 0.07 kg N/ha.year. This is 0.32 % of the CDW of this habitat type. For habitat type 6510, the maximum contribution is 0.05 kg N/ha.year, which is 0.25% of the CDW of this habitat type. Based on the currently valid ministerial instruction, a contribution of 1 % is the threshold for the appropriate assessment. Thus, the plan remains well below this. Therefore, no significant effects are expected because of nitrogen deposition.

The impact of avoided depositions is more difficult to assess. Obviously the impact is positive, but whether it is also meaningful and thus contributes noticeably to the goals for the Natura 2000 areas is less clear. This is mainly due to the fact that the impact of the avoided emissions cannot be situated spatially. The air discipline states that an impact would occur mainly in the zones in the immediate vicinity of the 'replacement plants' and would be negligible at a greater distance. Therefore, given the wide differences in sensitivity of habitats and species, the potential impact of these 'avoided emissions' could vary greatly. In addition, it is also true that most SPA-H even now, without 'replacement plants' have exceedances of the CDW. For most SPA-H, the presence or absence of additional nitrogen deposition does not make the difference between achieving or not achieving the nature objectives. On the other hand, nitrogen deposition can accumulate and the additional deposition would have increased the "distance to target" for meeting nature goals. So in this sense, there is a limited positive effect for achieving the targets.

However, the main impact of the nuclear power plant (apart from potential radiological effects) is in terms of water quality. The nuclear power plant has a significant thermal impact and also discharges wastewater for which a possible eutrophying and ecotoxicological impact cannot be excluded a priori. However, as indicated earlier, this impact is limited to the zone within the breakwater and the contribution to overall water quality is negligible. This also means that an impact at population level can be excluded for the species occurring in the Scheldt. There are also no indications that the discharges locally cause reduced food availability for the birds of the SPA-V. The zone within the breakwater is even just richer in fish and the species richness and biomass of macroinvertebrates is also high. Therefore, a meaningful effect is not expected.

Finally, no significant effects of disturbance are expected for birds in SPA-V, either in the existing or in the areas yet to be constructed. Although the operation of the nuclear power plants gives rise to increased noise levels, the contribution from Doel 4 alone is likely to be limited. Moreover, the noise is continuous and predictable, so habituation may occur and the disturbance impact will be limited. Other forms of disturbance, such as light disturbance or disturbance from the presence of people do not change significantly because of the plan.

Therefore, it can be concluded that the plan does not have a meaningful impact on the conservation status of habitats and species in the context of the appropriate assessment and that the plan's contribution to this objective is neutral.

To what extent can the plan be expected not to cause harm to species protected under the Species Act?

As discussed above, no significant impact is expected for the species targeted in the SPA or in the VEN. Little impact is also expected for Annex IV species of the Habitats Directive, which are also protected outside the SPA.

Indeed, the plan does not create any meaningful disturbance and the impact on water quality is also negligible when viewed across the entire body of water.

The fish species river lamprey, shad and bitterlings are targeted in the SPA-H 'Scheldt and Durme estuary from the Dutch border to Ghent'. For these species, mortality due to the intake of cooling water could be relevant to the nature objectives. Sea lamprey are not registered for this SPA-H, only for the Western Scheldt, so no effect is expected anyway.

Chub and bitterling are species with swim bladders that are effectively deterred by the sound of the deterrent system. River lamprey are mentioned in the study by Maes et al. (2004) as one of the species that will have a passage through the cooling water system. This species will be led back towards the Scheldt in the current system. It can therefore be concluded that mortality due to the intake of cooling water will not compromise the nature objectives for these species.

Therefore, it can be concluded that the plan has no meaningful effects in the context of the species decision and the plan's contribution to this objective is neutral.

To what extent can the implementation of the plan be expected not to impede the achievement of objectives formulated in species protection programs (cfr. Species Decree)?

For the species for which an SBP has been drawn up, the sites of interest in the SBP are already part of a protection zone, which means that the impact is investigated anyway. It is worth noting that the cooling tower has had a nesting box for peregrine falcons on it since 1996, in which peregrine falcons regularly breed.

The extension of Doel 4 ensures that the cooling tower will be needed longer, therefore no negative impact is expected for the peregrine falcon.

Therefore, it can be concluded that the plan does not impede the achievement of the objectives in the SBPs and its contribution to this objective is neutral.

1.3.7 Summary of key findings

The nuclear power plant is located near the various protection zones. There are therefore several policy objectives on which the plan could have an impact. Both the Nature Decree and its implementing decrees and the Integrated Water Policy Decree are relevant in this context. The biological aspects of the Integrated Water Policy Decree are also assessed in the discipline of Water, but are discussed here in the impact analysis.

The plan was examined in terms of modification of surface water quality, barrier effects, mortality, disturbance, acidification and eutrophication from air and direct land take. For barrier effect and direct land take, no effects were found to be expected.

For mortality, there may be an effect because of the intake of cooling water. However, due to the modifications to the system (deterrent system and diversion back towards the Scheldt), the number of victims is strongly reduced, so that only a limited effect is expected.

In terms of disturbance, only changes are to be expected in terms of noise disturbance. These changes are rather limited given that the plan only includes a modification for the Doel 4 nuclear power plants. Moreover, the noise is an existing noise that is continuous and predictable. A significant impact on nearby species is therefore not expected.

The effects of the operation of the nuclear power plants themselves in terms of acidifying and eutrophying depositions are negligible. Moreover, other factors such as the quality of the Scheldt water are much more decisive at that location. However, positive effects can be expected because of the avoided emissions. However, a significant impact is only expected in the immediate vicinity of the 'replacement plants' while their location is unknown. This makes it difficult to estimate the importance of these positive effects.

However, the main impact of the plan is this on the water quality of the Scheldt River. The discharge of cooling water, sanitary water and industrial water causes a local deterioration of the water quality. However, the impact is limited to the zone within the breakwater, preventing meaningful effects. Also locally, there are no indications that the effects are strongly detrimental to the organisms present. Given the designation of the Scheldt itself as SPA-H and the possible importance of this zone for the birds of SPA-V, this is an important conclusion.

Based on this analysis, it was concluded that the plan had no appreciable negative or positive impact on the relevant policy objectives. The effect is neutral.

1.3.8 Mitigating measures

Given that the project has no noticeable effects on policy objectives, no mitigation measures are envisioned.

1.3.9 Gaps in knowledge and monitoring

The main gap in knowledge concerns the location of avoided emissions. This concerns a positive impact of the plan. Because of uncertainty, the positive impact is considered limited.

In addition, there are also uncertainties about the possible local impact on water quality. Since the general water quality of the Scheldt is still recovering, it is difficult to know whether the quality could have been even better without the plan. However, as it concerns only local effects that will moreover decrease compared to the current situation, the impact on the assessment is negligible

1.4 Theme Air

1.4.1 Relevant policy objectives

The most relevant policy objectives in the context of this strategic EIA are the emission reduction targets as set at the European level with respect to the federal level, and further distributed at the regional level.

The National Emission Ceilings Directive or NEC Directive (National Emission Ceilings, 2001/81/EC) was published in 2001. It defined emission ceilings not to be exceeded from 2010 for:

- sulfur dioxide (SO_2);
- nitrogen oxides (NO_x);
- non-methane volatile organic compounds (VOCs);
- ammonia (NH_3).

At the end of 2016, the revised NEC Directive came into force (2016/2284/EU). It contains targets for 2020 and 2030 formulated as relative reductions compared to 2005 emissions. It also included emission ceilings for $PM2_{.5}$.

Table 26: NEC reduction targets 2030 as cited in the Flemish Air Quality Plan 2030.

Belgian reduction targets for 2030 and distribution among regions						
	BE-2005	**BE 2030**	**Emission ceiling 2030**			
	Emissions Belgium	**Reduction objective**	**BE**	**Vl**	**WAL**	**BRU**
	kt	**% vs. 2005**	**kt**	**kt**	**kt**	**kt**
NOx	303,5	-59	124,4	71,8	49,4	3,2
SOx	142,1	-66	48,3	32,5	15,4	0,4
$PM2_{.5}$	34,8	-39	21,2	11,9	8,8	0,5
NMVOC	145,8	-35	94,8	58,8	32,1	3,9
NH3	78,8	-13	68,6	41,5	27,0	0,1

NMVOCs : non-methane volatile organic compounds

In addition to emissions targets, reference can also be made to air quality targets. These objectives are also based on European legislation.

European Directive 2008/50/EC on ambient air quality and cleaner air for Europe stipulates that air quality must be maintained where it is good, and improved in other cases. It further stipulates that where the standard for one or more of the pollutants is exceeded, the period of exceedance should be kept as short as possible.

Table 27: Air quality objectives in accordance with the European Air Framework Directive (revision approved April 14, 2008).

Polluent	Middle Time	Limit value	Date by which limit must be met
Suspended particulate matter ($_{PM10}$)			
Daily limit value for the protection of human health	24 hours	50 $\mu g/m^3$ $_{PM10}$ shall not be exceeded more than 35 times per year.	January 1, 2005
Annual limit value for the protection of human health	calendar year	40 $\mu g/m^3$ $_{PM10}$	January 1, 2005
Particulate matter ($PM2_{.5}$).			
Annual limit value for the protection of human health	calendar year	25 $\mu g/m^3$ $PM2_{.5}$ [1]	January 1, 2015

Polluent	Middle Time	Limit value	Date by which limit must be met
Indicative annual limit value for the protection of human health	calendar year	20 µg/m³	January 1, 2020
National exposure reduction target relative to the GBI in 2010	GBI	15.2 µg/m³	2020
Flemish exposure reduction target relative to the GBI in 2010	GGBI	15.7 µg/m³	2020
Exposure concentration requirement	GBI	20 µg/m³	2015
Nitrogen dioxide (NO_2) and nitrogen oxides (NOX)			
Hourly limit for the protection of human health	1 hour	200 µg/m³ NO_2 shall not be exceeded more than 18 times per calendar year be exceeded	January 1, 2010
Annual limit value for the protection of human health	Calendar Year	40 µg/m³ NO_2	January 1, 2010
Alert threshold	1 hour	400 µg/m³ NO_2 for 3 consecutive hours	January 1, 2010
Annual limit on vegetation protection.	Calendar Year	30 µg/m³ NO_x	July 19, 2001 In Flanders, however, no defined areas where the limit applies
Sulfur dioxide (SO_2)			
Hourly limit for the protection of human health	1 hour	350 µg/m³ shall not exceed 24 times per calendar year are exceeded	January 1, 2005
Daily limit value for the protection of human health	24 hours	125 µg/m³ shall not exceed Be exceeded 3 times per calendar year	January 1, 2005
Alert threshold	1 hour	500 µg/m³ SO_2 for 3 consecutive hours	January 1, 2005
Critical level for vegetation protection.	Annual and winter season	20 µg/m³	July 19, 2001 In Flanders, however, no defined areas where the limit applies
Carbon monoxide (CO)			

Polluent	Median time	Limit value	Date by which limit must be met
Limit value for the protection of human health	Top 8-hourly average of a day	10 mg/m³	January 1, 2005
Lead (Pb)			
Annual limit value for the protection of human health	calendar year	0.5 µg/m³	January 1, 2005 (Jan. 1, 2010)
Benzene (C_6H_6)			
Annual limit value for the protection of human health	calendar year	5 µg/m³	January 1, 2005
Ozone (O_3)			
Target value for human health protection.	Top 8-hourly average of a day ($NET60ppb$)	120 µg/m³ (averaged over 3 year: max. 25 exceedance days per year)	January 1, 2010
Long-term for the protection of human health	Top 8-hourly average of a day ($NET60ppb$)	120 µg/m³	
Information threshold	hourly average	180 µg/m³	
Alert threshold	hourly average	240 µg/m³	
Target value for vegetation protection.	AOT40ppb	18.000 (µg/m³).hours averaged over 5 years	
Long-term for the protection of vegetation	AOT40ppb	6,000 (µg/m³).hours	

In October 2019, the Flemish air policy plan 2030 (VLP) was approved by the Flemish government. This plan shows that especially the pollutants NO_2 and particulate matter must be remediated to arrive at a situation where air pollution no longer has a negative impact on humans and the environment. It also appears that the air quality standard for NO_2 is exceeded in many places throughout Flanders, especially in areas with heavy traffic. The background concentrations are caused by the cumulative effect of all emission sources in the environment. In order to keep the period of exceedance as short as possible, additional emissions will have to be minimized.

Link: https://omgeving.vlaanderen.be/luchtverontreiniging-actieplannen#luchtbeleidsplan

Regarding the possible future tightening of air quality standards, reference can be made to the following proposal from the European Commission as formulated at the end of 2022. This proposal takes more account of the adjusted advisory values as formulated by the WHO in the context of reducing the impact of air quality on health. (EUR-Lex - 52022PC0542 - EN - EUR-Lex (europa.eu)).

EUROPEAN COMMISSION
Brussels, 26.10.2022
COM(2022) 542 final
2022/0347(COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
on ambient air quality and cleaner air for Europe

ANNEX I

AIR QUALITY STANDARDS

Section 1 - Limit values for the protection of human health

Table 1 - Limit values for the protection of human health to be attained by January 1, 2030

Averaging period	Limit value	
PM2.5		
1 day	25 µg/m3	not to be exceeded more than 18 times per calendar year
Calendar year	10 µg/m³	
PM10		
1 day	45 µg/m3	not to be exceeded more than 18 times per calendar year
Calendar year	20 µg/m3	
Nitrogen dioxide (NO2)		
1 hour	200 µg/m3	not to be exceeded more than once per calendar year
1 day	50 µg/m3	not to be exceeded more than 18 times per calendar year
Calendar year	20 µg/m3	
Sulphur dioxide (SO2)		
1 hour	350 µg/m3	not to be exceeded more than once per calendar year
1 day	50 µg/m3	not to be exceeded more than 18 times per calendar year
Calendar year	20 µg/m3	
Benzene		
Calendar year	3.4 µg/m3	
Carbon monoxide (CO)		
maximum daily 8-hour mean (1)	10 mg/m3	
1 day	4 mg/m3	not to be exceeded more than 18 times per calendar year
Lead (Pb)		
Calendar year	0.5 µg/m3	
Arsenic (As)		
Calendar year	6.0 ng/m³	
Cadmium (Cd)		
Calendar year	5.0 ng/m³	
Nickel (Ni)		
Calendar year	20 ng/m³	
Benzo(a)pyrene		
Calendar year	1.0 ng/m³	
(1)The maximum daily 8-hour mean concentration will be selected by examining 8-hour running averages, calculated from hourly data and updated each hour. Each 8-hour average so calculated will be assigned to the day on which it ends i.e. the first calculation period for any 1 day will be the period from 17.00 on the previous day to 1.00 on that day; the last calculation period for any 1 day will be the period from 16.00 to 24.00 on that day.		

In the context of European policy objectives in the area of greenhouse gas emission reduction (including through the accelerated phase-out of fossil fuel use), the associated measures will also have a positive impact on air quality. Please refer to the climate chapter for this specific policy framework.

1.4.2 Relevant effects and cause-effect relationships

Potentially relevant impacts examined in this EIR within the air discipline are the emissions to the atmosphere associated with the operation of Doel 4. This relates primarily to combustion parameters from emergency groups, auxiliary steam and heating systems, and from transport to and from the site.

Other sources relate to maintenance work, with the use of various machines (woodworking and metalworking), possible leakage losses from cooling installations and the impact via cooling towers. Of possible emissions of salt aerosols from the cooling tower, previous studies have already indicated that there is hardly any impact from this.

In view of the expected shutdown of the Doel 1 and Doel 2 plants, and in view of the already shut down Doel 3, lower emissions and lower impacts than those in the current situation can be assumed for the planned situation anyway.

1.4.3 Delineation of study area and description of reference situation

The study area, given the different scales and locations, actually depends on the effect being studied. For the different elements, the following areas can be delineated in this regard:

- Area of 5 km around the plant for assessing local emissions from the plant;
- Federal territory for assessing emission levels versus NEC targets

The baseline mapping takes into account the expected future decrease in emissions and impacts by 2025 from both local and more remote sources, given the 2030 targets to be met, which are expected to be tightened.

1.4.3.1 Current air quality

Initially, immission measurements conducted by VMM could be used to map local air quality.

Limited measurement data are available for the most relevant substances whose impact needs to be assessed. Area-wide model calculations (source VMM) are therefore used to describe air quality. As the COVID pandemic was associated with a positive impact on air quality, and this impact is visible on map material for 2020 and 2021 (2022 not yet available), 2019 data will still be used.

The maps are based on interpolation of results from monitoring stations in Flanders and surrounding regions, supplemented by high resolution modeling. In addition to measurement results, the so-called Atmo-street model is applied to produce these model maps. This basically includes three models to estimate air quality: RIO, IFDM and OSPM.

On the cards:

- Is also taken into account the specific situation in street canyons.
- Are local results limited by information on local emissions (traffic counts, speeds driven, vehicle fleet).

Some limitations with these maps are:

- No information is available on traffic emissions on low-traffic roads. Traffic on those roads is assigned to the larger roads to which the smaller roads connect. As a result, the model cannot perform a separate calculation on each street. For those streets, the "background concentrations" are shown. These are the concentrations as calculated for a larger zone with an area of 4x4 km²;
- In addition, traffic is model-assigned. There are few if any traffic counts at the Flemish level for non-motorways. Calculations are based on traffic counts, driven speeds and fleet information. Through the combination of traffic counts and modeled road section loads, the traffic intensity is determined. On the highways, permanent intensity and speed measurements are used for this purpose. For the secondary road network, there are far fewer measurements available. For the vehicle fleet, the average Flemish vehicle fleet is taken into account;
- Temporary traffic situations (e.g. detour or traffic jams) are not taken into account;
- The impact of new traffic situations (new roads, mobility plans in progress,...) is not immediately visible;
- The repeated blowing up of dust by traffic and the effect of the presence of greenery (such as trees in a street) are not taken into account;
- Local pollution caused by wood stoves, fireplaces and large livestock farms, among others, is not visible on the maps. However, pollution from these sources is included in the "background concentration" (with a lower spatial resolution of 4x4 km²).

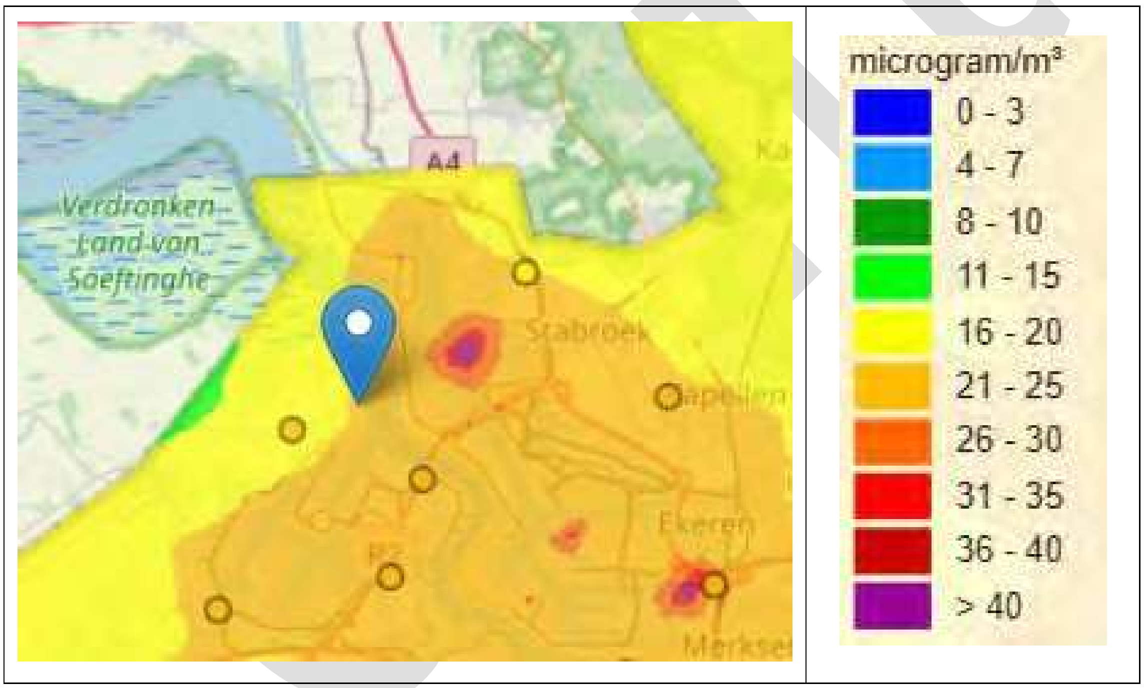

Figure 55: Annual average $_{PM10}$ concentration in 2019 (source VMM).

Overall, in terms of $_{PM10}$ (particulate matter), the legal limit value of 40 µg/m³ is amply met. Large parts of the study area have concentrations of 16 to 20 and 21 to 25 µg/m³. Only at some specific locations, such as the port of Antwerp and some specific urban locations, are relevant higher values established. These areas extend over a limited surface area.

Health advisory values do get exceeded in much of the study area.

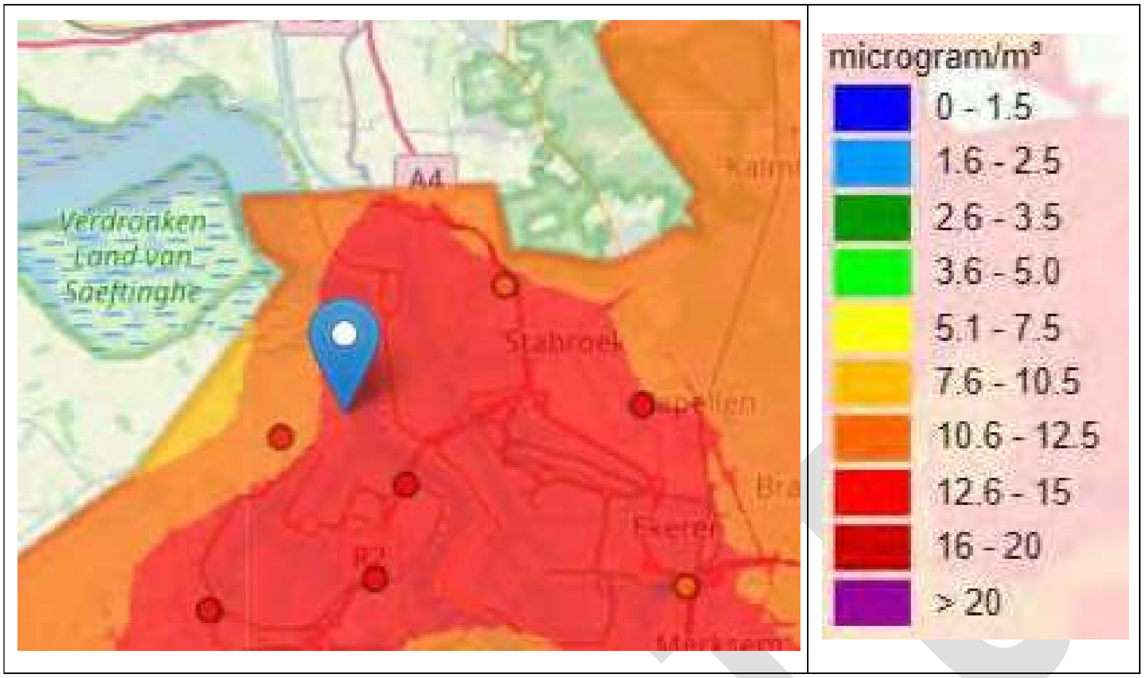

Figure 56: Annual average PM2.5 concentration in 2019 (source VMM).

Overall, the legal (indicative) limit value of 20 µg/m³ for $PM_{2.5}$ is amply met. Large parts of the study area have concentrations of 11 to 12 and 13 to 15 µg/m³. Only at some very specific locations (very busy (highways) are slightly higher values calculated. These locations extend over an extremely limited area.

Health advisory values do get exceeded in much of the study area.

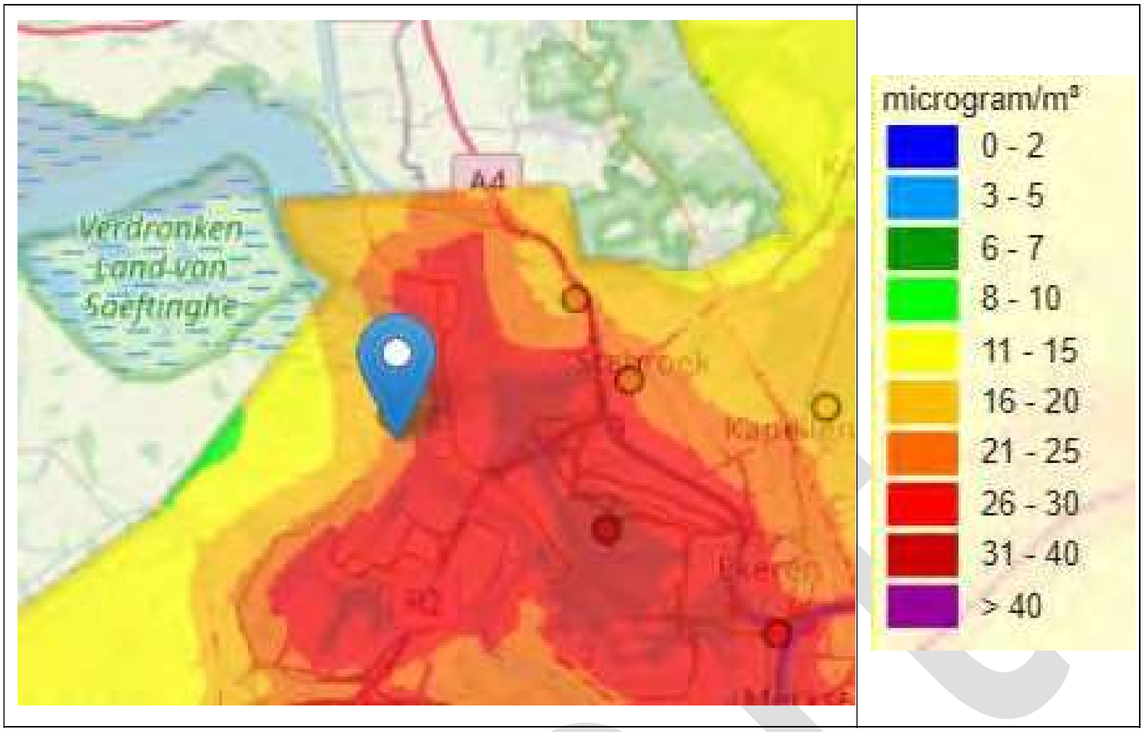

Figure 57: Annual average NO_2 concentration in 2019 (source VMM).

In terms of NO_2, a very strong spatial variation is observed. Overall, the legal limit value of 40 µg/m³ is amply met. Large parts of the study area are situated in an area with concentrations of 11 to 15, 16 to 20 and 21 to 25 µg/m³. A large part of the port of Antwerp has significantly elevated concentrations, largely caused by shipping, road traffic and industrial emissions. Urban agglomerations are also significantly negatively affected by building heating. Only near very busy roads and motorways are the values calculated so high that exceedances occur (e.g. along the Antwerp ring road). It should be noted that the legal limit values do not apply to the roads themselves or their verges. Furthermore, considerably higher concentrations are also calculated at tunnel mouths and along (busier) roads with contiguous buildings on both sides of the road, which can also lead to exceedances of the limit value.

Health advisory values are exceeded in much of the study area.

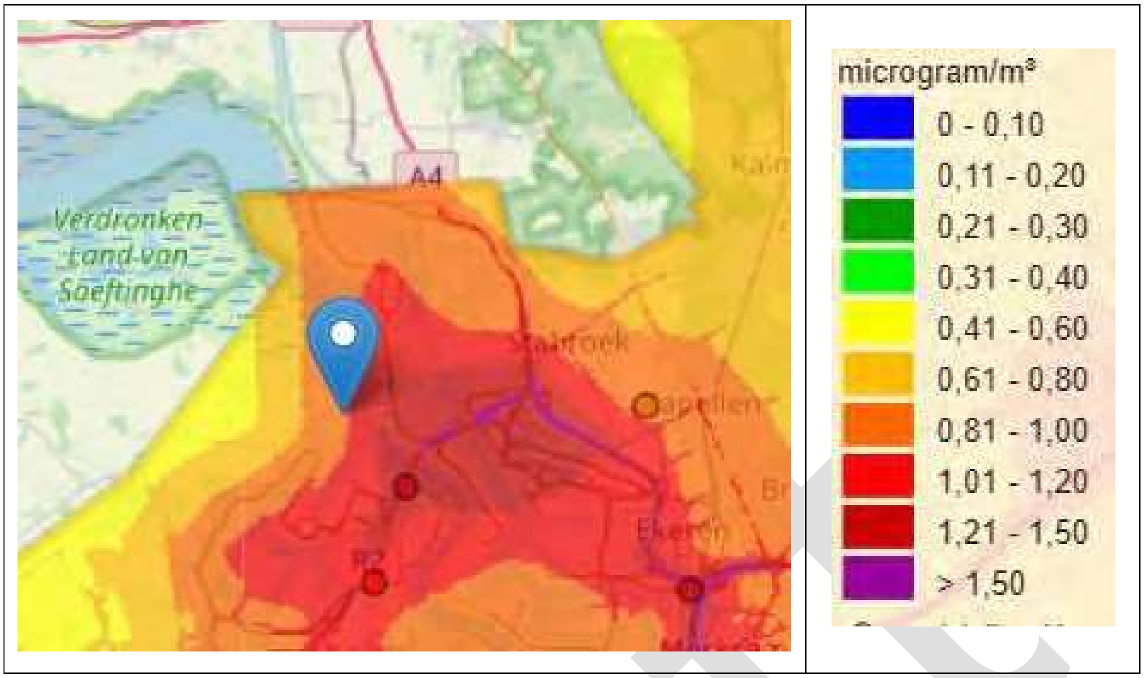

Figure 58: Annual average EC concentration in 2019 (source VMM).

Strong spatial variation is also observed for elemental carbon (EC) (parameter that can be considered as a measure of black carbon (BC: black Carbon) and for soot content), mainly caused by fossil fuel use. Neither limit nor target values apply to EC and BC. Large parts of the study area are located in an area with concentrations of 0.5 to 1 µg C/m³. Within larger urban agglomerations and within the port of Antwerp, even higher values are calculated, up to about 1.5 µg C/m³. Along the busiest roads, these concentrations are even higher.

Conclusions current air quality

Current air quality in the vicinity of the project area was evaluated For those parameters for which no measured data are known in or near the study area, an estimate of local air quality was performed based on literature and/or model data.

For the emissions/impact of fixed installations and transports, NO_x/NO_2 is the most important parameter. In terms of NO_2, the following conclusions can be formulated for the vicinity of the study area:

- A large spatial variation of NO_2 concentrations is observed, largely determined by road traffic, shipping, industrial emissions and building heating;
- The highest NO_2 concentrations are calculated in the immediate vicinity of the busiest (motor) roads. At these locations, exceedances of the annual average limit value of 40 µg/m³ occur (and of the WHO guideline value);
- Road traffic impacts do decrease relatively quickly with distance from the road;
- The VMM readings indicate that the hourly average limit (of 200 µg/m³), which may be exceeded 18 times per calendar year, is met;
- Shipping, in addition to industrial emissions within the Port of Antwerp, appears to be a very important source of the globally elevated NO_2 concentrations observed there.

For particulate matter (PM_{10} and $PM_{2.5}$), although the legal limits are met, there are exceedances of WHO advisory values. The concentrations of particulate matter do show much less spatial distribution.

Important local sources here, too, are industry and shipping.

1.4.3.2 Air quality in the reference situation

To map air quality in the reference situation, reference is made to the results of modeling background concentrations at a number of assessment points in the vicinity of the project area. Data from 2025 are used for this purpose.

Table 28: Concentrations 2025 at a number of assessment points in the vicinity of the project area at surrounding habitations, VMM monitoring stations and Dutch border (IMPACT model output).

				AG2025	AG2025	AG2025
				$_{NO2}$	$_{PM10}$	$PM2_{.5}$
		X	Y	avg	avg	avg
n°	assessment point	m	m	µg/m³	µg/m³	µg/m³
12	Zandvliet	146100	227500	23,5	19,2	12,7
13	Berendrecht-Hoefbladstraat	147100	226200	23,7	19,2	12,6
14	Berendrecht	145540	225450	30,1	20,4	14,1
15	Lillo	144510	221650	34,0	20,4	15,3
16	Fort Liefkenshoek	144160	220390	33,6	20,2	15,2
17	Target	142710	222380	28,8	19,5	14,4
18	Saftingen	140490	221730	19,1	18,4	12,8
19	Kieldrecht	136300	220400	13,4	18,4	11,7
20	Verrebroek	137500	216100	17,1	17,6	12,1
21	Vrasene	137600	212400	13,1	17,0	11,0
29	Zwijndrecht	147100	212000	23,3	17,8	11,6
30	Castle	148500	210900	26,0	18,3	11,8
31	L.O.	151000	213300	29,9	18,8	12,2
32	Antwerp	152200	211500	32,2	18,8	11,8
45 -MP	Antwerp Left Bank	150865	214046	29,6	18,9	12,3
51 -MP	Zandvliet-Scheldelaan	148139	215578	27,7	19,7	13,1
53 -MP	Berendrecht-Hoefbladstraat	147976	226558	21,1	18,5	11,8
54 -MP	Beveren-Meerminendam	141037	211484	16,2	17,0	11,0
57 -MP	Kallo Lock	143727	217020	31,8	19,5	14,1
58 -MP	Chapels Fort Street	155302	223403	21,3	17,0	10,7
60 -MP	Stabroek Laageind	149541	224212	24,8	19,1	12,3
Nl-1	Dutch border	137700	222700	15,2	16,8	13,0
Nl-2	Dutch border	140500	226400	19,8	17,1	13,5
Nl-3	Dutch border	142800	229500	21,1	18,4	13,1
Nl-4	Dutch border	147500	229700	16,3	17,2	11,0

The conclusions for 2025 are similar to those of the current situation: the legal limit values in terms of $_{NO2}$, $_{PM10}$ and $PM2_{.5}$ are met. However, the health advisory values are generally exceeded.

Further in time (2030/2035), it can be assumed that overall background concentrations will decrease even further because of policy constraints and the expected tightening of emission standards.

1.4.4 Description of effects

The non-nuclear impact on air quality in the operation of the site is mainly caused by:

- fixed combustion devices (conducted emissions);
- potential emissions from maintenance work (fugitive and conducted emissions);
- transport / movement of workers (fugitive emissions).

Initially, current emissions are mapped. Then, based on projections for the planned situation, the expected emissions after 2025 are identified and assessed.

1.4.4.1 Current emissions

Fixed installations

Fixed installation charged are:

- Combustion devices;
- Machinery used for maintenance work;
- Refrigeration plants;
- Cooling tower.

The actual impact of the entire site is mainly influenced by the presence of permanently installed combustion plants. Here the conducted emissions come from different combustion plants: auxiliary steam boilers, emergency groups and heating plants. These plants are fueled by gas oil.

Judging from the permit status (permit with expiration date March 30, 2031l with reference M03/46003/46/2/M/4/CW), these are:

- 71 permanently installed engines with a total rated thermal input power of 247.943 MWth, broken down as follows: - D12: 75.6 MWth (4 x 6.2 MWth, 2 x 4.3 MWth, 2 X 6.1MWth, 5 X 6.0 MWth) - D3: 72.3 MWth (4 X 12.6 MWth, 2 x 2.4 MWth, 3 X 5.7 MWth) - D4: 59.7 MWth (3 X 12.6 MWth, 2 x 2.4 MWth, 3 X 5.7 MWth) - Site: 40.343 MWth (1 X 0.020 MWth, 1 X 0.025 MWth. 1 X 0.033 MWth, 1 X 0.034 MWth, 4X0.044 MWth, 2 X 0.066 MWth, 1 X 0.103 MWth, 2 X 0.125 MWth, 5 X 0.234 MWth, 5 X 0.5 MWth, 4 X 4 MWth,11 X 1.7 MWth, 3 X 0.4 MWth)

- 2 auxiliary steam boiler combustion plants with a thermal capacity of 43.26 MWth each and **1 heating plant** with a thermal capacity of 0.204 MWth (total 86.724 MWth).

Under normal conditions, the auxiliary steam is supplied by the units in service. If this is not possible, the 2 auxiliary steam boilers can take over the function.

The emergency groups operate on gas oil and provide an assured electrical supply to the safety, emergency and auxiliary installations in case the external electrical supply should be unavailable. Under normal conditions, these installations are not in operation. Periodically, however, they are tested to check their availability. This limits the running hours of all these installations, as well as their emissions.

According to Title II of VLAREM, no emission limit values are applicable for combustion plants not fed with solid fuel, if the number of operating hours is less than 100 per calendar year.

No validated results of emission measurements are available from these installations. The legal requirement for such measurements depends on the capacity of the individual plants (each with its own emission point, which was not indicated by the licensing authority as a composition of plants), and the number of operating hours on an annual basis. The applicable emission limit values are also linked to this.

Measurement data for the auxiliary steam boiler are available from a technical maintenance of the i-installation. Although not performed by an accredited laboratory, these measurements are taken into account in the impact assessment, as the emissions calculated from them can be considered more accurate compared to the use of emission figures.

Table 29: Results emissions auxiliary steam boiler when tested after burner adjustment (Saacke report dd 19/10/2021) with both burners operating simultaneously

Testing Saacke		at current $_{O2}$		at 3% $_{O2}$		
	$_{O2}$	CO	NOx	CO	NOx	temp.
tax	%-full	mg/Nm³ dr	mg/Nm³ dr	mg/Nm³ dr	mg/Nm³ dr	°C
0%	7.2	0	179	0	233	162
10%	7.3	0	232	0	305	172
20%	6	0	252	0	302	175
30%	6.2	0	241	0	293	176
40%	5.8	8	300	9	355	177
50%	6.4	4	218	5	269	179
60%	6.2	20	211	24	257	181
70%	5.3	34	263	39	302	188
80%	4.7	73	273	80	301	187
85%	4.3	76	274	82	295	185
average	5.9	21	244	24	291	178

The frequency and duration of engine testing depends on the function of the diesel generator (auxiliary diesel, safety diesel, emergency diesel, diesel generators GUM).

The operating time of the auxiliary steam boilers, given the presence of several reactors, is also limited on an annual basis.

The impact of these plants is almost exclusively in terms of $_{NOx/NO2}$, and to a much lesser extent in terms of $_{SO2}$, CO and dust.

The current impact is contained in the current air quality as mapped by VMM based on measurements and calculations. The emissions from the plants are so limited that no demonstrable impact can be determined from VMM's model maps.

Since in the planned situation most of these plants will no longer be in service, it is considered of little use to model the impact of these plants in the current situation based on emission and impact calculations. However, this will be done for the situation when the project is implemented.

In addition to combustion plants, a number of machines with potentially occurring emissions used in maintenance works can also be reported. In principle, this only concerns smaller works. Larger works in the field of wood and metal processing are outsourced.

The maintenance workshop is equipped with smaller machines for the mechanical treatment of metals and the manufacture of objects from metal (forge), such as welding-blasting booth, lathe, drilling machine, sawing machines. The emissions from such installations are basically released diffusely into the workshop, except for welding fumes, which are extracted. Larger welding jobs are outsourced, however.

The workshops also include facilities for the mechanical treatment and manufacture of articles of wood (Joinery with drilling machines, milling machines, panel machines, trimming machines, edge-gluing machines, among others ....). Diffuse emissions can also occur from these installations, which can be emitted through an extraction system. The total power/capacity of these installations is so low, and their use so limited, that no demonstrable impact is expected at the boundaries of the site, even if the extractors are not equipped with dust filters.

No emission measurement values are available from these installations. The powers and capacities are so limited, and their use is so sporadic, that no emissions occur that are expected to exceed the thresholds above which the general Vlarem- II emission limits become applicable.

In view of the very limited operation of these installations (in the context of maintenance work), their very limited power/capacity and the fact that the relative emissions of such installations are very limited, no demonstrable impact is expected from these installations outside the boundaries of the site, even if the exhaust systems were not equipped with dust filters. Especially since the mechanical activities mainly generate coarse dust that quickly settles in the workshop, so that only a limited part can be emitted through the building ventilation.

Emissions may also occur when degreasing metals or metal objects using organic solvents. These emissions also occur diffusely in the workplace and can be emitted through the building ventilation. The total consumption of organic solvents is so limited that no demonstrable impact is expected beyond the boundaries of the site.

Degreasing of large establishments is done externally. In the workhouses there are local degreasing devices based on biocircle L and biocircle L ultra CMS 34627. Of the latter, 2 * 200 l were purchased in 2022. These products contain only relatively limited amounts of organic substances, then with limited vapor pressure, so the amount of volatile organic compounds (VOCs) released into the air can be considered negligible.

A workshop for repairing motor vehicles (including body work) is also present. During such repairs, emissions of dust and volatile organic solvents are possible. However, the use of these facilities is so limited that no demonstrable impact is expected at the level of the property boundaries.

Accidental leak emissions can also occur from refrigeration plants. Based on the legal obligations to record refrigerant refills, leak emissions can be estimated.

Table 30: Summary of leakage losses.

Date refill	PKD code device	type refriger ant gas	kg refill in period 2020-2022	Employed until
15/01/2020	Scaldis CIAT right side B	R410A	88.4 kg	2038
1/04/2020	D3/CF-ML0029	R134A	1.2 kg	2025
2/04/2020	D3/CF-ML1020	R134A	33 kg	2025
1/04/2020	D0/0VE-FA4	R407C	15kg	2029
23/06/20	D4/CF-ML0026	R134A	4.9kg	2038
17/09/2020	D3/CF-ML0018	R134A	14.12 kg	2025
30/07/2020	D3/CF-ML0019	R134A	13.7 kg	2025
5/11/2020	D4/VK-PP0090	R134A	2 kg	2038
20/01/2020	D4/CF-ML0029	R134A	13.59 kg	2038
29/10/2020	D4/CF-ML0029	R134A	5.5 kg	2038
5/06/2020	CGB - refrigeration kitchen	R410A	11kg	2038
14/07/2020	MAG - fire department garage	R410A	0.6kg	2025
17/12/20	D4/CF-ML1010	R134A	15.4 kg	2038
20/05/20	MAG - 034	R410A	1.7 kg	2025
18/01/21	D3/CF-ML0027	R134A	19.4 kg	2025
27/01/21	D4/CF-ML0026	R134A	4.51 kg	2038
02/03/21	D3/CF-ML0018	R134A	2.8 kg	2025
16/02/21	D3/CF-ML0019	R134A	1.9 kg	2025
12/04/21	D4/CF-ML0019	R134A	6.5 kg	2038

06/05/21	D3/CF-ML0019	R134A	9.71 kg	2025
17/03/21	D4/CF-ML1010	R134A	50.5kg	2038
04/11/21	WPG - 135 (Vinçotte) (DS/VOG006)	R410A	2.9 kg	2025
03/01/21	D0/0VE-FA4	R407C	10 kg	2029
16/12/21	D3/CF-ML1020	R134A	1.8 kg	2025
11/01/22	DS/VAG-ML0825	R410A	1.8 kg	2038
11/04/2022	D3/CF-ML0026	R134A	3.12 kg	2025
9/04/2022	D4/CF-ML0023	R134A	3.4 kg	2038
9/05/2022	D3/CF-ML0019	R134A	3.7 kg	2025
16/05/22	SOC-103	R410A	3.5 kg	2038
02/06/22	D4/CF-ML0018	R134A	5.93 kg	2038
26/07/2022	D4/CF-ML0018	R134A	1.42 kg	2038
25/07/2022	D3/CF-ML0018	R134A	20 kg	2025
15/06/22	Refrigerator kitchen	R134A	0.25 kg	2038
22/08/22	D4/CF-ML1020	R134A	23.92 kg	2038
08/09/22	D4/CF-ML0019	R134A	20.06 kg	2038
17/10/2022	DT/CFV-ML0003	R410A	21.3 kg	2038
24/10/2022	D0/CF0E87B	R134A	107.75 kg	2029
10/11/2022	D3/AF-ML0100	R410A	18.17 kg	2025
16/11/2022	D0/0VE-FA3	R407C	26.9 kg	2029
8/12/2022	DT/CFV-ML0003	R410A	21.3 kg	2038
06/12/22	WDG server room	R410A	0.46 kg	2038

No detectable impact is expected from the recorded leakage emissions at the level of the property boundaries.

Hydrazine is also used at the site. Emissions of this could cause an odor impact (NH_3-like odor), given the relatively low odor threshold (approx. 2 to 3 ppm). Delivery is made according to a well-defined procedure which always guarantees that the stored concentration does not exceed 5% (first water and then 15% delivery added). There are also water locks on the tanks that catch the breathing of the tanks. These water locks are refreshed at specific intervals so that the concentration in them does not become too high. The use of N_2H_2 is limited in slight overconcentration. In the presence of air, the product disintegrates into nitrogen and water. In wastewater, the smaller residues also react away. Higher concentrations are used when conditioning steam generators at shutdown. Residues from these discharges may be found in the wastewater. Besides hydrazine, ammonia is also dosed. The concentrations are also low. Given the measures taken and the nature of the consumption, possible emissions of hydrazine and NH_3 into the air can be considered negligible. No (odor) impact is expected outside the boundaries of the site.

No demonstrable impact on air quality is expected from the very limited consumption of other substances such as e.g. H_2SO_4 (e.g. in water treatment) either.

One emission source with potential air quality impacts is the cooling tower, and the potential emissions of salt aerosols that may be associated with it.

The cooling circuits of the Doel 3 and 4 units are partly closed cooling circuits, meaning that cooling water circulates between the cooling tower and the condenser. Supplementation (and additional cooling) also occurs through the continuous supply (and discharge) of Scheldt water. In the cooling tower, part of the cooling water evaporates. With this evaporation and atomization, aerosols are also released into the air. These aerosols also contain salt concentrations from the brackish water of the Zeeschelde River. In fact, the potential impact of these salt aerosols will diffuse into the ambient air and potentially lead to locally increased salt concentrations. However, due to the very significant emission height (over 140 m), these salt aerosols will be very much diluted before some of them would be at ground level. No annual average concentrations are hereby expected in the immediate vicinity to exceed the particulate matter-bound salt concentrations as they occur at the coast due to dispersion. On the coast, the proportion of $_{PM10}$ originating from salts is about 4 to 6 µg/m³. This concentration decreases systematically inland. Based on previous studies also referred to in the EIR by Arcadis (2021), there is therefore an acceptable impact.

Moreover, the Arcadis EIR calculates a salinity of the circulation water in the cooling towers (which is pumped from the Scheldt) of 20 g/l, which is a pessimistic estimated annual average, given that measurements over the period 2010-2019 show a maximum salinity of the pumped Scheldt water of about 10.8 g/l (Arcadis, 2021). An average value of 10 g/l could therefore be assessed as more realistic.

Current impact traffic to and from the site

In total, the number of transports by truck is estimated at 2370/year. On average per calendar day, this means at most 14 transport movements. Even if these were all heavy trucks, and they all followed the same route, no demonstrable impact on air quality is expected from this number of transports.

The number of employees at the site of Electrabel nv Kerncentrale Doel amounts to approximately 1000 own personnel. To this must be added 1000 permanent contractors.

These are people who work during the day and in a full-time shift system. During overhaul works, the number of outside workers can reach 2,000 people.

Collective transportation is organized via buses that pick up own employees via pick-up rounds. The use of bicycles is promoted. External employees usually travel by collective transportation organized by their employer.

All these movements will at most temporarily have a limited impact on air quality in the immediate vicinity of the road to and from the site near the site itself (along those road segments where all the traffic passes). Once this traffic is distributed in different directions, it is no longer expected to have a demonstrable impact on air quality.

1.4.4.2 Emissions and impact in the planned situation

The initial time horizon for the planned situation is 2025.

The buildings are heated with auxiliary steam generated by the power plants in service (or by auxiliary steam boilers if none are in service). Under DECOM program (not LTO program), new ways of heating the buildings are envisaged. Since no data are yet available on this, it is not included further in this report.

When mapping the emissions in the planned situation, not only the plants linked to the operation of Doel 4 are taken into account but also all other plants that will still be operational on the site. In this sense, the total cumulative impact linked to the phasing out of the other plants is assessed, and not only the specific impact of Doel 4. In fact, it can even be assumed that if Doel 4 is shut down, most of the emissions calculated for the planned situation will still occur at that time, since many of the existing installations still need to be operational and therefore still need to be tested periodically, as is the case after the shutdown of Doel 3 and the expected shutdown of Doel 1 - 2 for the installations linked to it (see overview of operation forecasts for the various installations). Keeping Doel 4-temporarily in service will therefore cause (much) less additional emissions until about 2035/2037 than the emissions mapped for the planned situation. Also the impact calculated assuming emissions in the planned situation is therefore not purely the result of keeping Doel 4 open.

Impact fixed installations in the planned situation

In the planned situation, only a limited number of plants remain in service.

As for the emergency groups, it can be assumed that they will be in service at a similar frequency and duration.

In contrast, auxiliary steam boilers can be expected to be in service more frequently and for longer periods than in the current situation (during the overhaul of Doel 4, the frequency of which is once a year). The relative emissions from auxiliary steam boilers are considerably lower than those from internal combustion engines, however.

In the short term, it is not expected that one or more of the installations remaining in service will be replaced by new ones. Emissions mapping can therefore be based on emission characteristics as applied in the past.

Due to lack of results of emission measurements, the impact is assessed on the basis of fuel consumption and emission factors. For the emission factors, the emission factors used in the previous MER (Arcadis, 2021: EIA Doel Nuclear Power Plant for Life Extension Doel 1 and 2).

As described earlier, in order to provide the necessary certainty that no underestimate is obtained, it is assumed that the diesel engines will operate slightly more hours compared to the situation in 2022.

Table 31: Overview of combustion plants in planned situation (from 2025).

Evolution installations in service (v = installation in service in that year)																				
	Functional element	**Description**	**Power [MWth]**	**Type**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
Doel 1 / 2	PKD-D1/DG11	DIESEL-ALTERNATOR GROUP 11 (CONTAINER DG)	4.3	diesel engine	v	v	v	v	v	v										
	PKD-D2/ED22	DIESEL-ALTERNATOR GROUP 21 (CONTAINER DG)	6.1	diesel engine	v	v	v	v												
	PKD-D2/DG21	EMERGENCY DIESEL 12 D1/GNS	4.3	diesel engine	v	v	v	v	v	v										
	PKD-D1/ED12	EMERGENCY DIESEL 22 D2/GNS	6.1	diesel engine	v	v	v	v												
	PKD-D0/DGS12	PACKAGE DIESELGRP DGG POLARI 12	6.79	diesel engine	v	v	v	v												
	PKD-D0/DGS22	PACKAGE DIESELGRP DGG POLARI 22	6.79	diesel engine	v	v	v	v												
	PKD-D0/DGS24	PACKAGE DIESELGRP DGG POLARI 24	6.79	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-D0/DGS99	PACKAGE DIESELGRP DGG POL 99(PHI)	6.79	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
Doel 3	PKD-D3/ES-DG0012	AUXILIARY DIESEL GMH	2.4	diesel engine	v	v	v	v	v	v										
	PKD-D3/ES-DG0022	AUXILIARY DIESEL GMH	2.4	diesel engine	v	v	v	v	v	v										
	PKD-D3/ES-DG0001	SAFETY DIESEL R	12.6	diesel engine	v	v	v													
	PKD-D3/ES-DG0004	SAFETY DIESEL PHI	12.6	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v				
	PKD-D3/KE-DG0001	BUNKERDIESEL R	5.7	diesel engine	v	v	v													
	PKD-D3/KE-DG0003	BUNKERDIESEL B	5.7	diesel engine	v	v	v													
Doel 4	PKD-D4/ES-DG0022	AUXILIARY DIESEL GMH	2.4	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-D4/ES-DG0012	AUXILIARY DIESEL GMH	2.4	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-D4/ES-DG0001	SAFETY DIESEL R	12.6	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-D4/ES-DG0002	SAFETY DIESEL G	12.6	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v			
	PKD-D4/ES-DG0003	SAFETY DIESEL B	12.5	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v			
	PKD-D4/KE-DG0001	BUNKERDIESEL R	5.7	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-D4/KE-DG0002	BUNKERDIESEL G	5.7	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v			
	PKD-D4/KE-DG0003	BUNKERDIESEL B	5.7	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
WAB	PKD-DT/ABN	auxiliary steam boiler	43.126	steam boiler	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DT/ABZ	auxiliary steam boiler	43.126	steam boiler	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
Miscellaneous	PKD-DS/FU-ML0010	BURNER HEATING MAI	0.204	boiler	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-D0/FE0P2	DIESEL FIRE PUMP	0.125	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-D0/FE0P12004	DIESEL FIRE PUMP FEG202	0.400	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-D0/FE0P12005	DIESEL FIRE PUMP FEG203	0.400	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-D0/FE0P12006	DIESEL FIRE PUMP FEG204	0.400	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	-	-	-	-																
	PKD-DS/SIT-PP0002	PUMP. MOB. REFILL.DOCKS GNH AND RWST D12	0.044	diesel engine	v	v	v	v												
	PKD-DS/SIT-PP0031	PUMP. MOB. REFILL.PRIM.CIRCUIT.AND.SP.DOEL3	0.234	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v				

	PKD-DS/SIT-PP0041	PUMP. MOB. REFILL.PRIM.CIRCUIT.AND.SP.DOEL4	0.234	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v				

Evolution installations in service (v = installation in service in that year)																				
	Functional element	**Description**	**Power [MWth]**	**Type**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
	PKD-DS/SIT-PP0044	PUMP. MOB. REFILL.STEAMGENERATORS DOEL4	0.234	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v				
	PKD-DS/SIT-PP0051	SPARE PUMP MOB.REFILL. 200M³/H	0.044	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-PP0052	SPARE PUMP MOB.REFILL. 130M³/H	0.234	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0031	BEST DIESEL GROUP D34 GEH-BKR 500kVA	1.700	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0032	BEST DIESEL GROUP D34 GEH-BKR 500kVA	1.700	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0041	BEST DIESEL GROUP D34 GEH-BKR 500kVA	1.700	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0042	BEST DIESEL GROUP D34 GEH-BKR 500kVA	1.700	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0050	BEST DIESEL GROUP D34 GEH-BKR 500kVA	1.700	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0006	BEST DIESEL NPK-OTSC 400kVA	0.500	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0007	BEST DIESEL NPK-OTSC 400kVA	0.500	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0008	BEST RESERVE DIESEL GROUP 400kVA	0.500	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/NPD-PK0002	EMERGENCY DIESEL GROUP V DS/B-LVS-LVG0004	0.103	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0001	BEST DIESEL GROUP D12 GNS 500kVA	1.700	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0011	BEST DIESEL GROUP D12 GEH 500kVA	1.700	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0021	BEST DIESEL GROUP D12 GEH 500kVA	1.700	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	PKD-DS/SIT-DG0002	BEST DIESEL COMPUTER LOCAL ADG032 10kVA	0.010	diesel engine	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v

Table 32: Projected operating hours and fuel consumption in 2022 and extrapolation to projected situation in 2025.

	Functional element	Running hours [h] 2022	Running hours [h] max. planned	gasoil consumption [m^3] 2022	gasoil consumptio n m^3 max.planned
Objective 1 / 2	PKD-D1/DG11	4.0	5	0.91	1.1
	PKD-D2/ED22	1.1	2	0.33	0.6
	PKD-D2/DG21	7.4	10	1.69	2.3
	PKD-D1/ED12	54.0	65	16.98	20.5
	PKD-D0/DGS12	33.3	40	11.67	14.0
	PKD-D0/DGS22	23.3	30	8.16	10.5
	PKD-D0/DGS24	25.6	30	9.00	10.5
	PKD-D0/DGS99	25.0	30	8.77	10.5
Doel 3	PKD-D3/ES-DG0012	18.4	25	1.75	2.4
	PKD-D3/ES-DG0022	176.7	210	16.80	20.0
	PKD-D3/ES-DG0001	31.7	40	22.15	28.0
	PKD-D3/ES-DG0004	79.9	100	55.91	70.0
	PKD-D3/KE-DG0001	66.0	80	18.75	22.7
	PKD-D3/KE-DG0003	35.4	45	10.07	12.8
Doel 4	PKD-D4/ES-DG0022	17.0	20	1.62	1.9
	PKD-D4/ES-DG0012	17.0	20	1.62	1.9
	PKD-D4/ES-DG0001	39.2	50	27.43	35.0
	PKD-D4/ES-DG0002	33.4	40	23.37	28.0
	PKD-D4/ES-DG0003	87.3	105	61.08	73.5
	PKD-D4/KE-DG0001	86.4	105	24.56	29.8
	PKD-D4/KE-DG0002	1.1	2	0.31	0.6
	PKD-D4/KE-DG0003	102.0	120	29.00	34.1
WAB	PKD-DT/ABN	0.0	0	0.00	0.0
	PKD-DT/ABZ	79.5	156	179.96	353.1
Various	PKD-DS/FU-ML0010	N/A		1.61	1.9
	PKD-D0/FE0P2	10.0	15	0.20	0.3
	PKD-D0/FE0P12004	119.2	145	3.55	4.3
	PKD-D0/FE0P12005	7.0	10	0.21	0.3
	PKD-D0/FE0P12006	8.1	10	0.24	0.3
	PKD-DS/SIT-PP0002	1.3	2	0.01	0.01
	PKD-DS/SIT-PP0031	1.4	2	0.04	0.1
	PKD-DS/SIT-PP0041	5.4	10	0.17	0.3
	PKD-DS/SIT-PP0044	1.7	2	0.05	0.1
	PKD-DS/SIT-PP0051	1.3	2	0.01	0.01
	PKD-DS/SIT-PP0052	1.1	2	0.03	0.1
	PKD-DS/SIT-DG0031	2.0	5	0.14	0.3
	PKD-DS/SIT-DG0032	2.0	5	0.14	0.3
	PKD-DS/SIT-DG0041	3.0	5	0.20	0.3
	PKD-DS/SIT-DG0042	3.0	5	0.20	0.3

	Functional element	Running hours [h] 2022	Running hours [h] max. planned	gasoil consumption [m^3] 2022	gasoil consumptio n m^3 max.planned
	PKD-DS/SIT-DG0050	3.0	5	0.20	0.3
	PKD-DS/SIT-DG0006	3.0	5	0.16	0.3
	PKD-DS/SIT-DG0007	3.0	5	0.16	0.3
	PKD-DS/SIT-DG0008	3.0	5	0.16	0.3
	PKD-DS/NPD-PK0002	0.6	2	0.01	0.03
	PKD-DS/SIT-DG0001	3.0	5	0.20	0.3
	PKD-DS/SIT-DG0011	3.0	5	0.20	0.3
	PKD-DS/SIT-DG0021	4.0	5	0.27	0.3
	PKD-DS/SIT-DG0002	0.0	2	0.00	0.003

Emissions are calculated using the emission factors as included in Arcadis and NRG's EIA regarding the postponement of the deactivation of Doel 1 and Doel 2 (2021).

Since there is no visibility as to whether or not the emissions from the most recent plants meet the more stringent emission numbers used in the Arcadis EIR, to be on the safe side, the emissions from all emergency generators and diesel groups are calculated using the emission numbers as used for the oldest plants.

In fact, an additional argument for using one set of key figures is also contained in the fact that actual emissions when engines are tested differ significantly from emissions during normal and long-term operation. Combustion temperature is an important factor here. Thus, significantly higher PM and CO emissions, as well as lower NO_x emissions compared to emissions at normal operation, should always be taken into account at start-up. With increasing temperature, NOx emissions systematically increase, and PM and CO emissions systematically decrease.

Since the emissions from these plants are almost exclusively related to test phases, it can be assumed that the actual NO_x emissions can most likely be relevantly lower than the assumptions used.

Therefore, the impact on NO_2 and on acidifying and fertilizing deposition will also most likely be overestimated.

Only on the basis of emission measurements is it considered possible to obtain a clearer picture of the actual emissions. The mapped emissions are therefore to be regarded as indicative values only.

Table 33: Emission factors used for (indicative) mapping of emissions from stationary diesel engines (source: Arcadis/NRG 2021)

Polluent	Dieselmotoren	
Bouwjaar	1982, 1984[13]	Eenheid
CO	12,2	kg/m³ diesel
NO_x	56,2	kg/m³ diesel
SO_x	3,74	kg/m³ diesel
PM_{10}	4,01	kg/m³ diesel
$PM_{2,5}$	4,01	kg/m³ diesel

For SO_2, however, the emission factor mentioned above is not used, as it is still based on the use of gas oil with a higher S content. The emissions are mapped on the basis of the maximum S content present in the fuel, which can therefore be regarded as a worst-case estimate.

This is because part of the S will not be converted to SO_2 but may end up as SO_4 in dust emissions, among other things. To the extent that S-poor gasoil would be used, SO_2 emissions will be even significantly lower.

The emissions from the (auxiliary) boilers are calculated based on the measurement data listed above, obtained during technical maintenance of deinstallation.

For the further time horizon (after 2025), a decrease in emissions due to the systematic further decommissioning of plants is taken into account. The results of the calculations are shown in Table 34 through Table 36.

Compared to the current situation, and in order to provide additional certainty that emissions are not underestimated, more operating hours are assumed than those recorded for 2022. This was done because in the past the number of operating hours also fluctuated.

For the auxiliary steam boilers, the number of operating hours is assumed to nearly double compared to 2022. Indeed, due to the elimination of Doel 1, 2 and 3, the slightly more frequent operation is expected.

Total emissions in 2025 and 2026 can be considered very limited.

Against the applicable reporting requirements in Flanders (IMJV), only slightly relevant emissions for NOx appear to be just over 50% of the threshold. Even if the actual emissions of CO and PM were twice as high as estimated (due to the higher emissions occurring at each start-up of the plant), these emissions can hardly be called relevant.

Only limited lower emissions are calculated in 2026 compared to 2025.

Further down the road, emissions will continue to decrease. If some of the engines should be replaced with new ones, emissions will decrease even further.

Table 34: Projected emissions of combustion gases from fixed installations for 2026

2026	**CO**	**NOx**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**
auxiliary steam boilers	ton/year	ton/year	ton/year	ton/year	ton/year
	0.1	1.02	0.025	0.018	0.018
generators	ton/year	ton/year	ton/year	ton/year	ton/year
Doel 1/2	0.86	3.94	0.01	0.28	0.28
Doel 3	1.90	8.76	0.01	0.62	0.62
Doel 4	2.50	11.51	0.02	0.82	0.82
various	0.11	0.53	0.00	0.04	0.04
total generators	5.4	24.7	0.04	1.8	1.8
Total	**ton/year**	**ton/year**	**ton/year**	**ton/year**	**ton/year**
total	**5.5**	**25.8**	**0.1**	**1.8**	**1.8**
IMJV threshold	200	50	100	20	10
Share to IMJV threshold	%	%	%	%	%
	2.7	51.5	0.1	8.9	17.8

Table 35: Projected emissions of combustion gases from fixed installations for 2030

2030	**CO**	**NOx**	**SO2**	**PM10**	**PM2.5**
auxiliary steam boilers	ton/year	ton/year	ton/year	ton/year	ton/year
	0.1	1.02	0.025	0.018	0.018
generators	ton/year	ton/year	ton/year	ton/year	ton/year
Doel 1/2	0.43	1.97	0.00	0.14	0.14
Doel 3	1.13	5.19	0.01	0.37	0.37
Doel 4	2.50	11.51	0.02	0.82	0.82
various	0.11	0.53	0.00	0.04	0.04
total generators	4.2	19.2	0.0	1.4	1.4
Total	**ton/year**	**ton/year**	**ton/year**	**ton/year**	**ton/year**
	4.3	**20.2**	**0.1**	**1.4**	**1.4**
IMJV threshold	200	50	100	20	10
share of IMJV threshold	%	%	%	%	%
	2.1	40.4	0.1	6.9	13.9

Table 36: Estimated expected emissions of combustion gases from fixed installations for 2035

2035	**CO**	**NOx**	**SO2**	**PM10**	**PM2.5**
auxiliary steam boilers	ton/year	ton/year	ton/year	ton/year	ton/year
	0.1	1.02	0.025	0.018	0.018
generators	ton/year	ton/year	ton/year	ton/year	ton/year
Doel 1/2	0.26	1.18	0.00	0.08	0.08
Doel 3	0.85	3.93	0.01	0.28	0.28
Doel 4	2.50	11.51	0.02	0.82	0.82
various	0.11	0.53	0.00	0.04	0.04
total generators	3.7	17.2	0.0	1.2	1.2
Total	**ton/year**	**ton/year**	**ton/year**	**ton/year**	**ton/year**
	3.8	**18.2**	**0.1**	**1.2**	**1.2**
IMJV threshold	200	50	100	20	10
share of IMJV threshold	%	%	%	%	%
	1.9	36.3	0.1	6.2	12.4

By 2035, compared to 2025, a decrease in NO_x, CO and PM emissions is expected of more than 30 %, attributable to the systematic retirement of several diesel engines.

The impact of permanently installed incinerators is calculated for 2026 using the Flemish government's dispersion model IMPACT. The impact calculations take into account the 2025 model background concentrations.

Since the inspection characteristics of not all installations are known, and since it is not possible to enter each installation in the model as a separate source (due to the very limited number of operating hours per installation), the model calculation is based on simplified source configurations (in terms of location, height, etc.). When defining the model-based emission height, the fact that the KC Doel site is about 6 m higher than the surrounding area is also taken into account.

Assumptions were also used for the flue gas temperature, i.e. 178 °C for the steam boilers, based on measurement data from Saacke after maintenance work), and 350 °C for the diesel engines. (For long-term operation of these installations, higher temperatures can be assumed, but since the installations are almost only effectively in operation during tests, a lower average temperature should be assumed).

In addition, a hypothetical distribution of effective operating hours spread over the year is used for the emission sources, because the actual emission periods are not known. As a result, it is also not considered possible to calculate the impact on the higher percentile values in a responsible manner. The impact is therefore only assessed on the basis of annual average impact. This is calculated at a number of selected assessment points in the vicinity of the project area (residential areas, VMM monitoring stations, and assessment points near the Dutch border).

For the purpose of the biodiversity discipline, depositions are also calculated. For a discussion of this, see the biodiversity chapter.

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Table 37: Model characteristics used in impact and deposition calculations.

	X	**Y**	**h**	**Equivalent diameter**	**Temp.**	**Model hours**
	m	*m*	*m*	*m*	℃	*number /y*
Doel 1/2	142447	223502	27	0.5	350	261
Doel 3	142311	223866	40	0.5	350	521
Doel 4	142247	224048	37	0.6	350	521
various 1	142430	223600	20	0.15	350	261
several 2	142200	224150	20	0.15	350	261
auxiliary steam boiler	142048	223916	46	1.2	178	156

The highest impact occurs in the NO direction, because of the prevailing W-SW winds.

No demonstrable/relevant impact is expected near the Dutch border. At the other assessment points, the impact on air quality can also be considered negligible (less than 1% of the limit or test value used in the impact assessment).

Note that in the NO_2 impact calculations, where the chemical conversion of NO to NO_2 is taken into account, and where the impact concerning NO_2 is calculated based on the difference in calculated impact in the planned situation, minus the impact in the reference situation, increased model uncertainties occur compared to e.g. the calculation of the NOx impact (as sum NO + NO_2 expressed as NO_2). This explains the negligible negative impact calculated at some assessment points.

Table 38: Calculation of impact in the planned situation based on estimated emissions 2026

				AG2025	AG2025	AG2025	project +AG2025	project +AG2025	project +AG2025	project	project	project	project	project
				NO2	PM10	PM2.5	NO2	PM10	PM2.5	NO2	PM10	PM2.5	CO	SO2
		X	Y	avg	avg	avg	avg	avg	avg	avg	avg	avg	P99.9	avg
n°	**assessment point (BP)**	**m**	**m**	**µg/m³**	**µg/m³**	**µg/m³**	**µg/m³**	**µg/m³**	**µg/m³**	**µg/m³**	**µg/m³**	**µg/m³**	**µg/m³**	**µg/m³**
1	Putte-1	152100	227500	13.0	13.8	9.6	13.0	13.8	9.6	0.0	0.000	0.000	0	0.000
3	Kalmthout	157200	231300	14.4	15.3	9.9	14.4	15.3	9.9	0.0	0.000	0.000	0	0.000
4	Maria Ter Heide	160600	223700	17.8	15.8	10.0	17.8	15.8	10.0	0.0	0.000	0.000	0	0.000
5	Chapels-1	154500	221100	24.2	18.0	11.1	24.1	18.0	11.1	-0.1	0.000	0.000	0	0.000
7	Stabroek-1	149800	224700	23.3	18.6	11.9	23.1	18.6	11.9	-0.2	0.000	0.000	0	0.000
9	Hoevenen-1	152700	221900	25.2	18.0	11.3	25.1	18.0	11.3	-0.1	0.000	0.000	0	0.000
11	Ekeren	153280	219290	30.2	19.4	11.9	30.1	19.4	11.9	-0.1	0.000	0.000	0	0.000
12	Zandvliet	146100	227500	23.5	19.2	12.7	23.4	19.2	12.7	-0.1	0.002	0.002	2	0.000
14	Berendrecht	145540	225450	30.1	20.4	14.1	29.9	20.4	14.1	-0.1	0.001	0.001	2	0.000
15	Lillo	144510	221650	34.0	20.4	15.3	33.8	20.4	15.3	-0.1	0.001	0.001	3	0.000
16	Fort Liefkenshoek	144160	220390	33.6	20.2	15.2	33.5	20.2	15.2	-0.1	0.001	0.001	2	0.000
17	Target	142710	222380	28.8	19.5	14.4	28.8	19.5	14.4	0.0	0.003	0.003	5	0.000
18	Sattingen	140490	221730	19.1	18.4	12.8	19.1	18.4	12.8	0.0	0.001	0.001	3	0.000
19	Kieldrecht	136300	220400	13.4	18.4	11.7	13.4	18.4	11.7	0.0	0.001	0.001	1	0.000
20	Verrebroek	137500	216100	17.1	17.6	12.1	17.2	17.6	12.2	0.1	0.000	0.000	0	0.000
21	Vrasene	137600	212400	13.1	17.0	11.0	13.1	17.0	11.0	0.1	0.000	0.000	0	0.000
22	Beveren	142300	211500	15.7	17.1	10.9	15.8	17.1	10.9	0.1	0.000	0.000	0	0.000
23	Kallo-1 center	143700	215900	27.9	19.0	13.3	28.2	19.0	13.3	0.3	0.000	0.000	0	0.000
29	Zwijndrecht	147100	212000	23.3	17.8	11.6	23.5	17.8	11.6	0.2	0.000	0.000	0	0.000
30	Castle	148500	210900	26.0	18.3	11.8	26.2	18.3	11.8	0.2	0.000	0.000	0	0.000
31	L.O.	151000	213300	29.9	18.8	12.2	30.3	18.8	12.2	0.3	0.000	0.000	0	0.000
32	Antwerp	152200	211500	32.2	18.8	11.8	32.4	18.8	11.8	0.2	0.000	0.000	0	0.000
43 -MP	Ekeren-Ekersedijk	151187	219057	33.1	21.0	13.1	33.1	21.0	13.1	0.0	0.000	0.000	0	0.000
45 -MP	Antwerp Left Bank	150865	214046	29.6	18.9	12.3	29.6	18.9	12.3	0.0	0.000	0.000	0	0.000
51 -MP	Zandvliet-Scheldelaan	148139	215578	27.7	19.7	13.1	27.7	19.7	13.1	0.0	0.000	0.000	0	0.000

				AG2025	AG2025	AG2025	project +AG2025	project +AG2025	project +AG2025	project	project	project	project	project
				NO2	PM10	PM2.5	NO2	PM10	PM2.5	NO2	PM10	PM2.5	CO	SO2
		X	Y	avg	avg	avg	avg	avg	avg	avg	avg	avg	P99.9	avg
n°	assessment point (BP)	m	m	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
53 -MP	Berendrecht-Hoefbladstraat	147976	226558	21.1	18.5	11.8	21.1	18.5	11.8	0.0	0.001	0.001	1	0.000
54 -MP	Beveren-Meerminendam	141037	211484	16.2	17.0	11.0	16.2	17.0	11.0	0.0	0.000	0.000	0	0.000
57 -MP	Kallo Lock	143727	217020	31.8	19.5	14.1	31.8	19.5	14.1	0.0	0.000	0.000	0	0.000
58 -MP	Chapels Fort Street	155302	223403	21.3	17.0	10.7	21.3	17.0	10.7	0.0	0.000	0.000	0	0.000
60 -MP	Stabroek Laageind	149541	224212	24.8	19.1	12.3	24.8	19.1	12.3	0.0	0.000	0.000	1	0.000
Nl-1	Dutch border	137700	222700	15.2	16.8	13.0	15.3	16.8	13.0	0.0	0.000	0.000	1	0.000
Nl-2	Dutch border	140500	226400	19.8	17.1	13.5	19.8	17.1	13.5	0.0	0.001	0.001	3	0.000
Nl-3	Dutch border	142800	229500	21.1	18.4	13.1	21.1	18.4	13.1	0.0	0.001	0.001	1	0.000
Nl-4	Dutch border	147500	229700	16.3	17.2	11.0	16.3	17.2	11.0	0.0	0.001	0.001	1	0.000
	maximum calculated thv BP			35.2	22.2	15.3	35.2	22.2	15.3	0.3	0.003	0.003	5	0.000
	GW/TW			40.0	40.0	20.0	40	40.0	20.0	40.0	40.0	20.0	10000	50.0

Table 39: Relative impact in the planned situation based on estimated emissions 2026 calculated as percentage contribution relative to limit or test values

				AG2020	AG2020	AG2020	project +AG2020	project +AG2020	project +AG2020	project	project	project	project	project
				NO2	PM10	PM2.5	NO2	PM10	PM2.5	NO2	PM10	PM2.5	SO2	SO2
				avg	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg
	relative impact to GW/TW			%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW
1	Putte-1	152100	227500	32	34.4	48.1	32	34.4	48.1	0.0	0.0	0.0	0.00	0.0
3	Kalmthout	157200	231300	36	38.3	49.7	36	38.3	49.7	0.0	0.0	0.0	0.00	0.0
4	Maria Ter Heide	160600	223700	44	39.6	49.9	44	39.6	49.9	0.0	0.0	0.0	0.00	0.0
5	Chapels-1	154500	221100	61	44.9	55.5	60	44.9	55.5	-0.2	0.0	0.0	0.00	0.0
7	Stabroek-1	149800	224700	58	46.4	59.5	58	46.4	59.5	-0.5	0.0	0.0	0.00	0.0
9	Hoevenen-1	152700	221900	63	45.1	56.5	63	45.1	56.5	-0.3	0.0	0.0	0.00	0.0
11	Ekeren	153280	219290	75	48.4	59.7	75	48.4	59.7	-0.3	0.0	0.0	0.00	0.0
12	Zandvliet	146100	227500	59	48.1	63.6	59	48.1	63.6	-0.3	0.0	0.0	0.02	0.0
14	Berendrecht	145540	225450	75	51.0	70.6	75	51.0	70.6	-0.4	0.0	0.0	0.02	0.0
15	Lillo	144510	221650	85	51.1	76.4	85	51.1	76.4	-0.3	0.0	0.0	0.03	0.0
16	Fort Liefkenshoek	144160	220390	84	50.6	75.8	84	50.6	75.8	-0.2	0.0	0.0	0.02	0.0
17	Target	142710	222380	72	48.8	71.9	72	48.8	71.9	0.0	0.0	0.0	0.05	0.0
18	Sattingen	140490	221730	48	45.9	64.0	48	46.0	64.0	0.0	0.0	0.0	0.03	0.0
19	Kieldrecht	136300	220400	33	46.0	58.4	34	46.0	58.5	0.1	0.0	0.0	0.01	0.0
20	Verrebroek	137500	216100	43	43.9	60.7	43	43.9	60.8	0.3	0.0	0.0	0.00	0.0
21	Vrasene	137600	212400	33	42.4	54.8	33	42.4	54.8	0.2	0.0	0.0	0.00	0.0
22	Beveren	142300	211500	39	42.6	54.4	40	42.6	54.4	0.3	0.0	0.0	0.00	0.0
23	Kallo-1 center	143700	215900	70	47.4	66.4	70	47.4	66.4	0.6	0.0	0.0	0.00	0.0
29	Zwijndrecht	147100	212000	58	44.6	58.2	59	44.6	58.2	0.4	0.0	0.0	0.00	0.0
30	Castle	148500	210900	65	45.9	58.8	66	45.9	58.8	0.6	0.0	0.0	0.00	0.0
31	L.O.	151000	213300	75	47.1	60.8	76	47.1	60.8	0.9	0.0	0.0	0.00	0.0
32	Antwerp	152200	211500	80	46.9	59.1	81	46.9	59.1	0.5	0.0	0.0	0.00	0.0
43 -MP	Ekeren-Ekersedijk	151187	219057	83	52.4	65.5	83	52.4	65.5	0.0	0.0	0.0	0.00	0.0
45 -MP	Antwerp Left Bank	150865	214046	74	47.1	61.4	74	47.1	61.4	0.0	0.0	0.0	0.00	0.0
46 -MP	Antwerp-Airball	153884	216790	77	48.6	59.4	77	48.6	59.4	0.0	0.0	0.0	0.00	0.0

				AG2020	AG2020	AG2020	project +AG2020	project +AG2020	project +AG2020	project	project	project	project	project
				NO_2	PM10	PM2.5	NO_2	PM10	PM2.5	NO2	PM10	PM2.5	SO2	SO2
				avg	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg
	relative impact to GW/TW			%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW	%-GW/ TW
51 -MP	Zandvliet-Scheldelaan	148139	215578	69	49.3	65.5	69	49.3	65.5	0.0	0.0	0.0	0.00	0.0
53 -MP	Berendrecht-Hoefbladstraat	147976	226558	53	46.2	58.8	53	46.2	58.8	0.0	0.0	0.0	0.01	0.0
54 -MP	Beveren-Meerminendam	141037	211484	40	42.5	54.9	40	42.5	54.9	0.0	0.0	0.0	0.00	0.0
57 -MP	Kallo Lock	143727	217020	79	48.8	70.7	79	48.8	70.7	0.0	0.0	0.0	0.00	0.0
58 -MP	Chapels Fort Street	155302	223403	53	42.5	53.6	53	42.5	53.6	0.0	0.0	0.0	0.00	0.0
60 -MP	Stabroek Laageind	149541	224212	62	47.8	61.4	62	47.8	61.4	0.0	0.0	0.0	0.01	0.0
Nl-1	Dutch border	137700	222700	38	42.0	64.9	38	42.0	64.9	0.0	0.0	0.0	0.01	0.0
Nl-2	Dutch border	140500	226400	49	42.8	67.7	49	42.8	67.7	0.0	0.0	0.0	0.03	0.0
Nl-3	Dutch border	142800	229500	53	46.1	65.7	53	46.1	65.7	0.0	0.0	0.0	0.01	0.0
Nl-4	Dutch border	147500	229700	41	42.9	55.1	41	42.9	55.2	0.0	0.0	0.0	0.01	0.0
	maximum calculated thv BP			88	55.5	76.4	88	55.5	76.4	0.9	0.0	0.0	0.05	0.0

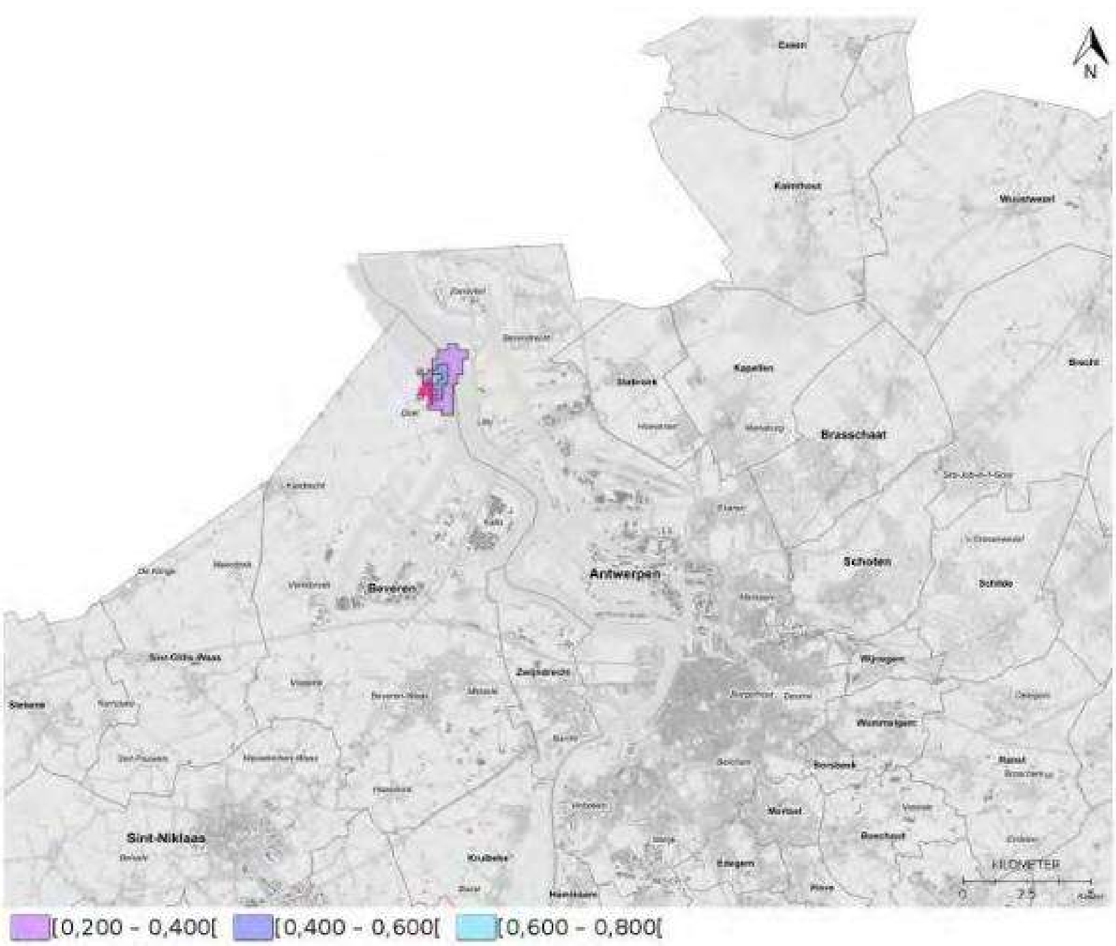

Figure 59: Presentation of calculated annual average impact in terms of NOx equivalents µg/m³ in the planned situation 2026 (NOx equivalents = sum of NO + $_{NO2}$ expressed as $_{NO2}$).

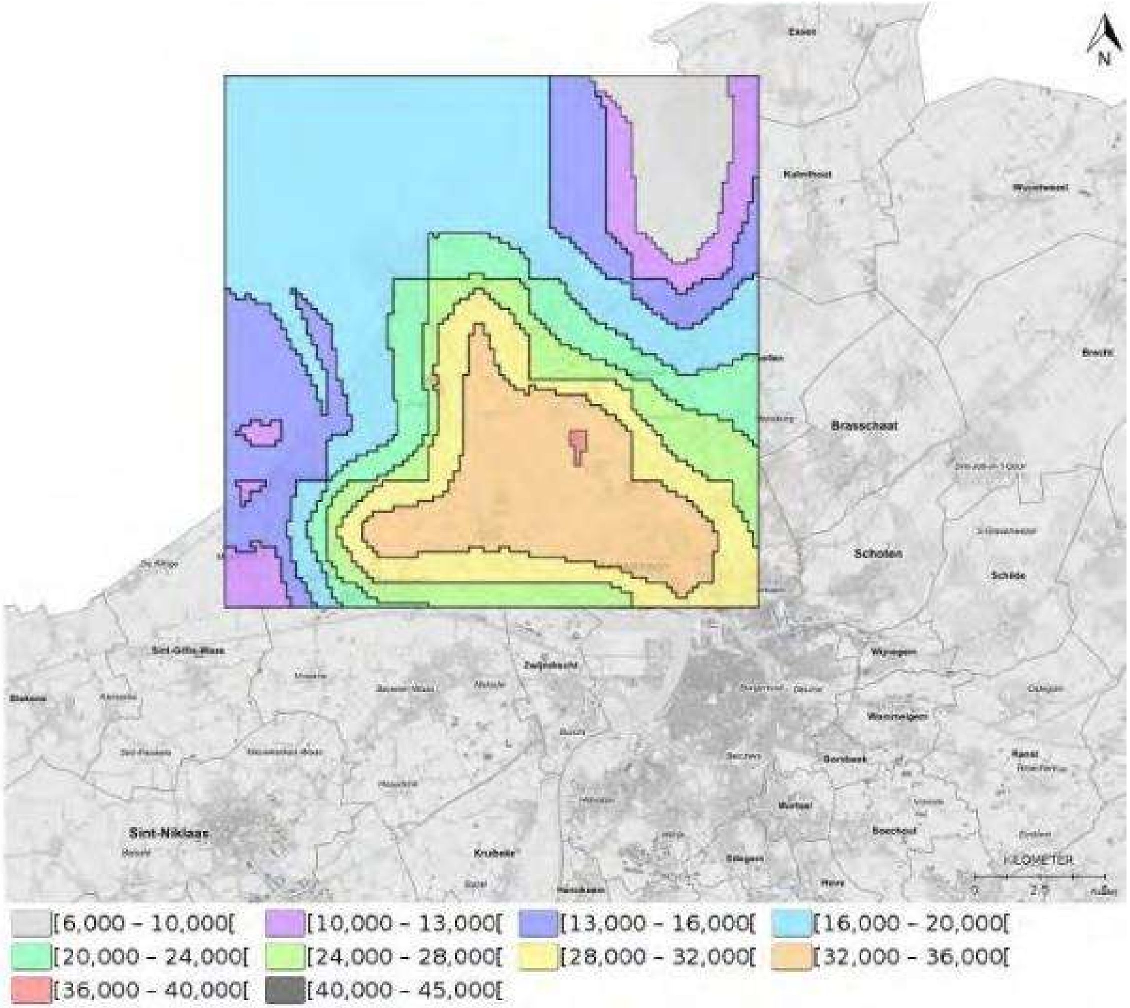

Figure 60: Annual average $_{NO2}$ concentration in µg/m³ in planned situation (impact 2026 + background concentrations 2025).

It can be assumed that no relevant changes are expected after 2025 with respect to the current situation. The impact of possible emissions outside the property boundaries is assessed as negligible, and will therefore not be discussed further.

With regard to the **cooling plants**, and possible leakage losses, the forecast of possible emissions can be performed based on the 2022 registrations. With proper maintenance, leakage emissions are not expected to increase significantly after 2025. The impact of these emissions can also be assessed as negligible beyond the property boundaries, and will therefore not be discussed further (except for the following overview of emission estimation based on 2020-2022 data).

Table 40: Overview of potential leakage losses after 2025.

Date refill	PKD code device	refrigerant gas type	kg refill in 2020-2022	Employed until
15/01/2020	Scaldis CIAT right side B	R410A	88.4 kg	2038
1/04/2020	D0/0VE-FA4	R407C	15kg	2029
23/06/20	D4/CF-ML0026	R134A	4.9kg	2038
5/11/2020	D4/VK-PP0090	R134A	2 kg	2038
20/01/2020	D4/CF-ML0029	R134A	13.59 kg	2038
29/10/2020	D4/CF-ML0029	R134A	5.5 kg	2038
5/06/2020	CGB - refrigeration kitchen	R410A	11kg	2038
17/12/20	D4/CF-ML1010	R134A	15.4 kg	2038
27/01/21	D4/CF-ML0026	R134A	4.51 kg	2038
12/04/21	D4/CF-ML0019	R134A	6.5 kg	2038
17/03/21	D4/CF-ML1010	R134A	50.5kg	2038
03/01/21	D0/0VE-FA4	R407C	10 kg	2029
11/01/22	DS/VAG-ML0825	R410A	1.8 kg	2038
9/04/2022	D4/CF-ML0023	R134A	3.4 kg	2038
16/05/22	SOC-103	R410A	3.5 kg	2038
02/06/22	D4/CF-ML0018	R134A	5.93 kg	2038
26/07/2022	D4/CF-ML0018	R134A	1.42 kg	2038
15/06/22	Refrigerator kitchen	R134A	0.25 kg	2038
22/08/22	D4/CF-ML1020	R134A	23.92 kg	2038
08/09/22	D4/CF-ML0019	R134A	20.06 kg	2038
17/10/2022	DT/CFV-ML0003	R410A	21.3 kg	2038
24/10/2022	D0/CF0E87B	R134A	107.75 kg	2029
16/11/2022	D0/0VE-FA3	R407C	26.9 kg	2029
8/12/2022	DT/CFV-ML0003	R410A	21.3 kg	2038
06/12/22	WDG serverroon	R410A	0.46 kg	2038

Of the expected leakage emissions, no detectable impact is expected at the level of the property boundaries.

An emission source with potential impact on air quality is related to the cooling tower, and the possible emissions of salt aerosols. As emissions of salt aerosols also occurred in the past during the operation of Doel 3 via the cooling tower, the impact in the planned situation will be (considerably) lower than before. Given that the impact in the past was already assessed as acceptable, this will obviously also be the case in the planned situation.

Impact traffic to and from the site in the planned situation

In total, the number of transports by truck is estimated at 970/year. On average per calendar day, this means at most 6 transport movements. Even if these were all heavy trucks, all following the same route, no demonstrable impact on air quality is expected from this number of transports.

The number of employees at the Electrabel nv Doel nuclear power plant site will be lower than in the current situation if Doel 4 is kept in service only. We assume for the operation of Doel 4 about 370 own personnel and about 160 permanent contractors.

For the phasing out and decommissioning of the other units, there will obviously be additional in-house personnel and contractors. However, this number cannot be estimated at this time, so it is not considered possible to assess the cumulative impact.

However, since it can be assumed that vehicle emissions will still decrease significantly in the future (also due to the accelerated phasing out of fossil fuels), it is not expected that the commuting traffic will have a relevant impact on air quality along the roads to and from the site, even on those road segments along which all traffic must pass.

1.4.5 Assessment of impacts against policy objectives.

The emissions that occur, both currently, and the lower emissions in the planned situation, are so low that they certainly cannot jeopardize the feasibility of the 2030 emission targets. Moreover, with only Doel 4 in operation, a systematic decrease in emissions can be taken into account in the future.

As mentioned above, by 2035 a further decrease in emissions is expected by about 30% compared to the estimated emissions for 2025.

To the extent that electricity must be supplied by (partially) burning fossil fuels or biofuels when Doel 4 is not in service, this will create emissions many times higher than those emitted by the Doel site when Doel 4 is in service.

In order to estimate the extent of the **emissions avoided**, a comparison is made with the emissions that would occur if use were made of the newest types of natural gas-fired CCGT plants, such as those for which EIA reports have been drawn up in the context of CRM in the Flemish Region (for the Vilvoorde and Tessenderlo sites). These calculations take into account in the first instance the emissions that would occur if the sectoral emission limit values (ELVs) as applicable in the Flemish Region were just met. Because of the very significant emissions, the level to which these emissions can still be cost-effectively reduced was investigated during the EIA and permit procedures for both dossiers. An estimate of the avoided emissions is also made for this situation (after mitigation : MM).

This calculation is also based on an assumption of an annual average electricity production that should then be absorbed by the CCGT plants. This amount is estimated based on the average production of Doel 4 in recent years.

Table 41: Historical electricity production Doel 4.

Year	GWh	Load factor
2012	7.819	89%
2013	8.477	97%
2014	4.887	56%
2015	7.744	88%
2016	8.782	100%
2017	7.461	85%
2018	5.514	63%
2019	8.730	100%
2020	7.270	83%
2021	7.953	91%
Gem.	7.464	85%

Table 42: Estimated avoided emissions relative to using the latest generation of natural gas-fired CCGT plants

Type	EF	NOx	NH3	SO2
STEG-EGW (1)	kg NOX/GWhe	140	46	1.5
STEG-MM (2)	kg NOX/Gwhe	50	5	1.5
	MWh/year	ton/year	ton/year	ton/year
STEG-EGW (1)	7 500 000	1050	345	11
STEG-MM (2)	7 500 000	375	38	11

(1) : assuming net compliance with emission limits

(2) : assuming relevantly lower achievable emission levels than sectoral limits

Therefore, based on the estimate performed, it can be concluded that the avoided emissions are to a very significant extent higher than the emissions associated with keeping Doel 4 open longer.

To the extent that part of the electricity would not be filled by gas-fired power plants but by alternatives without combustion emissions, the avoided emissions will of course be lower to the same extent. But even then they will remain substantially higher than the emissions from keeping Doel 4 open longer.

1.4.6 Summary of key findings

The main sources with a potential impact on air quality are steam boilers and diesel engines. However, these permanently installed plants are in very limited operation.

When Doel 4 is purely in service, the number of operating hours of the boilers will increase significantly (quasi double), but even then the total number of effective operating hours remains limited.

Based on various assumptions and raising the number of operating hours from 2022, the emissions in the planned situation are estimated. The emissions calculated here can be estimated as (very) limited.

Here, the highest calculated emissions (for 2026) are used as model input to calculate the impact on air quality. Due to unavailability of the model characteristics of all installations, a number of assumptions are used in these calculations. The impact calculations show that the impact on ambient air quality is negligible (less than 1% of the limit or test values used). Nor are exceedances of limit values calculated taking into account the expected background concentrations. Therefore, there is no need to investigate mitigation measures.

To the extent that electricity must be supplied by (partially) burning fossil fuels or biofuels when Doel 4 is not in service, this will create emissions many times higher than those emitted by the Doel site when Doel 4 is in service.

In addition to incinerators, mention can also be made of dust emissions in workshops (in wood and metal processing), possible leakage losses from cooling plants, emissions of organic substances, among other things, when repairing motor vehicles, and degreasing metals, and emissions from the cooling tower (salts). However, no relevant impact is expected from any of these sources.

Transportation and traffic to and from the site is also not expected to have a relevant impact on air quality along the relevant roads.

Overall, therefore, there is negligible impact on air quality.

1.4.7 Mitigating measures

No mitigation measures are considered necessary.

1.4.8 Gaps in knowledge and monitoring

The main gaps in knowledge are in the area of emissions from incinerators, as neither measured values nor model characteristics are known. By using emission factors from the literature and assumptions, these gaps are filled in. However, this leads to an increased uncertainty regarding the results of the impact calculations. But even taking this into account, the impact can be assessed as negligible.

1.5 Theme Climate

1.5.1 Relevant policy objectives

In terms of greenhouse gas emissions, Europe distinguishes between emissions covered by the European Emissions Trading Scheme (ETS) on the one hand and other (non-ETS) emissions on the other.

In 2016, as part of its Nationally Determined Contribution (NDC), the European Union made a commitment to achieve at least a 40% reduction in its total greenhouse gas emissions by 2030, compared to emissions in the year 1990[67]. To achieve this goal, a 43% reduction was assumed in the ETS sector on the one hand and a 30% reduction in the non-ETS sector on the other, both compared to the year 2005.

At the member state level, targets only apply to *non-ETS emissions* (transport, buildings, waste and agriculture). Through the Effort Sharing Regulation, the EU 30% reduction target for Belgium was translated into a 35% reduction (in 2030, compared to 2005). This percentage was adopted by Flanders in the Flemish Energy and Climate Plan (VEKP) 2021-2030[68].

However, as part of the European Green Deal, the European Union recently raised its ambitions to reduce greenhouse gas emissions by 55% by 2030; climate neutrality should be achieved by 2050. The increase in the European 2030 reduction target from 40 to (at least) 55 % obviously also has implications for member states' targets. In July 2021, the Commission published a proposal for adaptation of the "Effort Sharing Regulation" proposing new reduction targets for the various member states. For Belgium, this amounts to an increase in the original target from 35% to 47% reduction (in 2030 versus 2005).

However, the present project is not captured by the 35% reduction target included in the VEKP (or by any other reduction target based on the Effort Sharing Regulation), as these relate only to the non-ETS sector.

The *ETS* is governed by Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, originally published on Oct. 13, 2003, but regularly amended since its adoption. ETS applies inter alia to "Combustion of fuel in installations with a total rated thermal input exceeding 20 MW" (cf. Annex I to Directive 2003/87/EC), thus also to the present project. The concrete implementation of this Directive is regulated by various (European) Decisions and Regulations. These have also been (partially) transposed into Flemish regulations, e.g.

[67] See European Climate and Energy Framework 2030.

[68] Preparation of the FECP is in the framework of Article 3 of Regulation (EU) 2018/1999 of the European Parliament and of the Council of December 11, 2018, on energy union governance and climate action, which requires each Member State to submit to the Commission by December 31, 2019, an integrated National Energy and Climate Plan covering the period from 2021 to 2030.

in Vlarem, DABM and the Environmental Permitting Decree. In Flanders, the Environment Department has been designated as the competent authority under the EU ETS.

Since 2005, the European Emissions Trading System has been the cornerstone of the EU strategy to reduce greenhouse gas emissions from industry and from power and heat generation. About 45% of all greenhouse gases emitted by the EU are now covered by this system. The system assumes that through market forces (with the use of tradable emission allowances) under a defined "cap" (emission ceiling) of allowances), greenhouse gas emissions from the installations concerned can be reduced in the most efficient way. By gradually creating more "scarcity" in the allowance market (by phasing out the "cap"), the allowances increase in value and create an incentive to seek the most cost-effective way to reduce GHG emissions. Distribution of allowances is done primarily through auctions, but partly still through free allocation, the latter mainly to avoid "carbon leakage." However, free allocation has not applied to the electricity sector since 2013.

As indicated above, the European Climate and Energy Framework 2030 aimed to achieve a 43% reduction for the ETS sector by 2030 (compared to emissions in the year 2005), for the entire Union. So there are no specific targets at the member state level for the ETS sectors. The intention is to encourage ETS sectors to reduce greenhouse gas emissions in a level playing field at the EU level. A recent major revision of Directive 2003/87/EC (via Directive (EU) 2018/410), applicable for the period 2021-2030 (Fourth Trading Period), aims to meet this ETS target. This includes a stricter reduction path, with emission allowances being reduced by 2.2% per year from 2021 (in the Third Trading Period this was 1.74%).

On Dec. 11, 2019, the European Commission announced its "Green Deal," which 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 needed (globally) if global warming is to be limited to 1.5°C above pre-industrial levels. The European Parliament expressed support for the Commission's proposals on Jan. 15, 2020. On December 11, 2020, the European Council also endorsed a binding target to achieve a net reduction of greenhouse gas emissions in the EU of at least 55% by 2030, compared to 1990.

It is obvious that if these policy ambitions are translated into regulation, this will also have consequences for the targets within the ETS system. The ambitions in that area were set out in a proposal by the EP and Council to amend 2003/87/EC. This proposal includes a further increase in the annual linear reduction factor (to 5.1% from 2024 and to 5.38% from 2028), and an extension of the system to the Transport and Buildings sectors. This modified ETS system is expected to start in 2027.

In addition to policies on greenhouse gas emissions, the need for climate adaptation must also be taken into account. At European level, there are no generally applicable operational objectives for this, which is not surprising given that adaptation needs must be defined at the local level par excellence. Flanders does have an adaptation plan for the period 2021-2030, which was recently approved by the Flemish government.

Also relevant is EIA Directive 2011/92/EU as amended by Directive 2014/52/EU. As indicated earlier, Annex IV of that (amended) Directive states that an environmental impact assessment must include, in addition to a description of the project's impact on climate, an assessment of the *project's vulnerability to climate change*.

In summary, within the framework of the present EIA, an assessment of the following criteria is done within the discipline of Climate:

- The extent to which greenhouse gas emissions are reduced as a result of the project;

- The extent to which the project affects the resilience of the environment to the impacts of climate change;
- The extent to which the project itself is robust in a climate change context.

1.5.2 Relevant effects and cause-effect relationships

The Project that is the subject of the environmental assessment has a number of potential relationships to the achievement or non-achievement of the policy objectives summarized above.

In summary, these are the following relationships:

1. The Doel site contains a number of facilities that are the source of greenhouse gas emissions. These are primarily emergency diesel pumps and generators. These are not operational under normal conditions, but their operation is regularly tested. During those tests, CO_2 is generated. Some of these installations are specifically attributable to Doel 4.
2. In addition to these emissions, greenhouse gas emissions that are avoided by the deferral of deactivation must also be assumed, in the sense that if deactivation were not deferred, production capacity would have to be replaced by other sources (which would have been at least partly fossil).
3. Due to its significant surface area, the plant may have an effect on the resilience of its environment to the effects of climate change, in terms of heat phenomena or heavy precipitation, for example.
4. The plant itself may be susceptible to the effects of climate change such as flooding, flooding or heat.

Items 1 and 2 relate to the policy objective of "reducing greenhouse gas emissions," item 3 to the policy objective of "increasing environmental resilience," and item 4 to the policy objective of "reducing project vulnerability."

The following pages discuss each of these points in more detail.

1.5.3 Delineation of study area and description of reference situation

The project area corresponds to the sum of all locations where interventions take place or situations are changed or perpetuated. Within this project area, the sensitivity of the environment to the effects of climate change is assessed, as well as changes in emissions (or sequestration) of CO_2 and, where relevant, other greenhouse gases. The primary focus is on emissions from installations within the perimeter of the Doel site. Emissions due to e.g. traffic to and from the power plant are not considered at this strategic level. Vulnerability to the effects of climate change is also assessed within the project area.

As far as greenhouse gas emissions are concerned, no study area is delineated in terms of impact receptors since climate change caused by greenhouse gas emissions is a global phenomenon and its impact is also felt globally.

Avoided greenhouse gas emissions can in principle occur anywhere in Belgium or, in the case of electricity imports, even abroad. Since the impact of these emissions is not determined by where they are generated, this is not relevant for the impact discussion.

1.5.4 Description of effects

1.5.4.1 Emissions from the power plant

As mentioned above, greenhouse gas emissions from the plant come primarily from the operation of a number of diesel engines (to drive emergency pumps and emergency generators) and from steam and boilers.

In addition, the release of various refrigerant gases through leaks must also be considered; these refrigerant gases are also greenhouse gases.

The greenhouse gas emission inventory of Doel Nuclear Power Plant identifies 59 diesel engines and combustion plants with a total installed thermal capacity of 316 MW. However, the number of hours these plants operate is (very) limited; in 2022 it fluctuated (depending on the plant) between 0 and 120 hours, with an average of about 52h per plant.

The inventory makes the distinction between the different reactors on the site, allowing to estimate separately the Doel 4 related greenhouse gas emissions. These include 8 diesel engines with a total installed capacity of nearly 60 MW (see Table 43).

Table 43: Fossil fuel engines unambiguously attributable to the operation of Doel 4.

Name	**Power (MWth)**	**Functio n**
PKD-D4/ES-DG0022	2,4	AUXILIARY DIESEL GMH
PKD-D4/ES-DG0012	2,4	AUXILIARY DIESEL GMH
PKD-D4/ES-DG0001	12,6	SAFETY DIESEL R
PKD-D4/ES-DG0002	12,6	SAFETY DIESEL G
PKD-D4/ES-DG0003	12,5	SAFETY DIESEL B
PKD-D4/KE-DG0001	5,7	BUNKERDIESEL R
PKD-D4/KE-DG0002	5,7	BUNKERDIESEL G
PKD-D4/KE-DG0003	5,7	BUNKERDIESEL B

Together, these plants operated about 383 hours in 2022.

In addition to installations that can be unambiguously assigned to Doel 1 and 2, Doel 3 or Doel 4, there are a number of installations for which this is not the case. Judging from the 2022 emissions inventory, these together account for 30% of the total greenhouse gas emissions from the plant. We allocate these emissions to the different reactors a ratio of their relative power. For Doel 4, this means that 35 % of the emissions not directly attributable are additionally allocated to this reactor.

The figures relating to refrigerant gas emissions apply to the plant as a whole; thus, again, we apply a factor of 35% to estimate Doel 4's share of these emissions.

Table 44 shows the greenhouse gas emissions for the site and for Doel 4 for the years 2015-2021, as deduced from the emission inventories of the various combustion plants and from the reporting of cooling gas leaks. Doel 4's share fluctuates from year to year, with a maximum share of 43% of total site emissions.

Table 44: Greenhouse gas emissions (tons $_{CO2eq/year}$) for Doel Nuclear Power Plant (KC Doel) and reactor Doel 4 for the period 2015-2021.

	2015	2016	2017	2018	2019	2020	2021
Greenhouse gas emissions KC Doel (combustion)	1.887	1.420	1.414	1.675	1.272	1.294	1.523
Greenhouse gas emissions KC Doel (refrigerant gases)	151	570	55	76	83	360	163
Greenhouse gas emissions Doel 4 (*)	604	622	428	570	578	497	653
Share of greenhouse gas emissions D4 on KCD	30 %	31 %	29 %	33 %	43 %	30 %	39 %
Production Doel 4 (GWh)	7.744	8.782	7.461	5.515	8.730	7.270	7.953
Relative greenhouse gas emissions Doel 4 ($_{gCO2eq/kWh}$)	0,0780	0,0708	0,0574	0,1033	0,0662	0,0684	0,0821

(*) Includes 35% of unattributable combustion emissions and of total emissions attributable to refrigerant gases.

If we express the emissions against the electricity produced we get a value that for the years under discussion roughly fluctuates between 0.060 and 0.1 grams of $_{CO2}$ per kWh. The calculated specific emission is relatively higher at lower production, which makes sense, since the emissions themselves are relatively constant and not related to the capacity produced.

By comparison, a latest-generation CCGT plant has emissions of about 320 g $_{CO2}$ per kWh, and the specific greenhouse gas emissions of Belgian electricity generation as a whole were 154 g CO2 eq./kWh in 2021 (EEA, 2022).

Figure 61 compares the latter figure with other EU member states. It clearly shows that the specific emissions of the Belgian electricity fleet for 2021 are much lower than, for example, the Netherlands (418 g $_{CO2eq/kWh}$) and Germany (402 g $_{CO2eq/kWh}$), both countries with a significant proportion of fossil energy (including coal and, in the case of Germany, lignite) still in their energy mix in 2021. Countries doing better than Belgium are those with significant nuclear capacity and/or hydroelectric capacity.

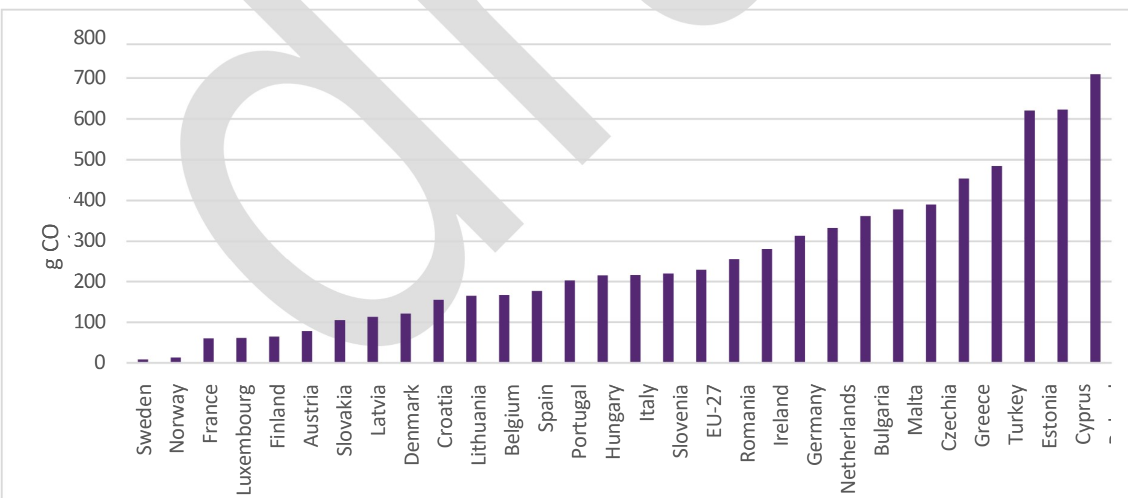

Figure 61: Greenhouse gas emission intensity (g $_{CO2eq/kWh}$)of the electricity sector for different EU member states, in 2020.

We can conclude that the CO2 emissions per unit of production of Doel 4 over the discussed period are three orders of magnitude smaller than the average emissions of the electricity production park in Belgium. This is obviously not surprising given the technology deployed. The emissions that do exist are not due to the normal operation of the plant, but to the test cycles of installations that are only used in emergency situations.

Even when looking at the life cycle emissions of nuclear power compare favorably with the emissions of most other forms of energy production. IPCC[69], based on a literature review, estimates the lifetime greenhouse gas emissions from nuclear power at between 3.7 and 110 g CO2-e/kWhe, with a median value of 12 g CO2-e/kWhe. Lenzen[70] (2008) estimates the CO2 intensity of nuclear power at between 10 and 130 g CO2-e/kWhe, with a median value of 65 g CO2-e/kWhe. Lenzen's figures include emissions associated with uranium mining and plant decommissioning. The life-cycle emissions of a nuclear power plant are at least 10 to 20 times lower than those of a thermal power plant, slightly lower than photovoltaics, and slightly higher than those of wind turbines.

To know how emissions will evolve during the period of lifetime extension of Doel 4, we need to know over what period each of the combustion plants at the site will continue to operate. After all, it is not only the plants directly associated with Doel 4 that will remain active; some of the plants that cannot be specifically assigned will also remain operational, and will therefore be regularly tested.

The necessary information for this was provided by Engie and can be found in Table 31 (Air discipline). This shows that of the 63 combustion plants present at the site in 2022, 31 will remain active throughout the life extension period. To calculate the annual emissions from those plants, each plant was assigned the average of its emissions over the 2011-2022 period for each year it was still active. For both auxiliary steam boilers, their operation is assumed to double from when only Doel 4 remains in operation, as argued in the Air discipline.

In combustion emissions, emissions from refrigerant gas leaks were counted. This was based on the average emissions for the period 2004-2021, which were 377 tons per year. An annual reduction factor corresponding to the percentage reduction factor of combustion emissions for that year was applied to this figure.

The course of the resulting emissions for the entire site is presented in the figure below. As a result of the higher operation of the auxiliary steam boilers from the time when only Doel 4 is still in operation, after an initial decrease we see a slight increase in the years 2026-2027, which is, however, reversed in the following years by the progressive retirement of the other plants.

[69] Steffen Schlömer (ed.), Technology-specific Cost and Performance Parameters, Annex III of Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014).

[70] Lenzen, M. Life cycle energy and greenhouse gas emissions of nuclear energy: A review. Energy Conversion and Management 49 (2008) 2178-2199.

Figure 62: Estimated evolution of direct greenhouse gas emissions from the Doel nuclear power plant between 2023 and 2040.

Since over the period 2027-2036 only the Doel 4 reactor will still be operating, it can be assumed that all greenhouse gas emissions over this period are somehow attributable to the operation of this reactor. The total emissions over this period amount to 13,857 tons $_{CO2eq}$, representing almost 0.08% of the total emissions of the energy sector in Belgium in the year 2021 (18,200 kton). These are the direct emissions resulting from keeping the Doel 4 reactor open for ten more years.

1.5.4.2 Avoided emissions from the power plant

Under this heading we discuss the emissions that would be generated if the Doel 4 reactor were to be permanently closed in 2025.

It is clear that the loss of nuclear capacity in Belgium will have to be at least partly absorbed by gas-fired power plants. Ember[71] estimated in 2020 that the carbon intensity of the Belgian electricity supply in 2030 would be 229 g CO2eq/kWh, an increase of almost 71% compared to the situation today. Belgium is thereby one of the few European countries where carbon intensity would increase rather than decrease. The reason for this, of course, is that even in 2030 the share of renewable energy will still be too low to compensate for the rapidly disappearing 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 63 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).

[71] Vision or division? What do National Energy and Climate Plans tell us about the EU power sector in 2030? EMBER, November 2020.

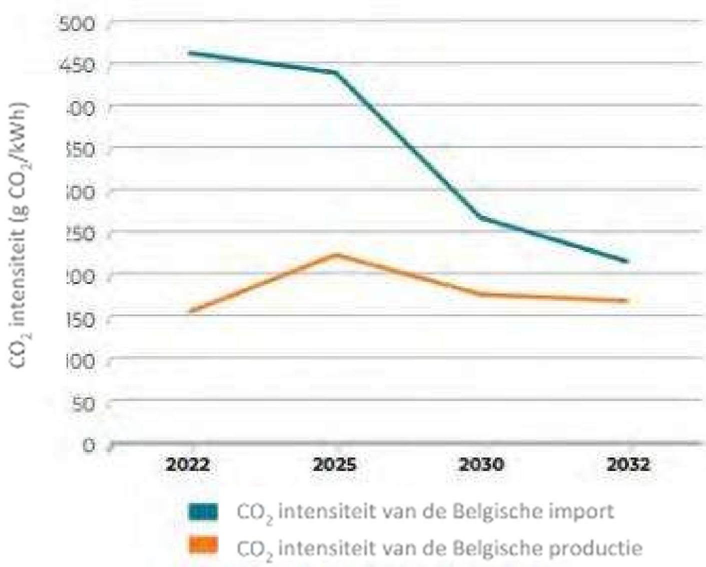

Figure 63: Projected carbon intensity of Belgian electricity production and imports (Elia).

In fact, as this figure shows, to know the carbon intensity of electricity use, one must also consider the carbon intensity of imported electricity. Here, however, we are interested in the carbon intensity of generation. As this figure also shows, Elia is a lot more optimistic (and probably more realistic) in this respect than Ember. The reason is that Elia, like Energyville, assumes a significantly lower share of gas than Ember. In 2032, Elia assumes 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 $_{CO2eq/kWh}$ in 2025 (after all nuclear power plants are shut down), but declines steadily 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.

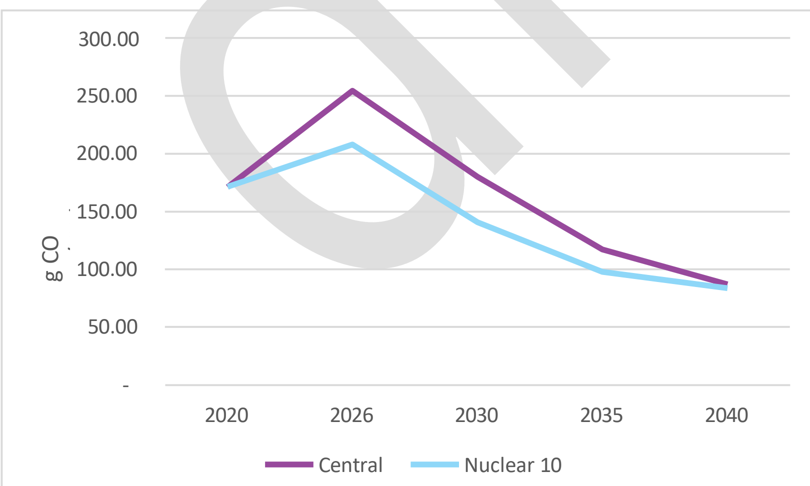

Figure 64: Evolution of carbon intensity of electricity generation under a scenario of full nuclear phase-out in 2020 (Central) and under a 10-year life extension scenario for 2 GW of capacity.

The course of this figure, for the "central" scenario is quite similar to the figure from 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 Figure 64, we obtain the data from the following table.

The table shows, by year from 2020 to 2040, the greenhouse gas emissions (in kton $_{CO2eq}$) corresponding to an annual production of 7,500 GWh of electricity, which is equivalent (rounded) to the average production of Doel 4 over the period 2012-2021) to the carbon intensity of electricity production in the same year.

Table 45: Estimated $_{CO2}$ emissions (in a scenario of full core exit in 2025 caused by the production of 7500 GWh of electricity per year, at the average carbon intensity of electricity production for each year.

	Central	
	gram CO2eq/KWh	Kton CO2eq
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 cumulative emissions over the period 2027-2036 correspond to the emissions that would not be emitted (and thus "avoided") if 7500 GWh of electricity based on nuclear production (Doel 4) would be produced. The value thus obtained is 12,417 kton or 12.42 Mton.

If we compare the emissions released from the operation of Doel 4 over approximately the same period (almost 14 kton), we can see that the emissions from Doel 4 over the period to which the deactivation deferral applies represent only 0.11% 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 lifetime extension of Doel 4 by 10 years thus leads to 12,417 kton less CO_2 emissions, or on average about 1242 kton/year. This amounts to annual savings equivalent to almost 10% of emissions in the electricity and heat production sector" in Belgium in the year 2021[72] (12.88 Mton). The annual amount saved decreases year after year over the lifetime extension period, as can be clearly seen from Table 45.

It is clear that the importance of "avoided emissions" is highly dependent on the assumed carbon intensity of energy production, and thus, among other things, on the share of renewable energy. In the calculations, this was accommodated through the insertion of a declining trend in carbon intensity from 2026 onwards.

1.5.4.3 Impact on environmental vulnerability

The question to be answered under this heading is to what extent keeping Doel 4 open longer may affect the vulnerability of the environment to the effects of climate change. Effects that could theoretically be relevant in this regard relate to stormwater management on the one hand and the creation of a heat island on the other.

As for the impact of **stormwater management,** reference can be made to the considerable paved area formed by the Doel nuclear power plant zone. Water falling on this area will not infiltrate into the soil and will therefore have to be collected and drained. This is of course currently being done (see description in Water discipline). As a result of climate change, showers may become more intense, which may result in the inability of the collection and drainage system to always process the precipitation. This may lead to local flooding. What this means for the plant site itself is discussed further below under the heading "Vulnerability of the Project to the Effects of Climate Change. The question is whether there could also be effects to the area surrounding the power plant. It can be argued that this will not be the case, since the stormwater will be drained in the direction of the Scheldt River (whose buffering capacity is considerable in relation to the volumes discharged), and not in the direction of the polders. Moreover, it is unlikely that the Doel 4 site would no longer be paved in the period 2027-2037 in case of deactivation, since the complete decommissioning of the plant may take at least 15 years.

The plant also forms a **heat island** in relation to its surroundings. This effect occurs because the site is largely paved and contains few trees that can provide shade or cooling through evaporation. The paving and buildings store heat during the day and gradually release it at night. As a result, the temperature on the site can be up to several degrees higher than in the surrounding polders. This effect is amplified as summers get warmer. This warming can be felt up to a distance of (at most) several hundred meters from the power plant. In practice, it does not matter for the period 2027-2037 whether Doel 4 is still in operation or not, since the Doel site as a whole will still be hardened during this period as a result of decommissioning activities, and will therefore contribute equally to the heat island effect.

Finally, reference can also be made to the **drought issue**, which will become more pressing as a result of climate change. The plant site today pays little attention to buffering and infiltration.

[72] The most recently available validated data is from 2020, but that was a Corona year, with noticeably lower emissions.

However, these practices will become more important as the climate becomes drier; they allow rainwater to be reused and/or used to feed groundwater, rather than draining into the Scheldt.

1.5.4.4 Vulnerability of the Project to the Effects of Climate Change

Two different issues are discussed under this heading:

- on the one hand, the impacts that the project itself may suffer as a result of climate change (in terms of, e.g., drought, flooding, etc.). An example is the availability of cooling water, which may decrease if the ambient and surface water temperatures rise too high;
- on the other hand, the extent to which project impacts, discussed elsewhere in this EIA, could change (be amplified or mitigated) as a result of climate change. For example, with increasing drought, flow rates in watercourses could be greatly reduced, and this could exacerbate the effects of a discharge by much less dilution than assumed.

Although these are two different types of effects, we treat them together here because the causes underlying them (heat, drought, flooding, etc.) are the same in both cases.

The present Project covers a clearly defined time period, which ends in 2037. The signs of a changing climate have become increasingly clear in recent decades and especially in recent years. The predicted and already observed evolutions will continue and also become more intense. Within the Project's reference period, it is therefore necessary to take into account:

- 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 winter rain (and possibly more flooding), but also noticeably drier summers;
- An increase in the peak precipitation intensity of short, bright showers, which can cause flooding;
- A rise in sea levels, resulting in a greater risk of flooding along the coast and estuaries;
- Higher wind speeds.

Most projections refer to future situations, in e.g. the year 2050 or even 2100. Such target years are obviously not relevant for the present project. The climate portal of the VMM (https://klimaat.vmm.be/) contains information per municipality, for a number of parameters also for the year 2030, which can be considered representative of the average situation over the period 2027-2037. It should be noted that the VMM projections are based on the so-called "high" Flemish climate scenario, which in practice means an evolution similar to the evolution of RCP 8.5, which is a rather pessimistic assumption.

Below we summarize the information available on the Climate Portal regarding the (maximum) expected changes in the municipality of Beveren by the year 2030. The comparison always refers to the situation in the year 2017:

- By 2030, the number of people within the vulnerable age groups (0-4 years and 65+) who may be affected by heat events will have increased by 52% compared to 2017;
- By 2030, the number of dry days per year will have increased from 171 in 2017 to 193;
- By 2030, the number of heat wave days will have increased from 4 in 2017 to 10.

For the Doel nuclear power plant, however, the main impacts of climate change are not related to heat or drought, but to flood risk, on the one hand from the Scheldt (due to sea level rise) and on the other hand due to increased peak intensity of precipitation. Both effects and a number of others were discussed in the report of the resistance tests conducted as part of the additional safety review of the facilities (Electrabel nv, 2011). In what follows we summarize its main findings. It is important to note that the degree of climate change taken into account in that report is beyond what is plausible in the year 2037. Nevertheless, it is still useful to present its results briefly, because they give an idea of the upper limit of the effects that can be expected.

Floods

To minimize the risk of flooding, two important measures were provided for in the design of the site: one, the entire site including all installations rests on an elevated platform, and two, the Scheldt dike that shields the site was raised by an additional meter. The highest Scheldt level ever recorded in our country is 8.10 m TAW (second general water level). The platform of the site was raised to 8.86 m TAW during construction. The levee along the site was raised to 12.08 m. A water level of 9.13 m TAW was established as Design Basis Flood (DBF). This DBF was chosen, based on studies known at design time, as a level with return period 10,000 years. Later, the water level with a return period of 10,000 years was reevaluated at (on average) +9.35 m TAW at the site. However, this is still well below the dike crest. All structures, systems and components, including the internal power supply in case of emergency, are indiscriminately protected from the DBF.

Flooding of the dike is therefore extremely unlikely, even in the event of a continued rise in sea level (the effects of which will probably only become potentially relevant in the second half of this century). However, dike failure at the most critical point of the dike could already occur with a return period of 1,700 years. In such a situation, water levels averaging 20 cm could occur at the site, with local water depths of up to 60 cm.

Wave overtopping of the levee can occur with a return period of 200 to 300 years. For a return period of 10,000 years, this can give rise to an average of about 10 cm of water at the site, with locally higher or lower values as well. The study in question examined the impact of this on the safe operation of the site. Water seepage was found to be possible in three buildings, albeit without consequences for the safety functions. In the event of a levee breach, the number of locations where flooding could occur would increase. Again, the second level of safety is maintained in all circumstances. Nevertheless, the resistance testing report suggested a number of additional measures to further increase flood safety, such as providing permanent barriers at critical building entrances. In practice, this involves the installation of perimeter protection of several tens of centimeters in height at the entrances to the safety buildings in question.

The platform on which the entire site is built is surrounded by 5-meter lower polders. In the event of a dike breach, there is a real possibility that these polders will be flooded. In such a situation, the Doel site becomes an island. In the event of such a flood, evacuation and access of persons and the supply of fuel for safety systems and emergency diesels, among other things, are obviously very important. The measures to deal with this are described in the site's emergency planning procedures.

Heavy rainfall

The report of the resistance tests states that the "current" precipitation data (i.e. anno 2011) did not show any significant increase in precipitation intensities since the design phase, and that the precipitation intensities used as a basis for the design were therefore still valid. The question is whether that conclusion will still be valid in 2037. After all, there are clear indications that peak precipitation intensities have indeed increased in the meantime.

The evaluation of the sewer system also showed that the drainage capacity of the sewer system was locally exceeded during heavy rainfall events (100-year return period), in a limited number of places and for a limited period of time. In those particular places, there may be some temporary flooding until the rainfall intensity decreases and the sewer system drains the excess water.

If we assume that intensities have indeed increased since then (and certainly by 2037), both the likelihood of such situations occurring and the magnitude of the consequences may obviously also increase. Given the relatively high return period used in the calculations and the fact that no critical functions are threatened by possible flooding, it can be said that the significance of this effect is small in practice.

Severe wind

The maximum wind speed of 49 m/s, which served as the design basis for all buildings on the site, has never actually been measured in Belgium. Moreover, the safety-bound buildings were calculated for heavier load cases than this maximum wind speed. Extreme wind speeds could give rise to partial or total LOOP. The scenario LOOP[73] is part of the design basis of the units. Such a situation does not compromise fuel cooling, either in normal operation or in shutdown.

Tornadoes

A severe tornado may result in a partial or complete LOOP, which may or may not be combined with a Station Black Out (SBO) 1st level and a loss of the primary cold source.

The design of Doel 4 takes into account a reference tornado that is unprecedented in this region. Since the phenomenon is not usually the defining criterion in building design, important safety-related buildings will also be able to handle heavier tornadoes than the reference tornado.

Higher average temperatures

If the ambient temperature is higher, the temperature of the discharged cooling water will also be higher. As a result of climate change, average air temperatures will increase, 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 discharged cooling water will increase on average, and thus additional measures will be required to meet the discharge standards for power plants. The temperature of discharged cooling water should normally not exceed 30°C, but power plants are subject to a separate emission limit of no more than 33°C (as an instantaneous value). However, Vlarem also states that this limit is not applicable (subject to compliance with a number of conditions) if, in exceptional meteorological conditions (and in particular a heat wave), grid safety is compromised. However, heat waves giving rise to higher discharge temperatures will become more frequent in the future; the "exceptional meteorological circumstances" will therefore become a lot less exceptional.

In addition, the temperatures of the ingested surface water will naturally also increase due to an increased average temperature of the ambient air. Under current Vlarem legislation, thermal power plants with cooling towers must gradually reduce the thermal load discharged at a daily average temperature of the captured surface water of 25 °C or more, among other things to avoid negative ecological effects. For example, at an average daily temperature of the captured water of 28 °C, the daily discharged thermal load must be limited to 10% or less of the maximum daily thermal load (Article 4.2.4.1 of Vlarem II). Such a situation will undoubtedly occur more frequently in the future under the influence of climate change.

Both 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 negative effects on the electricity production of the

[73] LOOP = loss of off site power, or the complete loss of the external grid, representing the simultaneous loss of the external 400 kV and 150 kV grids. In such a situation, the turbogenerator group is automatically switched to island operation through the electrical protection devices. In this process, the turbogenerator group feeds its own auxiliary systems. This is the first protection mechanism to ensure power supply to the unit's auxiliary systems. When at least one of the four units in Doel is successfully switched to island operation, there is also the possibility of connecting this unit to the other units via the 400 kV Doel substation.

plant. However, it is not expected that this effect would cause problems for the Scheldt and within the (extended) lifetime of Doel 4.

Extreme temperatures

Extreme temperatures were also taken into account in the design basis and in sizing the equipment. Standards in this area were determined based on statistics and according to the geographic location of the nuclear site. A period of extreme temperatures or of extreme drought is not a sudden natural phenomenon. They are evolutions that are predicted in time, which allows for timely action. Doel also has procedures in place to guarantee safe operation in the event of a heat wave or freezing temperatures.

As part of the preparation for the Doel 4 life extension, it was determined that managing potential heat waves (and associated temperatures, which may be higher than anticipated in the initial design) could lead to design improvements (e.g., additional air coolers or humidifiers of classrooms). Increasing the resistance of facilities to the effects of extreme temperatures resulting from climate change is thus integrated a priori into the project.

1.5.5 Assessment of impacts against policy objectives.

For the various high-defined policy objectives relevant to the Climate discipline (see §6.5.1), whether or not the Project contributes to achieving those objectives is shown below:

Objective "To achieve the greatest possible reduction in greenhouse gas emissions"

Over the entire period, the deferral of the deactivation of Doel 4 results in the avoidance of emissions of about 12,417 kton $_{CO2eq}$. If we compare the emissions released from the operation of Doel 4 over the same period (14 kton), we can see that the emissions from Doel 4 over the period covered by the deferral of deactivation represent only 0.11% of the avoided emissions over the same period. The emissions attributable to keeping the plants open longer are thus negligible compared to the emissions avoided by them. The Project thus contributes to achieving this objective and the score is therefore **positive**.

Objective "Maximum resilience of environment and society to climate change impacts"

Over the reference period 2027-2037, the Project will have no additional impact on the resilience of the environment to the effects of climate change. Potentially relevant impacts will not increase with life extension, primarily due to the fact that the Doel site will remain paved even with deactivation in 2025 throughout the reference period. Thus, the Project does not noticeably contribute to achieving the objective, but neither does it noticeably counteract it. Therefore, the assessment is **neutral** for this aspect.

Objective "To minimize the project's vulnerability to the impacts of Climate Change."

The analysis reported in this EIA clearly shows that the site can withstand impacts from climate change far beyond what can be expected in 2037. Whether or not Doel 4 is in operation over the 2027-2037 baseline period does not change this. Thus, the assessment is **neutral**.

1.5.6 Summary of key findings

The greenhouse gas emissions attributable to Doel 4 over the period 2027-2036 are of the order of 14 ktonnes (cumulative). If we express the emissions against the electricity produced we get a value that for the years under discussion fluctuates between 0.06 and 0.1 grams of $_{CO2}$ per kWh, which is very low.

The *avoided* greenhouse gas emissions from keeping Doel 4 open longer are of a different order. Over the entire period, delaying the deactivation of Doel 4 results in avoiding emissions of about
12,417 ktonnes $_{CO2eq}$. This amounts to a saving of about 0.97% of emissions in the sector "production

of electricity and heat" in Belgium in the year 2021 (12.8 Mton). If we compare with the emissions released from the operation of Doel 4 over the same period (14 kton), we can see that the emissions from Doel 4 over the period to which the lifetime extension applies represent only 0.11% of the emissions avoided over the same period. The emissions attributable to keeping the plants open longer are thus negligible compared to the emissions avoided as a result.

Doel 4 has no impact on the resilience of the environment to the impacts of climate change during the reference period given that both in the reference situation and with Project implementation, the site remains hardened. Within the time perspective of the lifetime extension, the Doel site itself is also not vulnerable to climate change impacts, and this situation is independent of whether the deactivation of Doel 4 is postponed or not.

1.5.7 Mitigating measures

No mitigation measures are needed from the discipline of Climate.

1.5.8 Gaps in knowledge and monitoring

There are no gaps in knowledge that are such that they could lead to different decisions. Monitoring of impacts is not necessary.

1.6 Man and Health

1.6.1 Relevant effects and cause-effect relationships

Health effects that (may) accompany the operation of nuclear power plants are primarily attributable to (potential) radiological effects. These are discussed elsewhere in this document. In addition, however, possible health effects attributable to the non-nuclear characteristics of the plant and its operation must also be taken into account.

The World Health Organization (WHO) defines health as, "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 environmental impact estimates, in addition to the direct impact of stressors, must also take into account the existing situation, longer-term effects, the social context, indirect psychosomatic effects and public perceptions.

The table below (Table 46) provides a brief overview of the potentially relevant environmental stressors, adapted from Arcadis (2021). Arguments are given of some of them why they are not included further. Further on, we discuss in more detail the potential impact of the stressors indicated in blue, for which significant impacts cannot be excluded a priori. 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 and KENTER, 2021).

Table 46: Overview of potentially relevant environmental stressors.

Stressors	**Specific description of stressor and/or source, health impact**	**Argumentation why stressor, if present, is not included**
Chemical stressors		
Air pollution	Emissions resulting from the operation of Doel 4.	The air discipline shows that the impact on air quality is negligible. Therefore, no relevant health effects are expected.

Stressors	**Specific description of stressor and/or source, health impact**	**Argumentation why stressor, if present, is not included**

Contaminated soil and groundwater	Accidental emission	In the event of any accidental emission, immediate action must be taken in accordance with the Soil Decree. Within the Doel site, the necessary measures are taken to prevent any damage to soil and groundwater quality. In addition, soil legislation requires immediate intervention in case of accidental pollution. Therefore, exposure to accidental soil or groundwater contamination is not investigated further in the Human Health discipline.
Surface water pollution	Discharge of wastewater	Sanitary wastewater is discharged into the Scheldt after treatment in 5 biorotors. Industrial wastewater is collected and discharged separately and may or may not be discharged into the Scheldt after treatment. Since the Scheldt water is not used for drinking water extraction, nor as recreational water, exposure to pollution through surface water is not relevant and is not further investigated 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 KCD are ammonia and hydrazine, but their storage characteristics avoid odor emissions (see also Air discipline). Odor nuisance is therefore not further investigated in the Human Health discipline.
Physical stressors		
Sound	Noise emissions from the operation of Doel 4.	Noise emissions from the power plant are limited (see also Biodiversity discipline), especially when compared to current and future noise sources in the vicinity (ECA, Ineos, etc.). In addition, 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 much greater source of noise disturbance to the vicinity of the site. Finally, it should be noted that habitation near the plant is limited.
Vibrations		The life extension of Doel 4 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.

Stressors	**Specific description of stressor and/or source, health impact**	**Argumentation why stressor, if present, is not included**

Light, shadow	Shadow of the steam plume	French research (Méry, 1989) showed that reduction in hours of sunshine due to shadowing from the steam plume is largely limited to a distance of 1.5 to 3 km from a power plant. Most habitation is located more than 3 km from the Doel nuclear power plant, and thus the reduction in solar hours there is negligible. The exception is the Doel core, which is located about 1.3 km south of the cooling towers. With a northerly wind direction, there is a chance of shadowing of vapor plumes here. However, this wind direction occurs in Belgium only about 12 % of the time (Arcadis, 2021).
Heat	Discharge of cooling water into the Scheldt River	No human health effects are expected from the thermal effects of cooling water discharge into the Scheldt.
Electromagnetic radiation		No effects of electromagnetic radiation are expected beyond KCD's site boundaries.
Biological stressors		
Infection hazard	Cooling towers may pose a risk of Legionella development.	The risk of exposure to Legionella will be assessed based on the history of any infections and existing preventive measures.
Acute poisoning from toxins		There are no relevant sources of toxins associated with the operation of Doel 4.
Chronic toxicity		There are no relevant sources of biological toxins associated with the operation of Doel 4.
Allergens		There are no relevant sources of allergens associated with the operation of Doel 4.
Other		
Dust nuisance		The lifetime extension of Doel 4 does not involve any activities that could give rise to dust pollution.
Proximity to green space	Occupation of green space	The project takes place within the boundaries of KC Doel. 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 the KCD (operation phase)	The potential for psychosomatic effects as a result of operating the Doel 4 will be investigated.
	Public concern over supply uncertainty	Supply (in)security is treated as an issue in this EIR.
Effects of blackouts		The potential (health) impact of power shortages is discussed.

1.6.2 Delineation of study area

The study area in the context of this discipline is defined by a 5 km zone around the Doel site. If the analysis shows that the potential effects extend further, a larger zone will be studied. Regarding perception, avoided emissions, effects of a blackout and dispersed nuisance, we take Flanders as the study area.

1.6.3 Description of the reference situation

Table 47 summarizes various aspects of space use in the study area.

Table 47: Land use in the facility study area.

Space use & population	**Unit**	**Area of influence**		**Clarification**
		Number or % of area	**Distance & wind direction from source**	
Space use				**Source: Geopunt, regional plan, orthophoto**
Nurseries	number	6	2 at 4.5 km - NO 4.7 km - NO 4.8 km - NO 4.9 km - NO 4.9 km - SW	
Kindergartens	number	3	4 km - NO 4.4 km - NO 4.9 km - NO	
Primary School	number	3	4 km - NO 4.4 km - NO 4.9 km - NO	
Secondary education	number	0		
Playgrounds, vacation rentals	number	0		
Sports fields, scout grounds, play forest, ...	number	10	4.2 km - NO 4.3 km - NO 4.5 km - NO 4.6 km - NO 4.7 km - NO 2 at 5 km - NO 3.7 km - O 500 m - Z 3 km - Z	
Hospitals	number	0		
Retirement homes/residential care centers	number	2	4.6 km - NO 4.7 km - NO	
Residential Zone	% of study area	2 %	900 m - Z	Doel
Agricultural activity	% of study area	25 %	100 m - W	Polder area

Land use & population	Unit	Area of influence		Clarification
		Number or % of area	Distance & wind direction from source	
Space use				**Source: Geopunt, regional plan, orthophoto**
Water reclamation area: surface water + groundwater	% of study area	17 %	800 m - O	Scheldt
Green zone/nature	% of study area	19 %	600 m - O	Horse Bark, Schor Elder Objective, Galgenschoor
Industrial area	% of study area	36 %	1.5 km - Z	
Other: recreational area, highways, community and public utility area	% of study area	0,4 %		

The KC Doel is bordered by polder areas. Within a radius of 5 km around the project area, the population density is rather limited. This perimeter includes a large part of the port of Antwerp, the Scheldt River and the sparsely populated polders. The number of people in the vicinity of the plant (within a radius of 2,000 m around the facility) is very limited. A maximum of 150 people live at such a short distance from the plant.

Table 48: Population in a 2 and 5 km radius around the Doel nuclear power plant (source: Statbel).

	Population of statistical sectors within 2 km radius of KCD	Population of statistical sectors within 5 km radius of KCD
2014	146	10.445
2015	141	10.486
2016	136	10.521
2017	121	10.557
2018	110	10.680
2019	110	10.685

About 20 residents live in the village center of the polder village of Doel, about 900 m south of KCD. The population in the village of Doel has declined for many years under the influence of port developments and housing insecurity. Recently, as a result of the ECA project, there has been a return to perspective on the survival of the village, which is still residential in planning terms. What this means in terms of future resident numbers is difficult to predict at this time. The disruption that will be associated with the Second Tidal Dock that will be located right next to the village is likely to limit its attractiveness.

Furthermore, there are no residential areas in the immediate vicinity of KCD. However, there are several residential units and residential clusters scattered in the polders, including the polder hamlets of Ouden Doel, Rapenburg, Saftingen and Prosperpolder. About 100 people still live in the scattered habitation of the Grote Doel polder. Lillo is located on the other side of the Scheldt at about 2.5 km, with a residential population of about 40 persons. Within a radius of 5 km, most residents are located in Zandvliet (about 3,500 persons) and Berendrecht (about 6,000 persons).

Finally, the Lillo Port Center (Scheldelaan 444 - Haven 621, Lillo) can be mentioned. The Port Center is located in the port area, at the level of Lillo-Fort (2.5 km in southeastern direction as far as KCD). Training is given here and large groups of people (schools, ...) can be located there during working hours.

The broad surroundings of the nuclear power plant are characterized by strong industrialization (port area). KCD is located near the Antwerp port area. This port area contains extensive industrial sites on both sides of the Scheldt River. The industrial enterprises in the Antwerp port area directly employ more than 60,000 people. In addition, there are the many subcontractors who are at work daily in the Antwerp port area. The presence of this industry causes a significant increase in the population within the study area, both during the day and at night, since a significant proportion of the companies produce on a continuous basis.

The Antwerp port area is characterized by the presence of a (petro)chemical cluster on the one hand and container terminals on the other. Examples of (petro)chemical plants around the site are BASF, Ineos Manufacturing Belgium, Invoyn Manufacturing Belgium, Gunvor Petroleum Antwerp and Bayer Agriculture. On the left bank, there are companies such as Borealis Kallo, Ineos Phenol Belgium and Ashland Specialities Belgium. Broadly speaking, these are installations subject to the so-called SEVESO Directive on the prevention of major-accident hazards that could be caused by certain industrial activities.

The nearest Seveso companies are located about 1.5 km from the KCD. These are the companies along the Scheldelaan located on the right bank of the Antwerp port area (including Gunvor Petroleum Antwerp, Ineos Manufacturing Belgium, Inovyn Manufacturing Belgium, Vesta Terminal Antwerp, Bayer Agriculture).

1.6.4 Impact discussion

1.6.4.1 Infection Risk for Legionella

Legionella is a bacterium found in water systems. Under proper growing conditions, the bacteria can multiply. Low amounts can grow to high concentrations if growth-promoting factors (iron pipes, rubber seals) are present.

Infection with legionella germs can lead to legionellosis. Infection can occur through the lungs after inhaling the bacteria in small droplets of water. Aerosol formation occurs when showering, spraying, and atomization in a cooling tower, among others. Legionella germs grow in water at temperatures between 20°C and 50°C, with a maximum peak between 35°C and 40°C. Below 20 °C there is inhibition, above 50 °C the germ dies. The higher the temperature, the faster the die-off. The essential nutrients for growth can be found in a biofilm, among other things.

Other conditions that promote a growth of Legionella bacteria include:

- Stagnant water;
- Acidity between 5 and 8.5;
- Sediment that gives rise to biofilm formation;
- Presence of microorganisms, such as algae, flavobacteria, Pseudomonas, amoebae.

To control Legionella, a legal framework was established in Flanders with standards and management regulations as well as a guideline for restarting cooling circuits after a period of inactivity.

There are the following cooling towers on KCD's site today:

- 2 open recirculating cooling towers (CW) of Doel 3 and Doel 4;
- various auxiliary cooling towers from D3 / D4 and WAB;
- cooling towers of D1/2.

However, the Doel 3 cooling tower is no longer active, as that reactor was shut down in September 2022.

Due to the presence of open cooling towers, the Legionella Decree (Flemish Government Decision of 09/02/2007) is applicable at KCD. This decree stipulates measures against *Legionella pneumophila* to prevent Legionnaires' disease.

According to the decree, KCD must prepare a management plan that includes a description of the installation, a risk analysis and prevention measures. With every change to the installation that may affect the likelihood of Legionella development and at least every five years, this management plan is evaluated and adjusted if necessary.

The open recirculating cooling towers of Doel 4 and the auxiliary cooling towers of D3 / D4 and WAB use Scheldt water. Given that this is brackish water, these cooling towers do not pose a risk of Legionella contamination due to the high salt content.

Only the auxiliary cooling towers of Doel 1/2 are kept up to standard with city water. In accordance with the management plan, these auxiliary cooling towers are sampled and analyzed at least twice a year for the presence of Legionella. If, exceptionally, the limit value of the decree is exceeded, then the necessary measures are taken (cleaning, biocide increase) and renewed controls are carried out.

To the best of our knowledge, Legionella infections have never occurred as a result of the operation of the cooling towers at KCD. It can therefore be concluded that provided the management plan is applied, the risk of Legionella contamination from the cooling towers in the current situation is negligible.

In a life extension situation, only the Doel 4 cooling tower and its associated auxiliary cooling towers are still active. As described above, the risk of Legionella infection is non-existent for these cooling towers, as they are fed with brackish Scheldt water. Therefore, there is no difference between the situation with and without lifetime extension of Doel 4.

1.6.4.2 Psychosomatic aspects and risk perception

With risk perception, psychosomatic complaints can go hand in hand. Psychosomatic' effects refer to possible physical complaints that have a psychological or non-medical cause. With 'psychosomatic' effects, the direct cause is not always clear. There is always a combination of factors at work. Psychological problems are mostly understandable human reactions to specific situations and are not simply a biomedical, genetic, neurological reaction or a disease of the brain.

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

A study by IPSOS in November 2011 commissioned by Greenpeace (representative of the Belgian population) shows that 76 % of respondents "agree to strongly agree" with the choice to invest in renewable energy sources instead of a lifetime extension of nuclear power plants. 14 % disagreed with this choice. 66 % agreed to very much agreed with closing the oldest nuclear power plants in 2016, as planned, and 22 % disagreed.

SCK CEN has been researching public perception of radiation risks and attitudes toward nuclear energy since 2002. The research is done mainly through the "SCK CEN Barometer". This is a broad survey of the population (more than 1,000 people), representative of adult Belgians (18+), divided into 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 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 misuse of nuclear technologies by terrorists as a high to very high risk. In the same study, half of the population considers a potential nuclear accident and radioactive waste a high to very high risk to their health in the next 20 years. 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 nuclear accident risks decreases between 2013 and 2018.

Regarding the future of nuclear energy in Belgium, the majority of the population thinks that the reduction of the number of nuclear power plants in Belgium is a good thing (71% agree to very agree) and they think that nuclear power plants are a danger to the future of their children (64%). On the other hand, more than half of the population thinks that renewable energy is insufficient to meet current energy needs. One in four Belgians in 2018 believes that nuclear power is a climate-friendly technology, but half of Belgians hold the opposite opinion.

In 2015, 38 % of the Belgian population indicates that they are willing to pay more to promote the use of renewable energy and 45 % are not willing to do so (SCK CEN Barometer 2015); in 2018, 49 % were willing to do so and 40 % were not. Additionally, 42 % indicate that they do not think renewable energy is sufficient to meet current energy needs and 35 % think it is possible; in 2018, 55 % and 29 % respectively.

Similar to the results regarding opinions on nuclear power, 37 % believed that the advantages of nuclear power outweighed the disadvantages. 36 % held the opposite opinion.

In 2018 (SCK CEN Barometer, representative data 18+ of the Belgian population), about 33% were in favor of operating existing nuclear power plants without replacement at the end of their operation (vs. 40% in 2015 and 57% in 2013). The share of the population in favor of building new power plants and maintaining or closing the existing ones is equal (about 30 %) to the share of the population that believes that all nuclear power plants should be closed as soon as possible without replacement. More precisely, 11 % believe that Belgium should close its nuclear power plants and build new ones, and 19 % say that Belgium should operate the current nuclear power plants and build new ones to replace the old ones.

About half of the Belgian population consider the risks linked to nuclear accidents to be high to very high. A large part of the population (75%) considers that even a low dose resulting from a nuclear accident is harmful to public health.

Opinions on the use of nuclear power for electricity generation are evenly split in 2018 between favorable and unfavorable. Compared to previous years, opinions are more polarized in 2018 (with fewer undecided respondents). One in two Belgians (49%) show a willingness to pay more for electricity in favor of using renewable energy. A similar proportion (55 %) thinks that renewable energy cannot meet current energy needs.

The above considerations show a mixed picture; in any case, it cannot be determined whether the use of nuclear energy or the existence of nuclear power plants gives rise to specific psychosomatic or psychosocial complaints. However, it can be assumed that 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 reactor unit Doel 4.

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 KC Doel site, let alone Doel 4. However, it can be assumed that with a lifetime extension of Doel 4, the risk perception (among local residents and more widely) will also remain ten years longer; admittedly, this risk perception will have decreased because three of the four reactors in Doel (and two of the three in Tihange) will be closed. 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.

It is clear that there is also public concern about the non-availability or inadequate availability of energy. In the IPSOS (2011) study mentioned above, 31% of respondents indicated that they were concerned about a possible blackout if nuclear reactors were to be phased out between 2015 and 2025, however, a majority (55%) did not share this concern. To our knowledge, similar data are not available for the current situation. However, since the likelihood of shortages has become much more concrete since then, including due to the geopolitical context, it can be assumed that the proportion of people concerned about security of supply is higher today than in 2011.

1.6.4.3 External security (non-nuclear accidents)

The Doel nuclear power plant is a low threshold Seveso facility. This means that hazardous substances are present in quantities exceeding the low threshold but falling below the high threshold. By presence is meant both actual or anticipated presence in storage facilities, in process facilities, in piping, in ... (as raw material, intermediate, catalyst, solvent, final product, etc.), as well as the presence that may occur when an industrial chemical process goes out of control. The Seveso review shows that the Doel nuclear power plant is a low threshold establishment as a result of the amount of gas oil stored.

As part of the EIA for the re-license, an assessment of the external man risks and environmental risks for the Seveso substances present was prepared in 2010 (Tractebel Engineering, 9/07/2010). The main findings are summarized below.

The following installations contain hazardous substances (i.c. Seveso substances):

- gasoil installations: storage tanks for the safety and emergency installations of the production units Doel 1, 2, 3 and 4, for the heating installation of the warehouse, for the auxiliary steam boilers and for the garage;
- hydrogen plants: hydrogen cooling circuit of alternators of production units Doel 1, 2, 3 and 4;
- hydrazine (4.9%) plants: storage tanks for the Doel 1, 2, 3 and 4 production units;
- plants with aqueous solution of potassium chromate[74], as a conditioning agent in the closed cooling circuit: buffer tanks for the production units Doel 1/2, 3 and 4 and for the water conditioning unit WAB.

The external man risks of a major accident were estimated in a quantitative manner through a quantitative risk analysis (QRA). Only products with properties (toxic, flammable, explosive) that could affect the external man risk were included in this analysis. For example, potassium chromate solutions are not considered in this section as they are environmentally hazardous.

Maximum impact distances (greatest distance to 1% lethality) were calculated for:

- heat radiation;
- overpressure effects;
- toxic vapors.

The calculated maximum impact distance for hydrogen plants was 84 m for an explosion; the maximum impact distance for fire in the containment of a gas oil tank was calculated as 30 m.

These impact distances do not extend beyond the site boundaries. The external man risk (risk to persons present outside the facility) is therefore negligible in the current situation.

The non-nuclear external security risks will be much lower with a lifetime extension of Doel 4 than today, as many of the stockpiles of hazardous substances will be greatly reduced. For example, the

[74] In 2010, buffer tanks still included concentrations up to 16.8% potassium chromate. However, under REACH since 21/9/2017, the use of potassium chromate is prohibited (unless one obtains an authorization or exception). For this reason, the plants are no longer refilled with these concentrations and the concentrations remain below 1 % (solution below 1 % are not covered by the rules).

closure of the three other reactors at the site, for example, would lead to the decommissioning of a significant portion of the combustion facilities, and thus also to a reduction in the stockpiles of diesel.

Obviously, the external man risk will theoretically be higher during a possible lifetime extension of Doel 4 than without such a lifetime extension, although even with a complete shutdown of all reactors, many hazardous substances will obviously remain present on the site, for example in the context of decommissioning. However, since it has been shown that even in the current situation the external man risk is negligible, this obviously also (and all the more so) applies to a situation with a lifetime extension of Doel 4. We conclude that external safety is not a distinguishing factor in any lifetime extension of Doel 4.

1.6.4.4 (Avoided) health effects of a blackout.

Lifetime extension of Doel 4 is aimed at ensuring security of supply, pending a situation where such security of supply can be guaranteed using other energy sources.

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

A 2014 study by the Federal Planning Bureau did a quantitative assessment 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 cost with 49%; the tertiary sector is responsible for about 40% of the cost. The model used also allowed for spatial allocation of the calculated damages. This showed that by far the greatest 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 also important to note that this estimate always considered a 1-hour outage. The impact of a 2-hour breakdown is not necessarily twice as great. This is borne out by the Simulator figures: the damage of a 2-hour breakdown for the whole of Belgium amounts to "only" 170 million euros (or 42% more than a 1-hour breakdown). However, when a disruption lasts longer, 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 may not be able to support some other services, including X-rays, air conditioning, refrigeration, elevators, etc. In addition, technical problems may arise with emergency 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 co-determinant; in fact, the power outages occurred during a heat wave. Effects based on this research include respiratory problems and probably increased mortality. Power outages 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 illness and mortality to all-cause hospitalizations, 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 adverse health effects, and thus can be viewed positively.

1.6.5 Summary of key findings

The project (the lifetime extension of reactor Doel 4 by 10 years) has no meaningful health impacts. Based on a preliminary screening, only the effects related to Legionella, possible psychosomatic aspects associated with risk perception, and avoided health effects associated with a black out were considered as potentially relevant.

The above analysis shows that Legionella cannot be a problem, given the brackish water with which the Doel 4 cooling towers are fed. As for risk perception regarding nuclear accidents, it can be stated that such risk perception does exist, but there is no demonstrable link to psychosomatic effects. Finally, it can be confirmed that the lifetime extension of Doel 4 significantly reduces the chances of a blackout (especially in the first years of the lifetime extension), thus having a positive effect on the avoidance of the health effects that can be associated with steam interruptions.

1.6.6 Mitigating measures

Mitigation measures are not an issue for this discipline.

1.6.7 Gaps in knowledge and monitoring

There are no significant gaps in knowledge. The various dose-effect relationships, and the causes that may underlie possible health effects, are sufficiently well known.

1.7 Cross-border effects

Most of the non-radiological effects attributable to the lifetime extension of Doel 4 are confined to the immediate vicinity of the nuclear power plant, are limited in scope and thus do not give rise to transboundary effects. Only for the Water theme can there be (limited) transboundary effects.

Based on monitoring ([2012lxii]) of the temperature influence of the cooling water of KC Doel on the Scheldt near the Dutch border (at ca. 3.4 km distance from the discharge point), the influence of the discharge of the cooling water can at most be considered as limited negative (i.e. the temperature increase due to the discharge will be smaller than 1 °C). This temperature rise will further slowly decrease downstream on Dutch territory.

It should be noted that several cross-border effects cannot be ruled out in the reference situation, if there is no lifetime extension and thus other means of production must be used to deploy the capacity of Doel 4. The importance and nature of those cross-border effects will depend strongly on the locations where the (theoretical) replacement capacity is provided, on the technical characteristics of those plants and on their licensing characteristics.

2 Radiological effects Doel 4

2.1 Direct radiation and discharges during normal operation

2.1.1 Current situation

As discussed in the general methodology (see §2.3.3), the potential radiation exposures for humans and the environment in normal operation are related to direct radiation from radioactivity present at and emitted from the site and the gaseous and liquid effluent discharges containing certain concentrations of radioactivity. We describe here the current situation for KC Doel.

Direct radiation

The TELERAD network operated by the FANC-AFCN continuously measures the radiation present in the environment (see §2.3.5). Specifically for the KC Doel site, the TELERAD network consists of 18 ring stations placed along the perimeter of the site and some 16 stations in the wider vicinity of KC Doel (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 KC Doel 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 natural background radiation as a function of time can be observed (e.g. when it rains, there will be an increase in background radiation due to the outgassing of the daughter nuclides of the natural radioactive radon in the air), 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 greatly increased dosistempi (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 from the site as well as that from radioactive discharges. Figure 65 shows the annual dose[75] recorded by the ring stations. Table 49 shows the data for all years considered. We see that average values vary between 0.66 and 0.80 mSv per year for the different ring stations. These values correspond to the typical values of background radiation in Flanders, which is around 0.7 mSv/year (0.3 mSv/year cosmic radiation and 0.4 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 KC Doel. The attentive reader will have noticed that the annual doses on the east side of the site are generally slightly lower than on the west side of the site. This is with high probability due to the fact that the stations on the east side are adjacent to the Scheldt River. River and sea water contain much less radioactivity than the natural radioactivity present on land. The stations with the highest dose values (0.85 and 0.77 mSv) are located near the Water and Waste Treatment Building (WAB). Increase due to storage of radioactivity is possible, but is indistinguishable from natural variations at those locations.

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.

[75] 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 65: Annual dose in mSv (average over period 2015 to 2022) as measured by the TELERAD stations operated by the FANC-AFCN around the KC Doel site (Figure made on the basis of 10-minute data obtained from the FANC-AFCN).

Table 49: Annual dose in mSv of external radiation as recorded by the 18 TELERAD stations around the Doel site (Data based on 10-minute data FANC-AFCN). Mean and standard deviation are also given.

	2015	2016	2017	2018	2019	2020	2021	2022	Averaged	Standard deviation
BE401	0,724	0,731	0,736	0,752	0,761	0,750	0,736	0,719	0,739	0,014
BE402	0,726	0,723	0,727	0,721	0,707	0,705	0,715	0,706	0,716	0,008
BE403	0,728	0,748	0,746	0,743	0,732	0,722	0,709	0,703	0,729	0,016
BE404	0,836	0,839	0,846	0,861	0,856	0,850	0,843	0,845	0,847	0,008
BE405	0,745	0,720	0,723	0,734	0,743	0,741	0,731	0,730	0,733	0,009
BE406	0,690	0,687	0,693	0,714	0,711	0,703	0,708	0,713	0,702	0,010
BE407	0,738	0,767	0,760	0,756	0,796	0,794	0,766	0,747	0,765	0,019
BE408	0,731	0,736	0,742	0,745	0,733	0,732	0,730	0,733	0,735	0,005
BE409	0,714	0,718	0,728	0,750	0,760	0,764	0,759	0,760	0,744	0,019

BE410	0,822	0,762	0,751	0,749	0,748	0,760	0,721	0,729	0,755	0,029
BE411	0,719	0,717	0,712	0,723	0,705	0,692	0,689	0,689	0,706	0,013
BE412	0,722	0,726	0,731	0,747	0,728	0,726	0,725	0,728	0,729	0,007
BE413	0,683	0,689	0,689	0,693	0,700	0,734	0,740	0,729	0,707	0,022
BE414	0,693	0,699	0,699	0,710	0,685	0,674	0,674	0,676	0,689	0,013
BE415	0,695	0,732	0,728	0,728	0,712	0,702	0,698	0,696	0,711	0,015
BE416	0,708	0,786	0,717	0,725	0,722	0,698	0,693	0,696	0,718	0,028
BE417	0,704	0,713	0,714	0,720	0,718	0,711	0,703	0,701	0,710	0,007
BE418	0,685	0,667	0,665	0,652	0,653	0,653	0,650	0,653	0,660	0,011

As part of a federal emergency planning exercise, on October 7, 2021, in a collaboration between SCK CEN, IRE, Defense, FANC-AFCN and in consultation with the operator of KC Doel, a helicopter flight was conducted over KC Doel and its surroundings with radiological equipment on board specifically designed to map post-accident contamination. This equipment, consisting of 4x4 liter NaI(Tl) detectors, is sufficiently sensitive to detect variations in the natural background or artificial sources of radioactivity. The results of these measurements (two flights in two directions: north-south and east-west over KC Doel and the nearby surroundings) are shown in Figure 66. This figure shows the dose rate in microSv/hour (µSv/h) as recorded every second along the path of the helicopter, corrected for height above the terrain, so that this dose rate corresponds to the value to which a person on the ground is exposed. No values were given above the Scheldt, as it is a wide river, the measured value -which was very low everywhere- from the helicopter is not representative of the value of a person near the water surface (e.g. on boat). Since water contains much less natural radioactivity than land, the dose rate above a water surface comes almost exclusively from cosmic radiation and is typically 0.03 µSv/h. Even above land you can still see an effect of the Scheldt, the values are lower along the banks of the Scheldt, than these at greater distances from the Scheldt. The dose rates above land and the site of KC Doel vary between 0.053 µSv/h and 0.090 µSv/h. This corresponds to an external radiation dose of 0.46 mSv to 0.79 mSv/year if we consider this value as representative for a full year. The dispersion here is somewhat larger compared to the TELERAD measurements as 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 four reactors were operating at the time of flight. The range of values is consistent with typical background values, the colors and scale used were chosen to visualize small differences. Thus, no increase is measured when the reactors are overflown, the average value over the site is not higher than the average value outside the site. The maximum measured value does lie above the KC Doel site and the location corresponds to a building where radioactive effluents/wastes are treated. Although, in addition to measuring the dose rate, the equipment also allows for identification and thus to determine whether this is natural or artificial radiation, given the very limited increase in dose rate, it could not be demonstrated with certainty that this is radiation from artificial radioactivity.

Together with the TELERAD measurements, these helicopter measurements show that radioactivity and radiation in the various reactors and auxiliary buildings on the KC Doel sites are very well shielded.

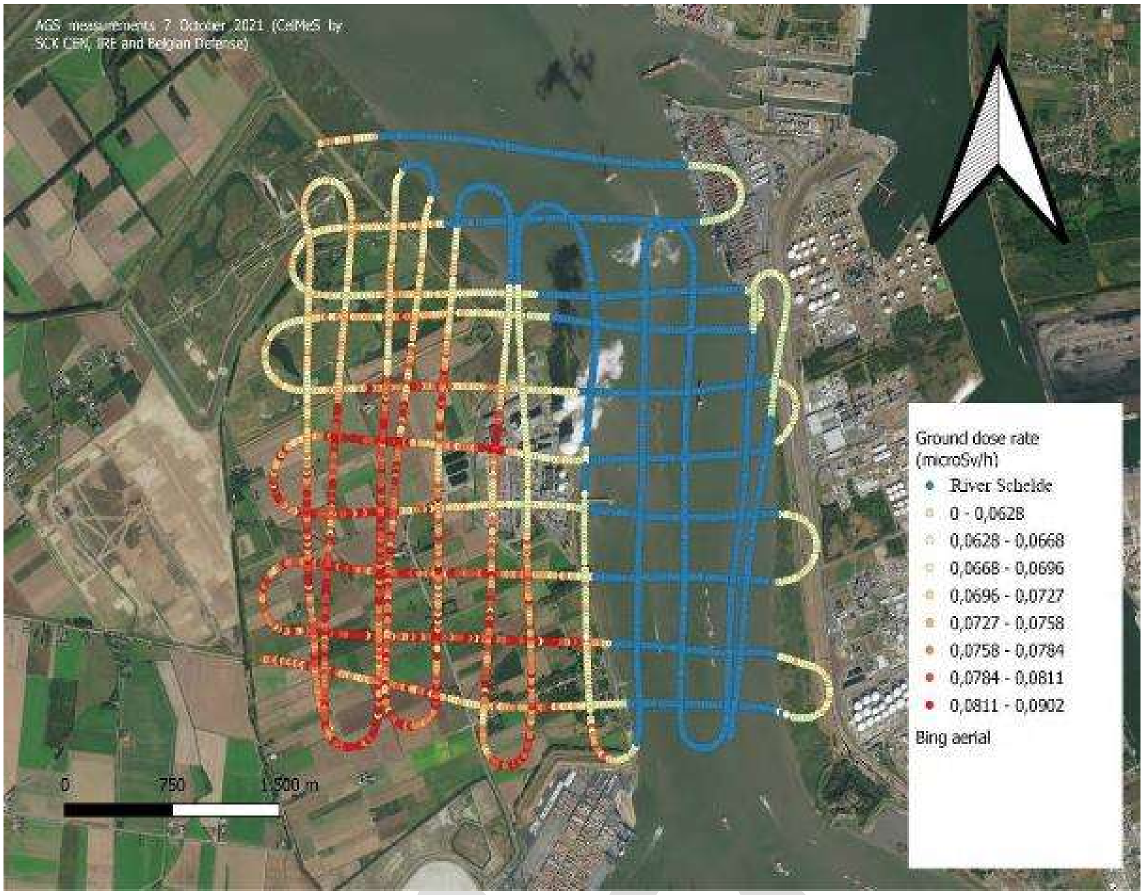

Figure 66: Results of helicopter measurements over the KC Doel site and surrounding area. Shown is the dose rate as measured from the helicopter, but corrected for height above the ground to get the exposure (dose rate) on the ground. More explanation: see text, the colors and scale were chosen to make small differences clearly visible. The variations fit within the natural variations of background radiation that can be expected in this environment.

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.

Atmospheric discharges are continuously monitored. This monitoring consists of:

- Noble gases:
    - Integration of continuous measurements or spectrometry for voluntary discharges;
    - Spectrometry for % proportion of Kr-85;
- I-131 and aerosols:
    - Spectrometry on the weekly collection filter
    - Analysis alpha-global and Sr-89 and Sr-90 on the monthly collection filter
- Tritium: monthly analysis of a representative sample

As described in §2.3.3.2, there are discharge limits for the KC Doel site for different groups of radionuclides. In Table 50, the discharge limits for the entire KC Doel site in annual total activity (being 12 sliding months) for the different groups and/or individual radionuclides are given, as also specified in KC [Doellxiii]'s operating permit. The operator must also submit a monthly overview of discharges to the FANC-AFCN. In addition, there are also specific operating limits for instantaneous concentrations for the various units (see Table 51).

Table 50: Discharge limits for the whole KC Doel site in annual total activity (12 sliding months) for different groups or individual radionuclides monitored (operating permit KC Doel).

Type	Discharge limits technical specifications
Noble Gases	2,960 TBq
I-131	14.8 GBq
Aerosols (beta gamma and alpha)	148 GBq
Tritium	88.8 TBq

Table 51: Instantaneous atmospheric discharge limits for the Doel 1 and 2, Doel 3 and 4 and water and waste treatment building (WAB) units.

Type	Doel 1 and 2	Doel 3 & 4		WAB
		Main vent	Reactor vent	
Noble gases (MBq/m^3)	148	111	185	148
Aerosols (MBq/m^3)	$7,4.10^{-3}$	$1,11.10^{-1}$	$2,22.10^{-1}$	$1,48.10^{-2}$
Iodine-131 (MBq/m^3)	$2,59.10^{-6}$	$1,85.10^{-4}$	$3,70.10^{-4}$	$2,59.10^{-6}$

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 (see §2.3.3.2). Nevertheless, only iodine-131 is monitored and reported, other iodine isotopes, particularly iodine-133 (^{133}I) are calculated from the iodine-131 measurements.

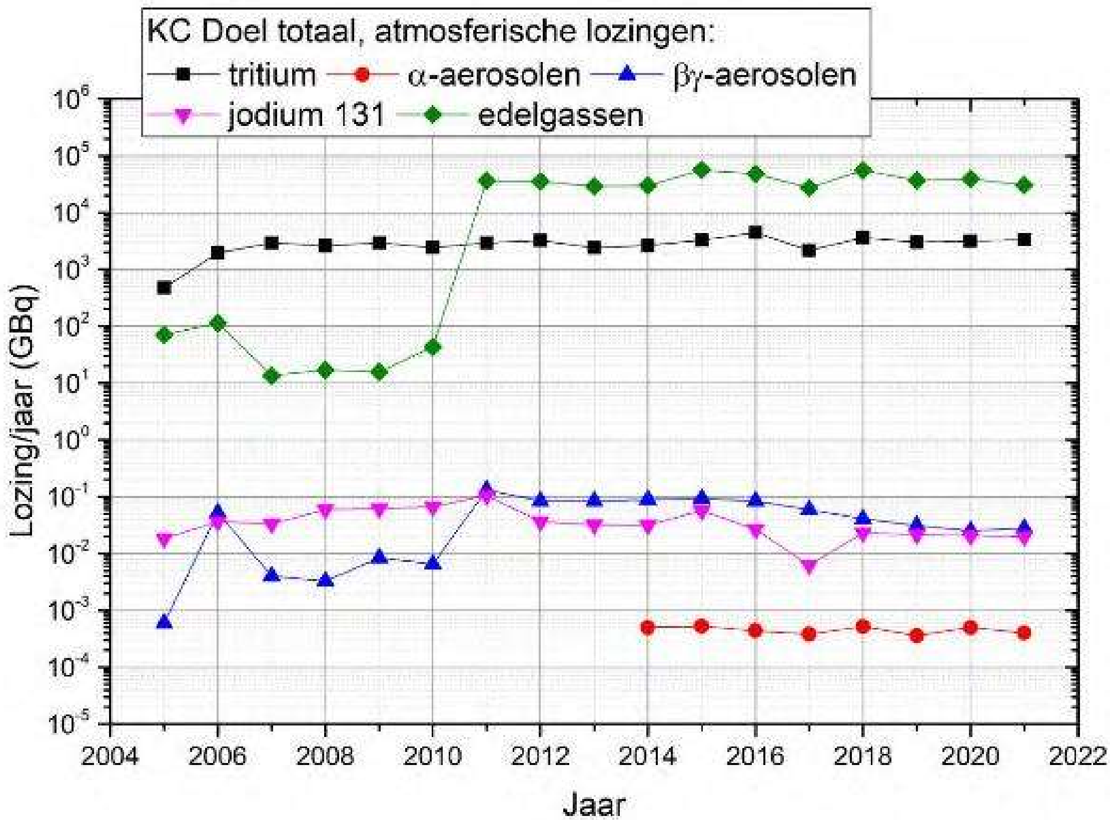

Figure 67: Gaseous discharges per year for the total site of KC [Doel76].

The atmospheric discharges per year for the different groups of radionuclides as reported to the authorities and found, among others, in the RADD database of the European Commission (https://europa.eu/radd/index.dox) are shown in Figure 67 for the years 2005-2021. These discharges are the atmospheric discharges for the entire KC Doel site. They are plotted on a logarithmic scale given the significant differences in magnitude of discharges between the different groups of radionuclides. The apparent increased values from 2011 onwards, in particular of the noble gases and beta-gamma aerosols, are due to a new guideline regarding [reportinglxiv]. Any discharged activity smaller 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 jump in 2011, so to be evaluated from 2011) 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 longer periods of time, however, in recent years a decrease in discharges of iodine-131, and aerosols is apparent. Alpha aerosols are reported separately as of 2014 and represent only a very small fraction of aerosols.

These atmospheric real discharges can be compared to the discharge limits according to KC Doel's operating permit. The results of this comparison are shown in Figure 68 as a percentage of the discharge limit per group and this for the period from 2014-2021. The beta gamma and alpha aerosols

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[76] 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.

(reported separately since 2014) are combined here. Actual atmospheric discharges are only a fraction of the discharge limits.

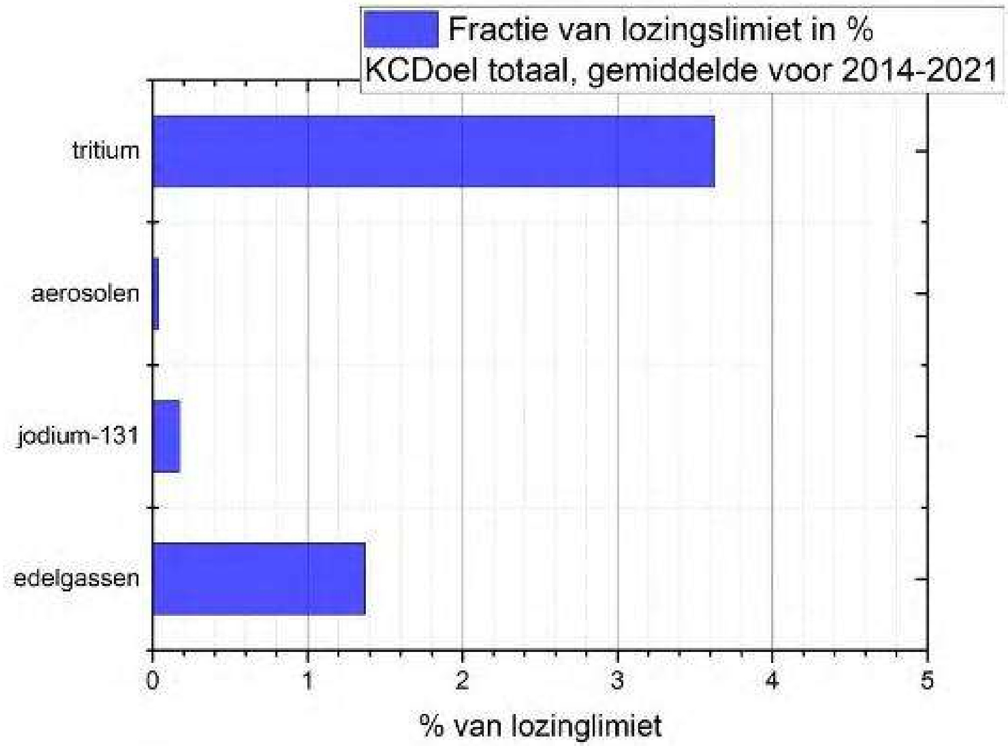

Figure 68: Actual annualized discharges for the entire KC Doel site, average for period 2014 through 2021, as a percentage of the discharge limit for different (groups of) radionuclides.

The impact (dose load critical individual) of the atmospheric discharges is discussed further together with the impact of the liquid discharges, but Figure 69 shows the effective dose by age group and by radionuclide discharged. The main contribution to the effective dose to the critical individual comes from discharges of carbon 14 (C-14).

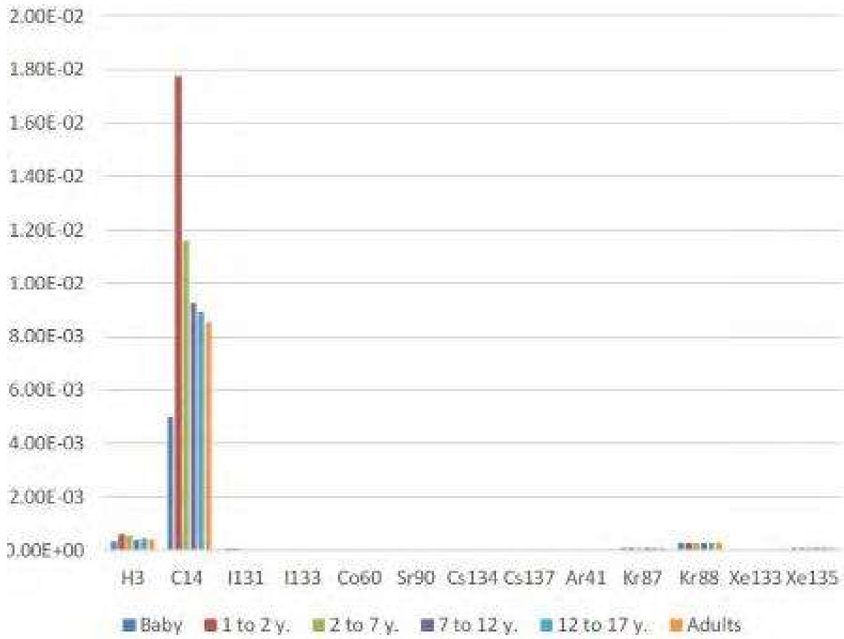

Figure 69: Distribution of the effective dose for the different age categories in mSv per year for KC Doel for the real atmospheric discharges of the main radioactive effluents (average for period 2009-2018). The predominance in the contribution to the effective dose of carbon 14 (C-14) is clearly visible herelxv.

Liquid discharges

The liquid radioactive effluents come mainly from the process circuits, for example the circuits for the treatment of primary cooling water in the nuclear power plants. They are also formed by the wastewater generated during decontamination of tools, sanitary wastewater and the water used for cleaning the floors in the nuclear zones such as the fuel storage docks, cleaning of deactivation docks for spent fuel, water leaks.

The discharge limits of the nuclear power plant in operational operation are based on the regulatory annual limit of 1 mSv for the most exposed population so that discharges cannot result in exceeding the dose limit. In addition to the maximum quantities that may be discharged annually, the discharge permit also contains the nature of the radioactive substances discharged. By the nuclear power plants In Doel and Tihange mainly tritium is discharged, the quantities of discharged fission and activation products are much lower (< 1% of the discharge limit in Doel, up to 4.2% of the discharge limit in Tihange over the last 10 years). The discharge limits for the radioactive substances are shown in Table 52.

The main radionuclides in the liquid effluents are:

- Tritium in the form of tritiated water. Tritium is mainly produced in the primary cooling water of nuclear reactors as it circulates in the core. It exists in the form of tritiated water (HTO) or tritium gas (HT) and thus can be found simultaneously in the liquid and gaseous effluents.
- Beta, gamma emitters; ^{58Co}, ^{60Co}, ^{89Sr}, ^{90Sr}, ^{134Cs}, ^{137Cs},^{110mAg}. Most of these radionuclides are produced by the fission of the nuclear fuel in the core of the reactors and can be found in both liquid and gaseous effluents.
- Alpha emitter; Am-241 is produced in nuclear reactors from plutonium 241 by beta decay and can also be found in the liquid and gaseous effluents.

The effluents are first treated in the WAB building to remove as much radioactivity as possible before being discharged into the Scheldt River.

Table 52: Liquid effluent discharge limits.

Radionuclide category	
Tritium	104 TBq/year
Beta, gamma, and alpha emitters (excluding tritium and dissolved noble gases)	1.48 TBq/year

Due to the flow and flow of the Scheldt water, the discharged radioactivity is dispersed and diluted. The tides improve the mixing of the effluents. The average volume discharged is 1,750 m^3/year or 0.2 m^3/h[lxvi] which is very low compared to the flow of the Scheldt.

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 monitoring program, the Doel nuclear power plant has also had a limited monitoring program since 2014 focusing on bioindicators such as aquatic plants and mosses. Soil and sediment samples are also taken as these can accumulate radionuclides.

Discharges for KC Doel are much lower than the discharge limits shown in Table 52. During the 2014-2021 period, beta and gamma emitters discharged less than 0.5% of the annual limit from the site (Figure 72). The tritium discharges are also below the annual limit and averaged 35 % of the annual limit during the period 2014-2021. No dose limit was given for alpha emitters because they were not discharged prior to 2011. Since 2011 this has changed, but discharges are very small compared to the discharges of the other radionuclides.

Discharges of tritium and beta gamma emitters into the Scheldt for KC Doel remain almost stable over the period 2004-2021, while discharges of alpha emitters decrease by a factor of 5 over the period 2011-2021 (Figure 67). Tritium is the main radionuclide discharged, tritium discharges represent 99.9% of the discharged activity and tritium is also the main contributor to the dose due to liquid discharges (Figure 68).

Figure 70 clearly shows that the discharge volumes are much lower than the discharge limits (Table 52). Over the last 8 years, discharges averaged 35% of the discharge limit for tritium and 0.3% of the discharge limit for the other radionuclides.

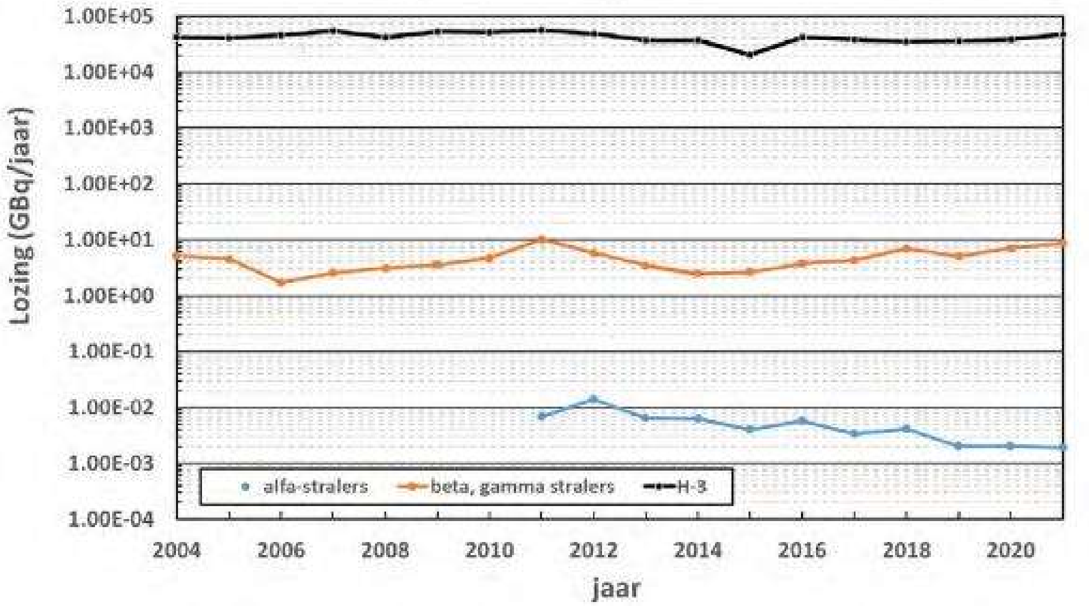

Figure 70: Evolution of liquid discharges from Doel Nuclear Power Plant into the Scheldt for the period 2004-202 1.[lxvii]

For calculating the dose to the representative person from discharges into the Scheldt, 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.

The use of river water for irrigation of food crops, grass and for watering livestock is not considered for the river water of the Scheldt due to the too high salinity of the water.

Since mainly tritium is discharged into the Scheldt, the effective dose is also mainly due to this isotope. Other isotopes contributing to the dose are: ^{110mAg}, ^{60Co}, 137Cs (Figure 71).

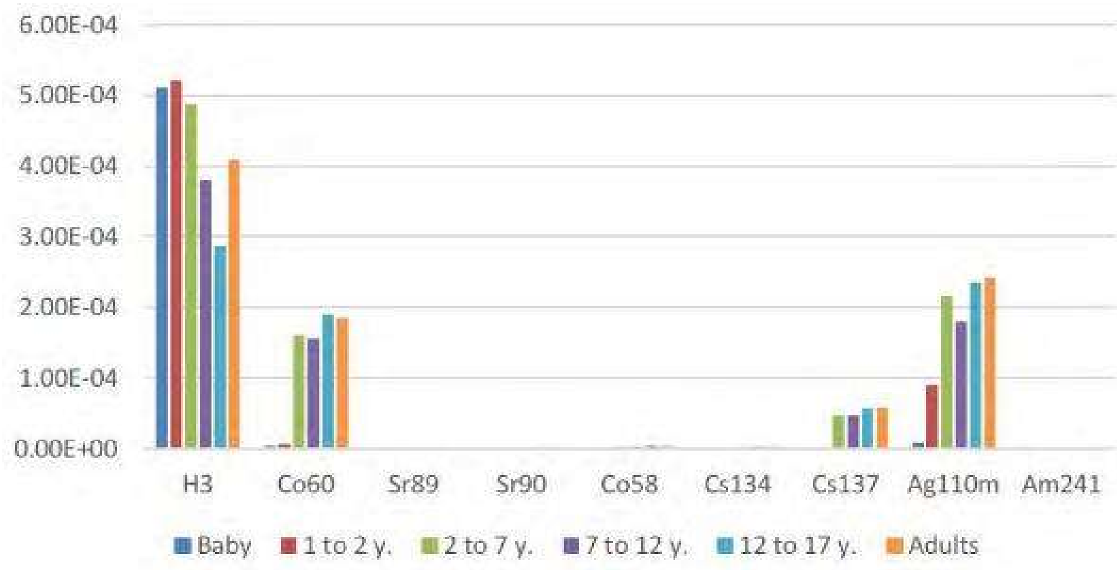

Figure 71: Distribution of the effective dose (in mSv/year) per radionuclide and age category due to liquid discharges into the Scheldt for the period 2009-2018*.*

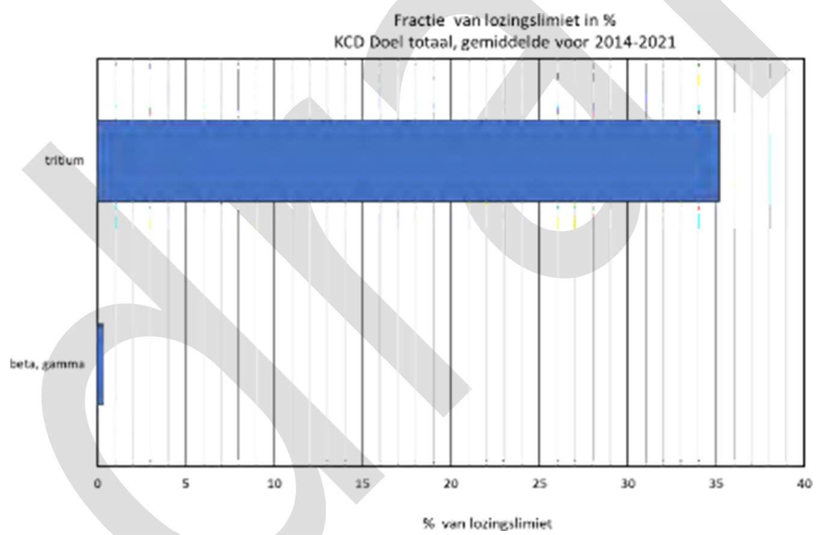

Figure 72: Liquid discharges in % of the discharge limit for liquid discharges into the Scheldt.

Environmental measurements

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 KC Doel.

The discontinuous measurements (sampling and laboratory analysis) around Doel determine the radioactivity levels of dust particles in the air, deposition in deposition basins (dry and wet deposition), soil and grass, water and sediments near KC Doel (downstream), and finally shrimps, mussels and algae (estuary downstream of Doel at Kieldrecht and North Sea, Hoofdplaat & Kloosterzande). 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[lxviii] onwards. Details of the FANC-AFCN monitoring program linked to KC Doel can be found in Table 53. Samples are taken upstream and downstream.

Table 53: FANC-AFCN surveillance program in the vicinity of KC Doel.

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 Alpha spectrometry: 234-235-238U, 238+(239+240)Pu	annual
Scheldt - water	Gamma spectrometry: 7Be, 134-137Cs, 141-144Ce, 103- 106Ru, 95Zr, 95Nb, 226Ra Beta total, alpha total, 3H, 40K	every two weeks
Scheldt - sediments	Gamma spectrometry: 7Be, 134-137Cs, (57)-58-60Co, 54Mn, 65Zn, 110mAg, 40K, 226-228Ra,228Th 90Sr, 234-235-238U, 238-(239+240)Pu, 241Am	every 4 weeks
Scheldt estuary downstream - shrimp Scheldt estuary/North Sea (Hoofdplaat and Kloosterzande) - crustaceans, mussels and algae	Gamma spectrometry: 7Be, 134-137Cs, (57)-58-60Co, 54Mn, 65Zn, 110mAg, 40K, 226-228Ra,228Th 90Sr, 238-(239+240)Pu 241Am 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 KC Doel 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 Doel, this has started since 2014. This program has a limited frequency compared to the sampling program but the focus is, on the one hand, entirely on artificial radionuclides potentially linked to the operation of KC Doel and, on the other hand, specific

samples examined such as these from bioindicators, which are organisms that concentrate certain radionuclides in particular. As a point of comparison, samples are also taken upstream in the operator's complementary monitoring program. The upstream sites are not impacted by the discharges and thus provide a picture of activity levels without input from the nuclear power plant and thus allow any evolutions to be followed over time. This program is shown in Table 54.

Table 54: Operator monitoring program.

Specific sampling	Location and frequency	Measurement specifications
Bioindicator: crust (moss) Soil Grass	Annually at 2 sites (S1-T and S2-T) in dominant wind direction and 1 reference site (R1-T)	Gamma spectroscopy (Cs-134 and Cs-137, I-131, Co-60), H-3, C-14
Aquatic bioindicator (fucus, seaweed, mussels)	Annually at 2 sites S1-A downstream and 1 reference site upstream	Gamma spectroscopy (Cs-134 and Cs-137, I-131, Co-60, Nb-95, Ag-110m), H-3, C-14
Sediment	Annually at 2 sites downstream and 1 reference site upstream	Gamma spectroscopy (Cs-134 and Cs-137, I-131, Co-60, Nb-95, Ag-110m),

Figure 73: Locations of sampling for additional program conducted by the operator of KC Doel (designations see Table 53, background map: OpenStreetMap).

The discontinuous program that has higher sensitivity via sampling and lab analysis for detecting potential artificial radionuclides around KC Doel shows:

- first, the broad predominance of natural radioactivity (mainly 40K and, to a lesser extent, ^{226}Ra and ^{228}Th);

- As for artificial radioactivity, traces of Cs-137 can be measured in soil (3.3 Bq/kg in soil in 2022[77]) almost entirely due to the Chernobyl accident and to fallout from nuclear tests in the atmosphere (which peaked in the 1960s). The concentrations measured near Doel 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 Doel 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 Scheldt. An analysis of measurement results in the vicinity of KC Doel is always representative of all activities at the site. The conclusions therefore apply in particular also to the operation of Doel 4.

Impact on humans

The current radiological status and impact of KC Doel 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 KC Doel.

On the one hand, we can look at the radiological impact of the licensed discharge limits for KC Doel as a whole (4 units) for the gaseous and liquid discharges. The conservatively estimated dose according to the methodology described in §2.3.3.3 is given in Table 55. 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 that would equal the discharge limits per year is about 0.36 mSv for the critical individual (teenage age group). 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 per age category due to liquid discharges, this is primarily due to diet.

Table 55: Effective dose per year to the critical individual by age group due to gaseous, liquid and total discharges corresponding to the current discharge limits for the KC Doel total site.

Effective dose in mSv/year for the gaseous and liquid discharge limits; site KC Doel 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	Adult
Atmospheric	0,131	0,168	0,135	0,123	0,128	0,118
Liquid	0,008	0,005	0,199	0,181	0,227	0,228
Total	0,139	0,173	0,334	0,304	**0,355**	0,346

The real discharges, as we described earlier, are well below the discharge limits and thus the real dose received by a critical individual as a result of operating the entire KC Doel 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 56.

[77] Radiological monitoring in the vicinity of the nuclear power plant at Doel : Results of the monitoring campaign of 2022. SCK CEN report.

Table 56: Effective dose per year to the critical individual by age group due to actual gaseous, liquid and total discharges for the total KC Doel site.

Effective dose KC Doel in mSv/year for the real gaseous and liquid discharges for the period 2012-2021 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	0,0068	0,0217	0,0146	0,0117	0,0114	0,0109
Liquid	0,0005	0,0006	0,0008	0,0007	0,0007	0,0008
Total	0,0073	**0,0223**	0,0154	0,0124	0,0121	0,0117

The calculations based on monitoring discharges thus show a maximum impact, i.e. an effective dose load for the most exposed critical person of about 0.02 mSv/year[lxix] (maximum 0.0223 mSv/year) and this exposure is also stable over the years as shown in Figure 74. This conservatively calculated effective dose for the most exposed person is at least 15 times lower than the dose according to the discharge limits for KC Doel and 50 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 in the operation of KC Doel.

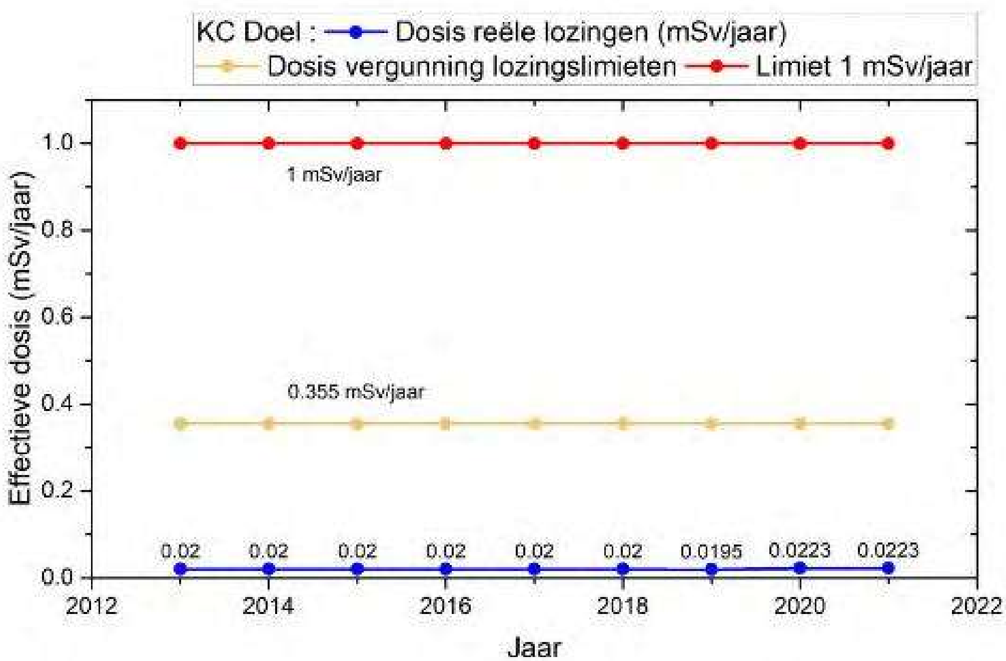

Figure 74: Effective dose for most critical individual in the vicinity of KC Doel calculated from reported real discharges[lxx]. For comparison, the dose limit for the public is shown and the dose corresponding to the discharge limits.

Environmental monitoring also shows that KC Doel has no measurable radiological impact on its surroundings. Therefore, exposure in the vicinity of Doel 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 KC Doel comes mainly from still from the 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, namely ^{3H}, ^{14C}, ^{60Co}, ^{95Nb}, ^{110mAg}, ^{131I}, ^{134Cs}, 137Cs considered in the additional monitoring campaign of Electrabel nv, only the ^{14C} and ^{137Cs} concentrations are above the detection limit. The measured concentrations for soil, sediment and bioindicators (moss and fucus) accumulating radioactivity show that the contamination of the ecosystem is very small, specifically 3.3 Bq/kg ^{137Cs} in soil and 4.5 Bq/kg $^{137Cs\ in}$ river sediment in 2022. Maximum measured concentrations are 0.23 Bq/kg ^{14Cs} for fucus. These measured concentrations are mainly due to naturally occurring 14C and Chernobyl-derived ^{137Cs}. A comprehensive environmental risk assessment was conducted in 2013 to estimate the impact of atmospheric and liquid discharges on fauna and ^{flora}[78]. Common reference organisms were selected for the Doel site and the impact of actual discharges and discharge limits on these organisms were calculated using the ERICA assessment tool. It was shown that the maximum dose rate for the discharge limits is 0.24 µGy/h and thus much smaller than the threshold value of 10 µGy/h, below which no adverse effects occur. It can thus be concluded that the current discharge limits for the considered Belgian nuclear power plants do not lead to harmful effects for the environment. Also the measurement results of the monitoring program of FANC-AFCN and the operator in the vicinity of KC Doel lead to the same conclusions.

2.1.2 Effects with deactivation of Doel 4 (baseline alternative).

Unit Doel 4 is currently licensed for industrial electricity production until July 1, 2025 at the latest. In case of non-renewal (deactivation, final shutdown), according to the current calendar, only unit Doel 2 will still be in operation at the KC Doel site for industrial electricity production and for a limited time (until December 1, 2025). The other units will then be in the post-operational phase. The situation for the entire KC Doel site if Doel 4 is not extended is therefore one in which one reactor (Doel 2) is still operational for a maximum of six months and the others are permanently shut down.

The shutdown of Doel 4 in itself gives rise to the elimination of a number of radioactive gaseous and liquid discharges to the environment. Discharges directly linked to the operation of the reactors (such as production of carbon 14) will disappear. Carbon 14 also has the main contribution to the dose due to 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 due to the POPs existing at the various facilities. Liquid discharges occur mainly from the Water and Waste Treatment Building (WAB);
- 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 partly offset by iodine residues in the fuel bath and there are also the tests of the filters. In short, a decrease can be expected; -

[78] Vandehove H., Sweeck I., Vives i Batlle, Wannijn J., Van Hees M., Camps J., Olyslaegers G., Miliche C., Lance B., 2013. Predicting the environmental risks of radioactive discharges from Belgian nuclear power plants. Journal of environmental radioactivity,126, 61-76.

- 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, one can look at effective experience with the post operational phase abroad[79] (however, this is rather limited). Based on experience in Germany, it can be estimated that the dose due to gaseous and liquid discharges resulting from the shutdown of 1 reactor unit in the first year after shutdown decreases to 25% of the level at operation and further decreases to about 10% in the following years (data available up to 7 years after final shutdown).

Based on this information, it can be conservatively estimated that the effective dose due to gaseous and liquid discharges for the entire site of KC Doel in the case of non-renewal of Doel 4, with no more reactors in service (i.e. from 2026), will decrease to a level **of the order of 0.007 mSv /year** and in the years thereafter - we consider a period of 10 years) **will further decrease to below 0.003 mSv/year**.

For 2025, the year in which Doel 1 and 2 and, if Doel 4 is not extended, shut down, we can conservatively assume an effective dose, which will be of the order of or slightly below 0.02 mSv/year, an effective dose similar to the current state.

2.1.3 Effects when extending Doel 4 for 10 years beyond 2025 (The Project)

The gaseous and liquid discharges related to the operation of Doel 4 will continue at the same level during prolongation, as we assume that the reactor will operate at the same power and that all gaseous and liquid effluents will be treated in the same way. A conservative estimate of the effective dose from operation of Doel 4 gives **0.01 mSv/year or lower 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. For the whole site of KC Doel, in addition to the operation of Doel 4, we must now take the discharges in the post-operational phase as we estimated them in the previous section concerning the zero alternative, i.e. the non-extension. Table 57 summarizes the effective dose from operation of Doel 4 and for the entire KC Doel site at extension and non-extension.

Table 57: 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 evaluation 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
Exploitation Doel 4	0.010 mSv/year
Whole of site KC Doel at renewal Doel 4	0.017-0.013 mSv/year
Whole of site KC Doel in case of non-renewal Doel 4 (all reactors out of service)	0.007-0.003 mSv/year*
Difference of project vs. null alternative	0.010 mSv/year for 10 years

[79] Based on Periodic Safety Review Tihange Unit 2 and TEF - SF14-2: Radiological impact to the public. PSR3/4NT/0791625/000/01, Tractebel Engineering S.A.,2022

*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 Doel 4 after 10 years of extension.

Consequently, the estimated effective dose per year from 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 extra dose a Belgian receives from increased cosmic radiation if he or she goes skiing in the mountains for two weeks[80]. 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 (§2.3.4). We present here the results of the impact assessment and discuss the results.

2.2.1 Draft base accident

The radiological impact of the two considered design basis accidents, i.e. a LOCA and FHA was assessed based on the general data under Article 37 of the Euratom Treaty and the Doel 4 safety file. In addition, an analysis based on a Tractebel study[81] under the 2017 FANC- AFCN/Bel-V guidelines for new Class 1 installations was also performed. The latter analysis is strictly speaking not applicable for Doel 4 as it concerns the lifetime extension of an existing Class 1 plant. Besides the consequences during atmospheric discharges resulting from the accidents considered for Doel 4, this analysis also allows to assess the longer-term consequences towards humans, food chain and environment. In the **LOCA** accident, it is assumed that 25% of the nuclear inventory of iodine and 100% of the noble gases are released to the reactor building, 91% of the iodine is present in elemental (molecular) form, 5% in aerosol form and the remaining 4% in organic 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 leak rate, as well as by safety injection (sprinkling) and recirculation for cooling (see §2.3.4.1). Limited amounts of beta(-gamma) aerosols. 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 work and have an efficiency of 90% for all iodine. A discharge time of 2 hours is assumed.

The dose results from both analyses for both accidents are given in Table 58. 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 iodine radioisotopes for the critical individual.

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[80] Comparison based on https://fanc.fgov.be/nl/dossiers/medische-toepassingen/vergelijking-stralingsdosis.

[81] LTO D4 - ELP - KCD4 - Radiological consequences of a Loss of Coolant Accident and a Fuel Handling Accident," CNT-KCD/4NT/29657/000/01, Tractebel Engineering S.A., 2023

Table 58: Effective dose and the equivalent thyroid dose at the site boundary of KC Doel (300 meters from discharge point) resulting from the occurrence of a LOCA and FHA for Doel 4, compared to the dose limits described in the general data under Article 37 of the Euratom Treaty, which are a 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.

Doel 4	Safety file/Art 37		Analysis according to guidelines for new Class 1 installations	
	Dose	Limit	Dose	Criterion
Effective dose				
LOCA	20.4 mSv	20.4 mSv	2.0 mSv	5 mSv
FHA	5.7 mSv	20.4 mSv	2.8 mSv	5 mSv
Equivalent thyroid dose				
LOCA	38.5 mSv	38.5 mSv	36.70 mSv	10 mSv
FHA	24.7 mSv	38.5 mSv	33.28 mSv	10 mSv

The above table shows that the effective doses and equivalent thyroid doses resulting from both reference design basis accidents for Doel 4 remain within the set limits, in context of the Article 37 analysis. It should be noted that different analyses of the same accident may show significant differences depending on the assumptions used. The analysis according to the guidelines for new Class 1 plants shows significantly lower effective doses, this is due to the fact that a very pessimistic (conservative) analysis was used for the estimation of this in the safety case and a less, but still conservative, estimation in this one for new Class 1 plants. Equivalent thyroid doses, according to the analysis for new Class 1 installations, are similar to those in the safety case. The criterion for equivalent thyroid dose was exceeded for the two design basis accidents. Consequently, in both accident scenarios, under the countermeasures guidelines (RD Federal Nuclear and Radiological Emergency Plan), the intake of stable iodine for thyroid protection by all age groups except non-pregnant adults may be recommended (10 mSv equivalent thyroid dose criterion). Shelter is therefore recommended in this measure, despite the criterion for this (effective dose of 5 mSv in 24 hours) not being exceeded.

Under the very conservative assumptions (including rain during discharge) made in the Tractebel analysis, the maximum deposition levels of total iodine isotopes will well exceed the derived food chain guidance values (see Table 17) in both accident scenarios (about 220,000 $^{Bq/m2}$ I-131 in the LOCA accident and about 925,000 $^{Bq/m2}$ I-131 in the FHA accident). Countermeasures for the food chain may thus be necessary in these scenarios. However, the implications will always be limited in time due to the relatively short half-life of the major iodine isotopes (8.02 days for I-131). For the aerosols (applicable to LOCA, not discharged at the FHA), including the long-lived Cs-137 (half-life 30.05 years), the deposition levels will not exceed the derived value for impact on the food chain (maximum deposition Cs- 137 is only around 9 $^{Bq/m2}$).

Lifetime Effective Dose (LOD) due to deposited radioactivity on soil and food consumption from 1 year post-accident for all age groups (adults 50 years, teenagers and children up to 70 years of age) of the order of no more than 5 mSv[82] and thus much smaller than the criterion of 1 Sv for both accident scenarios.

2.2.2 Draft expansion accident

The radiological impact of the enveloping design expansion accident for Doel 4, namely a Complete Station Blackout (CSBO) was assessed based on the analysis performed by Tractebel under the 2017 FANC- AFCN/Bel-V guidelines for new Class 1 installations. The results are given in Table 59.

Table 59: Effective dose and the equivalent thyroid dose at the site boundary of KC Doel due to the occurrence of a CSBO for Doel 4.

Doel 4 CSBO		
	Dose	Permit Limit
Effective dose	8.89 mSv	no
Equivalent thyroid dose	0.24 mSv	no

The effective dose is derived almost exclusively from direct exposure to radiation from the passing radioactive cloud due to the various controlled vents through the Containment Filter Venting System (at 65 meters altitude). This filtering system (CFVS) releases almost exclusively noble gases to the atmosphere; other groups of radionuclides are largely blocked. There are also limited leaks from the containment (at a typical height of 30 meters). Consequently, the amount of iodine released is limited, resulting in limited equivalent thyroid dose and limited contamination levels For design expansion accidents, there are no limits specified in the permit. Shelter could be an effective countermeasure in this case to further limit the dose (guideline defined in the Belgian nuclear emergency plan for sheltering is 5 mSv, see §9.2.1). The equivalent thyroid dose calculated for the critical individual is below the guideline for the intake of stable iodine tablets (10 mSv for children and pregnant women).

Limited contamination with iodine isotopes cannot be ruled out with possible impact on the food chain (deposition greater than 4000 Bq/m^2), but this will be short-lived due to radioactive decay. After 1 year (next harvest), no effects on the food chain are to be expected.

2.2.3 Impact of considered accidents on biodiversity

The reference organisms discussed in Vandenhove et al, 2013[83] for routine discharges were also used to calculate the environmental impact of accidental discharges due to a LOCA and FHA accident. The reference organisms representative of the ecosystems around Doel include an amphibian, reptile, flying insect, mole, rabbit, mouse, birds, moss, grass, tree, bat, badger. The impact calculations were performed with the environmental assessment tool ERICA which takes into account the radioactive decay of the radionuclides. The calculations only consider the maximum deposition, not the average deposition which leads to rather conservative calculations since flora and fauna are not limited to the location of maximum deposition. Also, the ERICA tool is used for chronic exposure where concentrations remain constant over a long period of time. Thus, the tool is especially suitable for routine discharges or an existing condition. In the case of

[82] We deviate here from the results in the Tractebel paper because we include in the total lifetime effective dose the dose of external radiation due to soil contamination (primarily iodine contamination) in the first year after the accident.

[83] Vandehove H., Sweeck I., Vives i Batlle, Wannijn J., Van Hees M., Camps J., Olyslaegers G., Miliche C., Lance B., 2013. Predicting the environmental risks of radioactive discharges from Belgian nuclear power plants. Journal of environmental radioactivity,126, 61-76.

accidental spills, with mainly short-lived radionuclides released, the deposited radioactivity in the soil decreases rapidly with time and consequently the dose rate to which flora and fauna are exposed. To get an idea of the chronic exposure after an accidental discharge, the average dose rate is calculated over the first month and the first year after the accident.

The calculations with the environmental risk tool show that the radiological doses to fauna and flora for the LOCA accident vary by more than a factor of 17 to 59, according to the time elapsed after the accident (immediately to 1 year after maximum deposition), with the most exposed organisms being mammals.

The dose values for maximum deposition range from 0.1 to 1.74 µGy/h (where external dose dominates internal dose) and are all lower than the screening value of 10 µGy/h below which no adverse effects on fauna and flora are observed. The average dose rate over the first month after the accident is negligible, i.e., lower than 4.5E-02 µGy/h and drops further over 1 year to less than 5E-03 µGy/h. Thus, based on these dose rates, we can conclude that there is no chronic exposure to radioactivity and thus the harmful impact of the exposure of fauna and flora to the discharged accidental radioactivity is negligible.

Radiological doses to fauna and flora for the FHA range from 19 to 159 µGy/h for the maximum deposition, with the most exposed organisms being arthropod detritivorous invertebrates, ringworms, small mammals and mice. The exposures are higher than in the LOCA case. However, the FHA accident releases only short-lived iodine isotopes, specifically ^{131I}, ^{132I}, ^{133I} and ^{135I} of which ^{131I} has the largest half-life of 8 days. The other iodine isotopes have half-lives ranging from 2 (^{132I}) to 20 hours (^{133I}). The radionuclides that contribute the most dose are ^{131I} and ^{133I} (in descending order), with external dose dominating internal dose. The fact that these iodine isotopes contribute the most is explained by their longer half-life, allowing them to remain in the environment longer than ^{132I} and ^{135I}. However, dose rates decrease with time. Over 1 month, average dose rates range between 9 and 46 µGy/h and are below the threshold of 10 µGy/h only for grass. Over 1 year, average dose rates range between 0.9 and 4.2 µGy/h and are thus lower than the threshold value for all reference organisms.

Thus, for a number of organisms, the dose rate exceeds 10 µGy/h when exposed during the first month after the accident. In this particular scenario, the next logical step is to compare the dose rates directly with ICRP-derived reference levels (DCRLs) for reference animals and plants, below which there is unlikely to be any likelihood of adverse effects occurring, based on the best available scientific knowledge. Each DCRL represents a range of dose rates for each reference organism within which there is likely to be some probability of the occurrence of adverse effects.

Information from ICRP Publication 108 (ICRP, 2008) shows that for deer, rat, pine and duck, the lower band of the DCRLs is 0.1 mGy/d (4 µGy/h). For grass and frog, the low level of the band is 1 mGy/d (40 µGy/h). For earthworms and bees, the lower band of the DCRLs is 10 mGy/d (400 µGy/h). The calculated doses exceed these lower levels for a number of reference organisms, the most relevant case being arthropod detritivorous invertebrates. However, while it is not possible to say that there is absolutely no risk to populations of fauna and flora in the event of such an accident, it is clear that some plants and animals are more resilient than others, especially at the level of populations. We conclude that exceeding the threshold of 10 µGy/h may lead to a number of adverse effects such as reduced reproduction and increased morbidity. In this particular scenario, the 1-year average dose rate falls below the 10 µGy/h threshold for all organisms. Thus, there is no long-term chronic exposure. We can therefore conclude that the harmful impact of the exposure of fauna and flora to the discharged accidental radioactivity is very moderate to negligible.

It should also be noted here that the calculations are conservative. Therefore, it is quite possible that a revised assessment with reduction in the conservatism of some of its assumptions (such as the assumption that fauna stays on site at the location with the highest soil concentrations) could further reduce some dose rates.

For the CSBO accident, based on the radionuclides discharged and depositions, it can be expected that at most moderate to negligible adverse effects on flora and fauna are possible.

2.2.4 Discussion of accidental discharges

If no lifetime extension takes place, Doel 4 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 loop. 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 at extension (because of small accident probability and limited radiological impact) is even smaller at non-extension given that at least the impact is smaller. The project therefore entails a limited risk related to accident (both design basis - and design extension accident). For the entire Doel site, however, the risk will decrease as according to the current calendar during the period of the project (period of 10 years after 2025) only Doel 4 will be exploited for industrial electricity production.

2.3 Operational radioactive waste

2.3.1 Waste treatment at the site

The operation of the nuclear power plant (normal operation) involves the production of various types of radioactive waste, with the volume minimized as much as possible by treatment in the Water and Waste Treatment Building (WAB) at the KC Doel site:

- Combustible waste

After volume reduction in the WAB, the combustible waste is transported to Belgoprocess as unconditioned waste for incineration. At Belgoprocess, the waste is further greatly reduced by incineration. The residual fraction (the ash), containing the collected radioactive substances, is conditioned.

- Non-combustible waste

The noncombustible waste or compactable waste will be split into different waste streams. Among other things, the various metals will be separated from the other various compactable waste with the objective always being to be able to reduce each individual waste flow as much as possible. In the KC Doel installations, the compactable waste is compacted a first time (with a 16-ton or 100-ton press), after which it is transported as unconditioned waste to Belgoprocess. There it is compacted for a second time in their facilities with a 2000 ton press. The compacted waste is then conditioned.

- Filters

In order to remove as much as possible any radioactive particles present from the air, the air from the controlled zone is continuously filtered through pre-filters, activated carbon filters (for iodine) and absolute filters. The ventilation filters originating from these installations are also processed, depending on their physical properties, as combustible or compactable waste and transported to Belgoprocess as unconditioned waste.

The liquid filters from the circuits of the nuclear part of the plants are also pressed and conditioned together in a concrete mixture when possible.

- Liquid waste

The volume of radioactive liquid waste is reduced mainly by evaporation. The radioactive substances present in the liquid are collected in the 'concentrate' and the non-radioactive portion of the liquids, the condensates, can be discharged after prior checks. The 'concentrate' is placed in

Doel's conditioning plant is further processed into conditioned waste. After acceptance[84] , the conditioned waste is transported by ONDRAF/NIRAS to Belgoprocess for disposal.

- Resin

Radioactive resins from ion exchangers, for purifying circuits, are not compacted but, like the concentrate, are processed into conditioned waste. The resins are mixed with a concrete mixture.

- Protective clothing

The use of disposable protective clothing (radioactive waste) is minimized, in the nuclear sections of the facilities, by using washable protective clothing. These reusable personal protective equipment (PPE) are cleaned in the specialized laundry of the WAB building. The laundry water is discharged after filtration and preliminary controls.

2.3.2 Quantities of low- and intermediate-level waste

After treatment of the various waste streams in the WAB, operational waste from KC Doel is transported to Belgoprocess (BP) for further processing and/or storage. A summary of the quantities of low- and intermediate-level waste (both conditioned (GA) and unconditioned waste (NGA)), and the resulting volumes to be disposed of after processing at BP, are shown in the second and third columns of Table 60. These data were compiled from KC Doel's environmental statement, which is updated annually lxxi. This does not distinguish between category A or category B waste. Note that in 2020, the volume of conditioned waste (GA) after treatment at BP is higher than previous years because previously stored waste was also disposed of, and additional cleanup operations were organized. In addition, more compressible waste was disposed of, which has a smaller volume reduction factor than combustible waste.

Column 4 shows the volume of GA expressed per TWh of net electricity produced at KC Doel in the corresponding year, resulting in a long-term average of **6.11** $^{\mathbf{m3/TWh}}$ **of low- and medium-active conditioned waste**. Taking into account the share of the Doel 4 reactor in electricity production, we arrive at a long-term average of **45.9** $^{\mathbf{m3}}$ **low- and medium-active conditioned waste** per year for Doel 4 (column 5). Here, the actual share of Doel 4 relative to total electricity production at the site fluctuated around 40% during the period 2011-2020. This is slightly higher than the ratio based on power (36 %), as other reactors (mainly Doel 3 in the period 2012-2015) have had some prolonged shutdowns.

[84] Acceptance is the set of checks carried out by ONDRAF/NIRAS that verify that the waste meets the acceptance criteria applicable to it.

Table 60: Annual volumes of low- and intermediate-level waste from KC Doel diverted to Belgoprocess, and the resulting volumes to be disposed of after processing there. GA: conditioned waste; NGA: non-conditioned waste; Note: data not available. In 2014, a correction was made to previous years' figures; the corrected values have been adopted here. From 2015, the volume is calculated with a different methodology: the volumes of unconditioned resins are included.

	Amount (m^3) of low- and intermediate-level waste diverted to BP (GA + NGA, KC Doel)	**Volume (m^3) of low- and intermediate-level waste (GA, KC Doel)**	**Volume of low- and intermediate-level waste (GA) per net electricity generated at KC Doel (m^3/TWh)**	**Volume of low- and intermediate-level waste for Doel 4 (m^3)**
2011	NB	196	8,62	68,6
2012	NB	124,7	6,84	53,5
2013	NB	125,9	6,08	51,3
2014	NB	46,8	3,33	16,3
2015	NB	108,2	9,68	75,0
2016	NB	100,5	4,54	39,9
2017	NB	95,1	4,60	34,3
2018	183,9	91,1	7,64	42,2
2019	372	61,9	2,96	24,9
2020	293	132	6,85	53,2
Long-term average		**108**	**6,11**	**45,9**

2.3.3 Effects of LTO and implications for waste management.

Based on Table 60, delayed deactivation of Doel 4 nuclear reactor is expected to give rise to an additional amount of low and medium level waste of about **460** m^3 for a 10-year production period. This estimate is quite conservative by averaging a broad time period (2011-2020) that includes years with higher waste production. Assuming that the impact of LTO preparation works is relatively limited in terms of radioactive waste generation, this estimate can be considered representative of both periods/aspects LTO preparation works + LTO operation. This is primarily Category A waste, with only a limited amount of Category B waste, which may include certain resins and filters. Compared to the ~50,000 m^3 of category A waste currently included as a source term in the surface disposal safety file[lxxii], this represents a marginal increase (<1 %).

Assuming that the additional amount of Category B waste is negligible, the additional volume of waste corresponds to approximately **287 monoliths** or **0.31 modules** in the repository for Category A waste. The (volumetric) capacity of the repository is 34 moduleses[lxxiii], 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 Doel 4 (among other decisions already made) thus consumes 0.31 modules or ~5.7%.

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

2.4 Spent fuel

In the nuclear power plant, electricity is generated from the energy released during nuclear fission of the uranium-235 present in the fuel elements. After three to four years in the reactor core, a fuel element is exhausted, meaning that all usable energy is gone from it. These exhausted fuel elements are cooled under water (at least 2 years) and then transported to the spent fuel storage building (SCG or SF2) where they are stored dry in Dual Purpose Cask (DPC) type containers. This type of containers have been in use since the late 1970s, operating according to a passive cooling system. In the case of the Doel nuclear power plant, the containers are equipped with a primary lid and missile protection. Resistance tests have shown that the extreme natural phenomena (earthquakes or floods) that might occur in Belgium cannot compromise the safety of the storage facilities.

2.4.1 Quantities

The amount of high-level waste generated by a nuclear power plant is highly dependent on the amount of electricity produced and the unit's recharge cycle. Table 61 shows the number of fuel elements permanently discharged annually in the various reactor units, based on data in KC Doel[lxxi]'s environmental statement. The same information is shown in Table 62, expressed in tHM (tonnes of Heavy Metal).

Table 61: Number of fuel elements permanently discharged in the different reactor units of KC Doel.

	Doel 1	**Doel 2**	**Doel 3**	**Doel 4**	**Total KC Purpos e**
2011	32	28	44	52	156
2012	32	32	44	60	168
2013	0	32	0	0	32
2014	36	28	0	56	120
2015	60	0	44	52	156
2016	28	40	40	0	108
2017	28	32	0	60	120
2018	0	28	40	56	124
2019	24	28	40	0	92
2020	24	28	44	52	148
Long-term average				**39**	**122**

Table 62: Number of tons of nuclear fuel (tHM or tonnes of Heavy Metal) finally discharged in the different reactor units of KC Doel.

	Doel 1	**Doel 2**	**Doel 3**	**Doel 4**	**Total KC Purpose**
2011	8,6	7,5	20,2	28,1	64,5
2012	8,6	8,6	20,2	32,5	69,9
2013	0,0	8,6	0,0	0,0	8,6
2014	9,7	7,5	0,0	30,3	47,5
2015	16,1	0,0	20,2	28,1	64,5
2016	7,5	10,8	18,4	0,0	36,7
2017	7,5	8,6	0,0	32,5	48,6
2018	0,0	7,5	18,4	30,3	56,2
2019	6,5	7,5	18,4	0,0	32,4
2020	6,5	7,5	20,2	28,1	62,4
Long-term average				**21,0**	**49,1**

The above tables show that annual production in the Doel 4 unit amounts to an average of 39 fuel assemblies, or 21.0 tHM of fuel.

2.4.2 Effects of LTO and implications for waste management.

Based on the above tables, it can be expected that the extension of the 10-year operation of Doel 4 will generate an additional quantity of about **390 spent fuel elements**. This represents an **increase of 3.5%** compared to the entire Belgian nuclear fuel inventory in case of final shutdown. These are 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 Doel 4.

Storage

At KC Doel, fuel assemblies are temporarily stored dry in containers in the SCG (Fuel Container Building), and from 2025 also in the SFB building of the SF2 storage facility (see §2.3.7.3). The deactivation basins act as a buffer, in which the fuel bundles can cool. More detailed information surrounding the SF2 project can be found in the relevant EIA report[lii]. Due to the postponement of deactivation of Doel 4, the disconnection from the grid of the 4 units will be more spread out, where otherwise it would be condensed in a few years.

The IAEA has conducted an international research program[xxiv] (Project SPAR: Spent Fuel Performance and Research Program, 1997-2001) on the behavior of irradiated nuclear fuel and of the materials used for its long-term (100 years and longer) storage. Based on the programs conducted, it was possible to uncover a number of degradation mechanisms for spent fuel elements. After detailed analysis, it has been concluded that those mechanisms are unlikely to affect the long-term integrity of the elements. The long-term goal of maintaining the integrity of irradiated nuclear fuel is to be able to keep all options open for the management of that spent nuclear fuel.

Storage

A long-term management solution will need to be worked out for these fuel elements, which amounts to geological disposal if fissile material is classified as waste (see §2.3.7.4). On the assumption that disposal will take place in little paved clay, with supercontainers as the primary container, the above additional consumption would correspond to **98 additional supercontainers** (Type SC-4) and an additional required disposal gallery length of approximately 600 m.

The implications for the long-term safety of such a disposal system will be limited. Long-term safety evaluations of disposal systems are complex analyses in which estimates of radiological impact or risk are made from scenarios in which expected, possible or hypothetical events determine the performance in terms of containment and isolation[85] of the SSCs[86]. The impact or risk results from very small fractions of radionuclides that could be released from the disposal system into groundwater over a very long period of time (several tens of thousands to hundreds of thousands of years). Use of that water for a variety of applications (e.g., drinking water, watering livestock, irrigation of crops) could then lead to potential radiological exposure. An additional amount of spent fuel to be disposed of will not cause a commensurate increase in estimated dose or risk since local peak concentrations in the biosphere receptor are considered, and these concentrations depend primarily on other factors: disposal configuration, rate of release from the waste, rate of migration-primarily by diffusion-through artificial and natural barriers, rate of water flow in surrounding aquifers, and rate of radioactive decay.

2.5 Decommissioning

Radioactive material released during the decommissioning of nuclear power plants is treated and decontaminated as much as possible, in accordance with strict standards, thereby limiting the quantity of radioactive waste to a minimum. The vast majority (98% according to Electrabel S.A. estimates) is non-radioactive or conventional waste that will be recycled to the maximum extent possible. The remaining 2% therefore consists mainly of category A waste that will be conditioned and packaged into monoliths at the sites, before being transferred to ONDRAF/NIRAS for surface disposal. Components of the reactor, the reactor itself and the concrete casing are likely to be transferred largely as category B waste in specially designed containers to temporary storage at the sites (SF²) pending final deep disposal[lxxv].

Part of the radioactive waste is due to neutron activation of large (structural) components. This activation occurs during reactor operation and is usually estimated through calculations, such as those given in the next section. Materials located close to the neutron source (such as the middle section of the reactor vessel) are activated more in this process than materials located further away. The waste classification (category A or B) is based on the radioactivity concentration of safety-relevant radionuclides and therefore depends on neutron flux during reactor operation and irradiation duration. Thus, longer neutron exposure could potentially shift the transition zone from Category A to Category B, which would increase the volume of Category B waste (see schematic in Figure 75). There is currently little to no measured data available to validate these calculations[87].

[85] Containment of radionuclides and isolation of waste are safety functions that the disposal system must perform to ensure long-term safety.

[86] structures, systems and components, as defined in article 1, 9° of the RD VVKI: all elements of an installation or activity - excluding human factors - that contribute to protection and nuclear safety.

[87] An example of validation of neutron activation calculations can be found in Annex IV of IAEA SRS-95[lxxvi] , in which EDF-CIDEN compares calculations and measurements of activation products in the Chooz A reactor vessel.

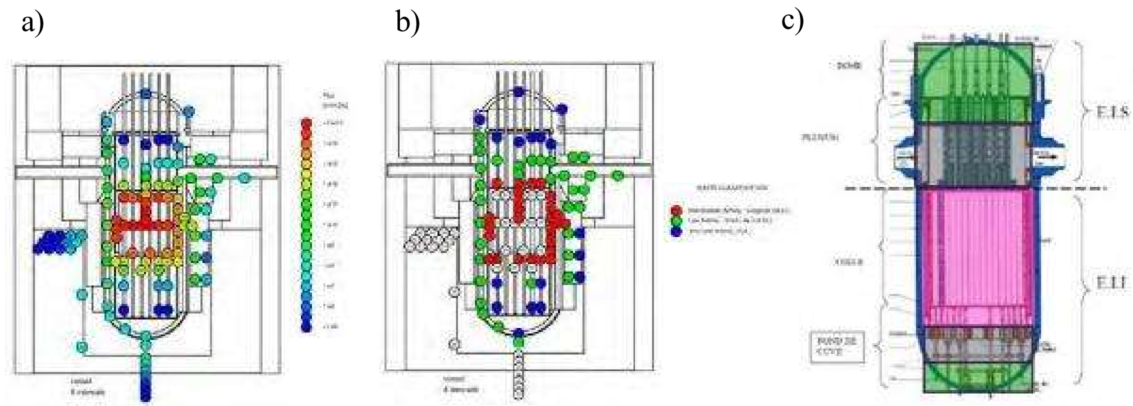

Figure 75: Schematic representation of (a) the simulated neutron flux in a reactor vessel, (b) the waste class classification derived from it, and (c) indication of the transition zone (in gray) for the a priori classification into category A (green) or B waste (purple). a) and b) taken from. lxxvi

In order to quantitatively estimate the effect of deferring deactivation for 10 years, activation was calculated at various locations in the Doel 4 reactor vessel using the activation code [ALEPH2lxxvii].

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 [capsules88] 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 [reactorslxxviii] 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.

[88] 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.

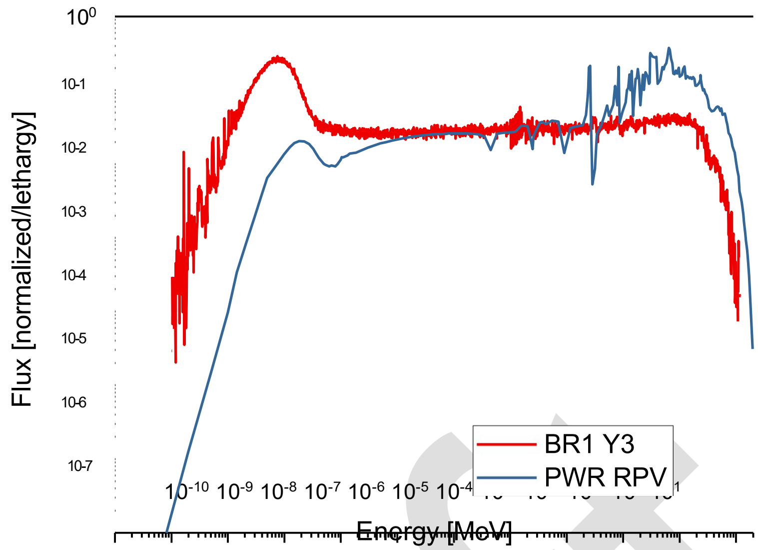

Figure 76: Normalized neutron spectrum per unit of lethargy.

iii) To calculate the activation, on the one hand, the actual irradiation history of Doel 4[lxxix] was used, with data from 1985 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 85% was estimated for Doel 4, which was extrapolated for the LTO period. Thus, as of 2022, the model considers annual cycles of 310 days of irradiation, and 55 days of decay. On the other hand, continuous irradiation without periods of shutdown is also applied to obtain conservative estimates of operations.

iv) Material composition relies on data provided for the monitoring capsuleeslxxx, and specified for the core jacket, transition ring and weld for the Doel 4 reactor vessel. The chemical composition by weight percent of the major elements (except iron) is given in Table 63.

Table 63: Composition of major elements of parts of the Doel 4 reactor vessel (in weight%).

Unit	Material	C	S	P	Si	Mn	Ni	Cr	Cu	Mo	V
Doel 4	Core mantle	0,20	0,0075	0,007	0,275	1,4	0,74	-	0,05	0,51	<0,01
	Transition ring	0,215	0,005	0,007	0,285	1,46	0,77	-	0,04	0,49	<0,01
	Las	0,062	0,006	0,015	0,15	1,11	0,8	0,075	0,093	0,480	0,019

These elements determine the thermochemical behavior of the steel. However, trace elements (or impurities) may also be present in the ores and during the production process that will be present in the final steel. These elements do not influence the behavior of the steel, but may be important in light of safe long-term management. Since no information is available on the amount of trace elements in the reactor vessels of Doel 1 and 2, the international guideline NUREG-3474lxxxi was assumed.

2.5.2 Results

Since a constant neutron flux of $1.^{4\times1011}$ [n/cm²s] was used for all calculations in this study and the total flux is higher for the Tihange 3 reactor vessel due to the assumed higher load factor, the results of the Tihange 3 activation calculations will be envelope to those for Doel 4. Reference is therefore made to §7.5.2 for a discussion of the results.

2.5.3 Conclusions

The conclusions regarding the activation calculations are analogous to those performed for Tihange 3, see §7.5.3.

2.6 Cross-border effects

2.6.1 Normal operation

The shortest distance from the border with the Netherlands is about 3.15 km from the KC Doel site. However, given the negligible and unobservable radiological impact (order 0.02 mSv/year from gaseous and liquid discharges and possibly limited dose from direct radiation, but within local variations of natural radiation) when operating all units of KC Doel for the most exposed person is located on Belgian territory just outside the KC Doel site and the fact that the impact only decreases with distance (dilution for discharges and inverse square law for any direct radiation coming from KC Doel), it can be stated that there are no transboundary effects on man and the environment during normal operation of KC Doel, m.i.e. also not when extending Doel 4 for a period of 10 years.

2.6.2 Accidents

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

Both methodologies do a conservative estimate for the critical individual. For example, for the Flexpart calculations, we conservatively considered the source term for the LOCA (duration 720 hours) as a 6-hour discharge (this gives less dispersion), for the FHA 2 hours (real duration of discharge) and for the CSBO also 6 hours (discharges during several vents and continuous discharge over 10 days). We also consider all iodine in the elemental form (I_2) in the Flexpart calculation.

The discharges to the environment assumed in these scenarios are given in Table 64.

Table 64: Discharged activity of the different groups of radionuclides important for impact.

	Draft baseline scenarios		Exterior design scenario
	LOCA	FHA	CSBO
Noble Gases	2.5 PBq	8.89 PBq	13.7 PBq
Iodine	64.5 TBq (74.4% I-131)	7.23 TBq (43% I-131)	0.49 TBq (14.6% I-131)
Aerosols (Cs-137 + Cs- 134)*	1.88 GBq	-	58.3 GBq

*Cs-134 only applicable for the CSBO accident

The calculated radiological impacts, in particular the total effective dose, the equivalent thyroid dose and the deposition level I-131 are given in Table 65. These are determined for the Netherlands at a distance of about 3 kilometers from the Doel site, according to the new guidelines of FANC-AFCN/Bel-V (studies Tractebel[89], suitable for short distances), for the other countries (and deposition Netherlands) with the Flexpart method (longer distances: see methodology §2.3.4.3). Both methods use the same total source term. In the Flexpart method, maximum air concentrations and deposition levels in the respective countries are used that were determined for a series of simulations with the start of discharge every hour of a full year (meteorological data ECMWF 2020 -) for the considered duration of discharge (6 hours or 2 hours, depending on scenario) and considered groups of radionuclides. Maximum values at sea were also determined. Based on these air concentrations and depositions, total effective dose, equivalent thyroid dose and deposition levels were then determined for different age groups. For the doses, the maximum across all age categories was tabulated (critical individual).

Table 65: Total effective dose (TED), equivalent thyroid dose (both for critical individual) and maximum deposition of I-131 for the different neighboring countries and for the different accident scenarios considered with the Flexpart methodology. Two values were given for the Netherlands. The first value was determined with the local impact methodology, the value in parentheses with the Flexpart methodology (see text), . For the assessment we use for the Netherlands (for the doses) the local methodology and for the other countries the Flexpart methodology.

Doel 4	**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	0,22 (0,55)	4,05 (16.0)	(3.4 105)	0,44 (0,14)	4,79 (1,46)	(33202)	0,44 (12,5)	0,011 (0,51)	(5980)
Germany	0,01	0,26	8400	0,01	0,04	992	0,99	0,009	190
Luxembourg	0,00	0,05	4970	0,00	0,01	380	0,12	0,002	61
France	0,03	0,90	12700	0,02	0,15	1600	1,11	0,032	289
United Kingdom	0,01	0,29	5330	0,01	0,03	410	0,56	0,009	70
Sea	0,37	10.62	-	0,10	1,03	-	8,57	0,340	-

We see that doses are highest in the Netherlands, given its proximity, but below the typical guideline values for immediate countermeasures such as sheltering or taking iodine tablets to avoid accumulation of radioactive iodine in the thyroid gland (see Emergency Planning section §9.4.1). Consequently, the radiological impact in neighboring countries will remain very limited. The deposition of aerosols (Cs-137 and also Cs-134 for the CSBO accident) for all neighboring countries and all scenarios is below the value at which some impact on the food chain can be expected. For iodine isotopes and especially I-131, the lowest derived value for the soil concentration (4000 Bq/m2 I-131) at which there may be an impact on the food chain (e.g. contamination of milk) can be exceeded in all neighboring countries for the LOCA accident. It is admittedly, with the Netherlands as an exception due to its proximity, a very limited exceedance. The calculated deposition values are, in accordance with the methodology used, for the most unfavorable moment that the accident can occur (concerning the

[89] LTO D4 - ELP - KCD4 - Radiological consequences of a Loss of Coolant Accident and a Fuel Handling Accident" CNT-KCD/4NT/29657/000/01, Tractebel Engineering, 2023 & DEC B: RC-1.5 - D4 - Radiological consequences off-site - Assessments DEC/4NT/0606802/150/04, Tractebel Engineering, 2022

meteorological conditions in the year 2020), for each neighboring country specifically. Furthermore, given the half-life of I-131 (8.02 days), this contamination will also have no long-term consequences.

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 when Doel 4 is operated is largely determined by the gaseous discharges of carbon-14, a radionuclide that also occurs naturally. The discharge is based on calculations and was verified only through measurements for Tihange 2. Here it was found that real discharges of carbon-14 at Tihange 2 are lower than the (conservatively) calculated ones. In this context, when extending Doel 4, it would be appropriate to quantify the discharges of carbon-14 on the basis of measurements, using a method analogous to that applied at Tihange 2, in order to obtain a better and realistic estimate of the doses in normal operation;
2. If Doel 4 is extended for 10 years, operation will coincide with the post-operational and possibly decommissioning phase of the other reactors and some auxiliary buildings on the KC Doel site. It seems recommended that the radiological exposures potentially resulting from decommissioning and those due to operation for further electricity production of Doel 4 be distinguished to the extent possible and reported separately publicly so that impacts from operation for industrial electricity production of Doel 4 can be analyzed separately from any decommissioning activities.

3 Synthesis and decision site Doel - Doel 4

3.1 Synthesis of effects

3.1.1 Non-radiological effects

Extending the lifetime of Doel 4 means that for an additional period of 10 years (treated) sanitary wastewater, treated industrial wastewater and (heated) cooling water will be discharged. During this period, the overflow problem, which is inherent to the mixed sewage system at the site, will also be perpetuated. This will not lead to a deterioration of the ecological status of the Zeeschelde, provided that continued attention to monitoring and timely adjustments continue to be made. Nor does the project jeopardize the achievement of the good ecological potential of the water body. However, it is recommended that thermal discharges be brought more in line with the evolution of the temperature gradient between the Dutch border and Antwerp.

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

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

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

The operation of KC Doel may also have an impact on air quality. The main sources with a potential impact are steam boilers and diesel engines, which, however, only have a limited number of operating hours annually. If only Doel 4 is still in operation, the number of operating hours of the steam boilers will almost double, but even then the total number of effective operating hours remains limited. Emissions from the plants are therefore very limited, and will continue to decrease as more incinerators are decommissioned.

The highest calculated emissions (for 2026) were used as model inputs to calculate air quality impacts. Because model characteristics were not available from all facilities, a number of assumptions were used for these calculations. The impact calculations show that the impact on ambient air quality is negligible (less than 1% of the limit or test values used). No exceedances of limit values are observed either, taking into account the expected background concentrations. Therefore, there is no need for mitigation measures.

If the lifetime of Doel 4 is not extended, electricity will have to be generated instead using (in part) fossil fuels. The emissions generated in this process (which can be considered "avoided" if Doel 4's lifetime is extended) are much higher than the emissions generated in the operation of Doel 4.

The greenhouse gas emissions attributable to Doel 4 over the lifetime extension period are of the order of 14 ktonnes (cumulative). The *avoided greenhouse* gas emissions from keeping Doel 4 open longer are of a different order. Over the entire period, delaying the deactivation of Doel results in

4 in avoiding emissions of about 12,417 ktonnes of $_{CO2eq}$. Annually, this represents a saving equivalent to almost 10% of emissions in the "production of electricity and heat" sector in Belgium in the year 2021 (12.8 Mton). If we compare with the emissions released from the operation of Doel 4 over the same period (14 kton), we can see that the emissions from Doel 4 over the period covered by the lifetime extension represent only 0.11% of the emissions avoided over the same period.

Doel 4 has no impact on the environment's resilience to the impacts of climate change during the reference period given that both in the reference situation and when the Project is implemented, the site remains hardened. Within the time perspective of the lifetime extension, the Doel site itself is also not vulnerable to the impacts of climate change, and this situation is independent of whether the lifetime of Doel 4 is extended or not.

The project has no meaningful health impacts. Based on a preliminary screening, only the effects related to Legionella, psychosomatic aspects (associated with risk perception), and the avoided health effects of a black out were considered as potentially relevant. The analysis carried out in this EIA shows that Legionella cannot be a problem, given the brackish water with which the cooling towers of Doel 4 are fed. Regarding risk perception related to nuclear accidents, it can be stated that there is such risk perception, but there is no demonstrable link to psychosomatic effects. Finally, it can be confirmed that the lifetime extension of Doel 4 significantly reduces the chances of a blackout (especially in the first years of the lifetime extension), with thus a positive effect on the avoidance of health effects that can be associated with power outages.

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 KC Doel is much smaller than the legal limit of 1 mSv/year, and indistinguishable from local variations in the natural background.

In the current situation, the Doel nuclear power plant does not have a significant measurable radiological impact on the environment via atmospheric discharges, nor does it have a significant measurable radiological impact on the Scheldt. This conclusion obviously holds even if only the operation of Doel 4 is taken into account.

A calculation based on the current discharge limits shows that even for (hypothetical) 'most exposed person' the dose resulting from atmospheric and liquid discharges is well below the effective dose limit for the public of 1 mSv per year. Since in practice the actual discharges are only a fraction of the licensed limits, the actual dose (for the entire KC Doel site) is obviously even smaller; it amounts (at most) to only about 2.2% of the dose limit.

In 2013, a comprehensive environmental risk assessment was conducted to estimate the impact of atmospheric and liquid discharges on fauna and [flora90]. It was shown that even for the discharge limits, the dose rates are much smaller than the threshold of 10 µGy/h, below which no adverse effects occur. Thus, the current discharge limits do not lead to harmful effects on the environment, which is also confirmed by the measurement results of the monitoring program of FANC-AFCN and the operator in the vicinity of the site.

[90] Vandehove H., Sweeck I., Vives i Batlle, Wannijn J., Van Hees M., Camps J., Olyslaegers G., Miliche C., Lance B., 2013. Predicting the environmental risks of radioactive discharges from Belgian nuclear power plants. Journal of environmental radioactivity,126, 61-76.

The shutdown of Doel 4 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 Doel 4 (i.e., with no reactor in service at the Doel site) will decrease to a level of the order of 0.007 mSv/year in the first year after shutdown and will further decrease to below 0.003 mSv/year in the years thereafter. This can be compared to an effective dose in 2025, which will be of the order of (at most) 0.02 mSv/year, and to the standard of 1 mSv/year.

If the project is implemented and the lifetime of Doel 4 is thus extended, it can be assumed that the gaseous and liquid discharges related to the operation of Doel 4 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 Doel 4 only gives a value of 0.01 mSv/year or lower, and this constant over the 10 years of extended operation. This is well below the current operating permit and also a factor of 100 below the legal limit of 1 mSv/year. An effective dose of 0.01 mSv corresponds to the extra dose a Belgian receives from increased cosmic radiation if he or she goes skiing in the mountains for two weeks[91]. The effective dose under normal operation of the project thus 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 Doel 4 safety file shows that the effective doses and equivalent thyroid doses resulting from both design basis accidents for Doel 4 remain within the set limits. If the analysis is done based on the FANC guidelines for new Class 1 plants, the criterion for equivalent thyroid doses is however exceeded, meaning that in such a case, taking stable iodine for thyroid protection would be recommended. In a design-basis accident, the effective dose appears to be of the same order as that of both design-basis accidents, but the equivalent thyroid dose is lower. In all 3 accident scenarios, contamination of the food chain could also occur, with typically exceedances of activity levels in milk, leafy vegetables and meat, with radioactive iodine isotopes. Given the relatively short half-life of these isotopes (8.02 days for I-131), this contamination would be limited in time.

The long-term impacts of both reference accidents are negligible: the calculated lifetime effective dose (due to deposited radioactivity on the soil and consumption of food from 1 year after the accident is much smaller than the criterion of 1 Sv for all age groups. The same applies to the long-term impact of the design expansion accident.

The project therefore entails a limited risk related to an accident (both design basis - and design extension accident). For the entire KC Doel site, however, the risk will decrease, since during the 10-year life extension period only Doel 4 will continue to be operated on the site.

It is expected that delayed deactivation of Doel 4 nuclear reactor will give rise to an additional quantity of low and medium level waste of about 460 ^{m3} for a production period of 10 years. This is mainly category A waste, with only a limited amount of category B waste. Compared to the approximately 50,000 $^{m3\ of}$ category A waste currently included as a source term in the surface disposal safety file, this represents a marginal increase (<1 %).

Assuming that the additional quantity of Category B waste is negligible, the additional volume of waste corresponds to approximately 287 monoliths or 0.31 modules in the disposal facility for Category A waste. The (volumetric) capacity of that repository is 34 modules

[91] Comparison based on https://fanc.fgov.be/nl/dossiers/medische-toepassingen/vergelijking-stralingsdosis

In addition, extending the operation of Doel 4 for 10 years will generate an additional quantity of about 390 spent fuel elements. This represents an increase of 3.5% 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 98 additional supercontainers (Type SC-4) and an additional required disposal gallery length of about 600 m. However, 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

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

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

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

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