PALLAS

Strategic Environmental Assessment PALLAS

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Strategical Environmental Assessment PALLAS

October 2017

This SEA was established on behalf of:

Foundation Preparation PALLAS-reactor
www.pallasreactor.com

In cooperation with:

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Document structure

This SEA (Strategic Environmental impact Assessment) concerns the SEA for PALLAS, and comprises part A, part B and Appendices. The purpose of part A of this SEA is to give a general overview of the (environmental) assessment conducted, without going into details and in-depth information. Please refer to part B of this SEA for that purpose. Part B of this SEA contains the detailed descriptions of the reference situation applied per environmental theme and further detailing of the environmental assessments. It contains specialist information and serves as support and supplementary information for part A.

Part A

Part A contains the core issues of the SEA and contains the information intended for managerial readers, civilians and other interested parties and stakeholders. Part A comprises:

- Chapter 1 which describes the reason for and background of PALLAS. It also discusses the decisions required and to be taken, the s.e.a. obligations and SEA, including the parties involved in this project.
- Chapter 2 which describes the objective of PALLAS and the purpose and necessity of the PALLAS-reactor.
- Chapter 3 which gives further information on both the PALLAS project and the variants under consideration.
- Chapter 4 which includes an explanation of the environmental assessment approach and the assessment framework applied.
- Chapter 5 which summarizes the conclusions of the environmental assessments.

Part B

Part B contains background information and more specialized information on the impact assessments conducted within the scope of this SEA. Part B can be consulted as a supplement to part A if required. Part B discusses the following subjects, per (environmental) aspect:

- The relevant policy, legislation and regulations.
- The assessment criteria and method, applied in the impact assessment.
- The description of the reference situation.
- The impact of the proposed design.
- Mitigating and compensatory measures.
- Knowledge voids and the initial design of an evaluation program.

Appendices

The Appendices are included as a separate Appendices Report to this SEA, and contain an abbreviations list and glossary, consulted sources, and the Appendices referred to in both parts A and B of the SEA. The Appendices also include various background reports and calculations. The following Appendices are included:

- Appendix A: Abbreviations and glossary.
- Appendix B: Countries informed.
- Appendix C: Design framework.
- Appendix D: Correlation table.
- Appendix E: Summary table of environmental impact.
- Appendix F: Background reports.
- Appendix G: Paper Medical isotopes.

Part A

1 Introduction to project, PALLAS procedures

This introductory section of the SEA for PALLAS describes the reason and departure point for the development of the new PALLAS-reactor. Paragraph 1.1 explains the purpose of a new reactor, and names the initiator. Paragraph 1.2 then describes the key spatial planning procedure, the decisions to be taken and the procedure regarding SEA. Finally, paragraph 1.3 provides cross-border information.

1.1 A new reactor in Petten

The Foundation Preparation PALLAS-reactor, hereinafter referred to as PALLAS, intends to construct a multifunctional nuclear reactor in the municipality of Schagen, suitable for three core activities:

- producing medical isotopes.
- producing industrial radioisotopes.
- conducting technological nuclear research.

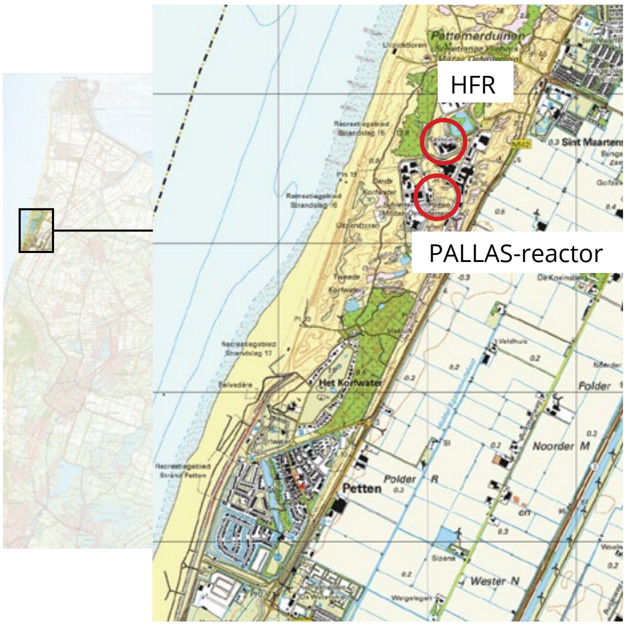


Figure 1 Map of Noord-Holland Noord showing an enlarged cut-out of the current Research Location Petten

Foundation Preparation PALLAS-reactor: PALLAS

The PALLAS project was the initiative of a group of companies and research institutions early in 2004: Mallinckrodt Medical (now called Curium), Reactor Institute Delft (part of TU Delft) and the European Commission's Joint Research Centre (EC-JRC). NRG formed a project team for this purpose, in 2009, and published a PALLAS start memo on 17 November 2009. The former minister for Housing, Spatial Planning and the Environment (VROM) issued guidelines for the SEA in June 2010. Until late 2013, PALLAS was therefore a project organization under the auspices of NRG (a subsidiary of the ECN Energy research Center of the Netherlands), the operator of the existing research reactor (HFR). As of 16 December 2013, the project became the responsibility of an independent foundation: the Foundation Preparation PALLAS-reactor[1] (see also the Articles of Association of the said foundation [1]).
The Foundation Preparation PALLAS-reactor was formed with the purpose of 'realization of the first stage (tender, design and permits) plus the attraction of private financing for the second and third stages (construction and operation) of the PALLAS-reactor'. The Foundation can be converted into a company once private parties have been contracted for the construction (phase 2) and operation (phase 3) activities. For the realization of stage 1, the foundation is financed via loans from the National and Provincial governments [2].

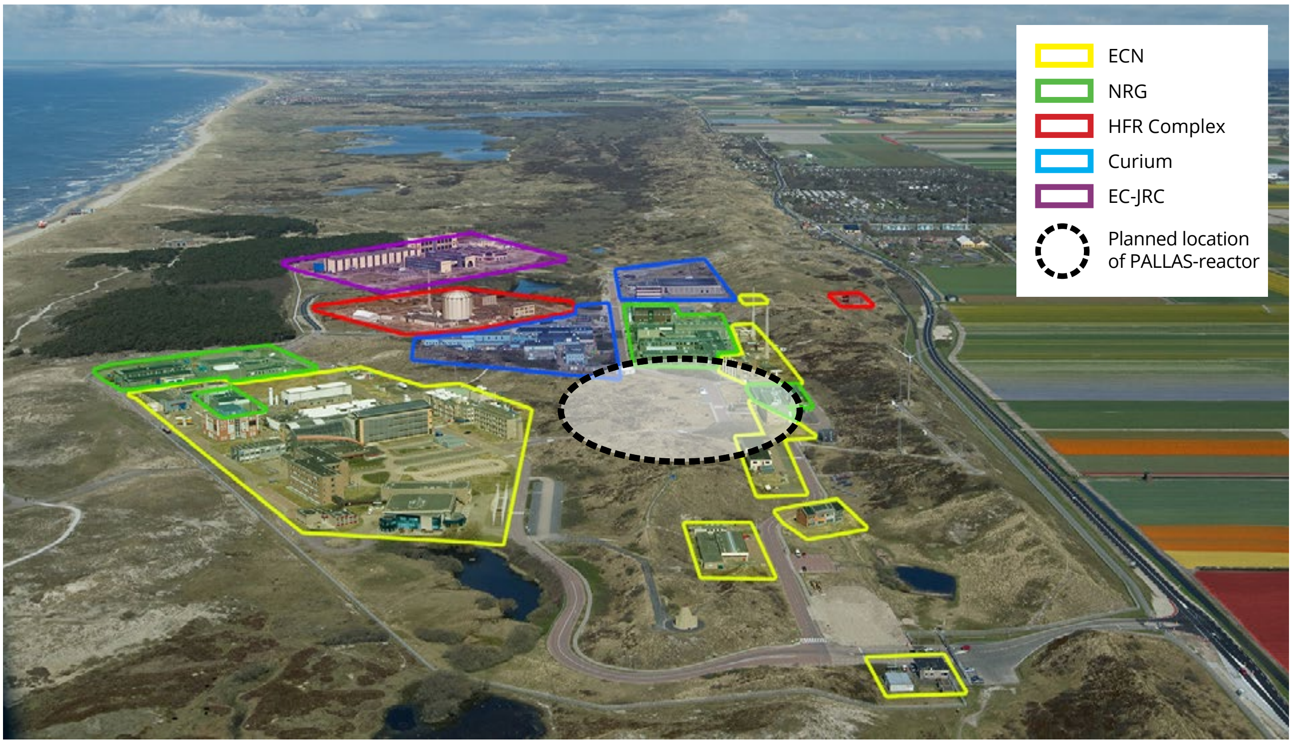


Figure 2 Aerial photo of the Research Location Petten

1 The reason behind this is that PALLAS is a large-scale project which entails considerable financial risks, which could not be borne by ECN/NRG. By organizing the realization of PALLAS in a new entity, the financial risks between the PALLAS project and ECN/NRG are avoided. The legal framework of the new PALLAS entity serves to protect the interests of the national and provincial governments in their role as financing bodies (House of Representatives letter 22/4/2013 | Reference: DGETM-ED / 13058312).

Upon establishment of the Foundation Preparation PALLAS-reactor on 16 December 2013, the PALLAS project became classified as an independent entity. As a zoning plan revision is required in order to facilitate the PALLAS-reactor, an s.e.a. procedure was started in January 2016. PALLAS is the initiator of the proposal and is thereby responsible for formulation of this SEA.

The PALLAS-reactor

The reactor to be built, hereinafter referred to as the PALLAS-reactor, serves to replace the current High Flux Reactor (HFR) in Petten, which will have been operational for 56 years in 2017 and is coming to the end of its technical and economic life cycle. The proposal is to build the PALLAS-reactor at the current Research Location Petten (in Dutch: Onderzoekslocatie Petten or OLP). For a visual impression of the area, see Figure 2.

1.2 Decisions to be taken and procedures to be followed

1.2.1 Revision of the zoning plan

The current zoning plan of the 'Zoning plan for Rural Zijpe Region' [3] concerns a conservation zoning plan. Certain sections of this plan are designated as 'specific forms of industrial estate – focal area for nuclear activities': commercial functions are permitted here as referred to in articles 15, 29 and 34 of the Dutch Nuclear Energy Act (NEA). In other words, commercial activities making use of fissile material, ores, radioactive materials and devices, and the generation of nuclear energy may take place at these locations. Realization of the PALLAS-reactor requires enlargement of the 'focal area for nuclear activities' zone and an increased construction height of the nuclear island, so that the intended location of the PALLAS-reactor falls entirely within this zone. The difference between the present scope and required scope of the area is shown in Figure 3.

1.2.2 Appropriate assessment

The permit procedure within the Dutch Nature Protection Act is based on the no-unless-principal. A Nature Protection Act permit will only be granted when it is determined that a plan or project has no negative impact on the Natura 2000 area. Unless there is certainty beforehand that a plan or project has no significant consequences, an appropriate assessment must be made. This takes an in-depth look at the consequences for Natura 2000 areas.

Figure 3 Current and newly planned concentrated area of nuclear activities

In the case of this project, the impact on at least the Zwanenwater & Pettemer dunes and the North Sea coastal zone cannot be excluded beforehand [4] [5]. This SEA, including the nature report, serves as the appropriate assessment.

1.2.3 The s.e.a. procedure

Rationale of s.e.a. obligation

The s.e.a. procedure is followed for the purpose of the zoning plan. There are two reasons for this:

- Firstly, establishment of a nuclear reactor requires an s.e.a. according to activity C22.2 of the Appendix to the EIA (Environmental Impact Assessment). The EIA (project) is thereby linked to the required permit. Revision of the zoning plan is an obligatory s.e.a. due to the zoning plan forming the framework for the future obligatory s.e.a. permit for realization of the PALLAS-reactor.
- Secondly, an s.e.a. obligation arises because of article 2.8, first paragraph, of the Dutch Nature Protection Act requiring formulation of an appropriate assessment. The Dutch Environmental Management Act requires a SEA to be formulated, and an appropriate assessment to be formulated, for the purpose of a zoning plan. The appropriate assessment is an integral component of the SEA.

S.e.a. procedure and zoning plan

The purpose of the s.e.a. procedure is to give the environmental impact of the proposal a full-fledged role in the decision to be taken on the zoning plan revision by the Authoritative body. The municipality of Schagen is the Authoritative body in the case of this zoning plan revision and accessory s.e.a. procedure. The municipal executive of this municipality is currently preparing the zoning plan, which is based on article 160, paragraph 1, under b, of the Dutch Municipal Act. The municipal council of Schagen decides on the zoning plan, as defined in article 3.1, paragraph 1 of the Dutch Spatial Planning Act.
An s.e.a. procedure will be followed for the purpose of the SEA. The s.e.a. procedure comprises a number of steps. Figure 4 shows the link between the (extended) s.e.a. procedure and the procedure for revision of the zoning plan. It also indicates the roles and activities of the various relevant actors, such as the Authoritative body, initiator, NCEA (Netherlands Commission for Environmental Assessment) and the Administrative Jurisdiction Division of the Council of State (AJD-CoS). This figure is followed by a brief explanation of the steps already undertaken and the steps of the s.e.a. procedure yet to be taken.

The steps already undertaken: announcement, communiqué of availability for inspection, consultation of administrative bodies involved and formulation of SEA

The initial phase of the s.e.a. procedure concerns the definition and establishment of the required approach in the SEA, the possibilities for all involved to submit their views regarding the communiqué, and consultation with the administrative bodies involved and the statutory advisers.
These were:

- Noord-Holland Noord Safety region.
- GGD Hollands Noorden, public health authority.
- Authority on Nuclear Safety and Radiation Protection (ANVS).
- Water Authority for Northern Holland (HHNK).
- Netherlands Department of Public Works (Rijkswaterstaat).
- Noord-Holland Noord Regional implementation office
- Province of Noord-Holland.

This first phase is already complete. PALLAS sent the communication memorandum of the SEA to the Authoritative body on 18 January 2016. The communication memorandum of the SEA was subsequently published in the Dutch National Gazette (No. 7310) at 09:00 hours on 10 February and in the Municipal Gazette (No. 15260), and was available for inspection from 12 February through 24 March 2016 at the municipality of Schagen, both at the municipal offices and via www.schagen.nl.
Although not obligatory in the preliminary phase, the Authoritative body (the municipality of Schagen) decided to request advice from the NCEA (Netherlands Commission for Environmental Assessment) in this phase, regarding the scope and details of the SEA for PALLAS. They did so in order to exercise the greatest caution in decision-making. On the advice of the Authoritative body, the NCEA also involved the submitted visions in its advice, published on 14 April 2016 (Project number 3086) [6]. The advice of the NCEA was then adopted by the municipality of Schagen on 5 September 2016, following a number of small adjustments [7]. The environmental assessment is given in the SEA in front of you, according to the proposed scope and detailing. Where possible and applicable, it takes account of the submitted visions, reactions and advice. Appendix D includes a so-called correlation table which states where each advisory point is discussed in this SEA.

Inspection period of SEA with draft zoning plan and assessment of the SEA by the NCEA.

The SEA will be made available for inspection at the same time as the draft zoning plan becomes available for inspection. Any interested party can submit their vision regarding the draft zoning plan and the SEA. Parallel to the inspection period, the NCEA will assess whether the SEA contains all information required for serious environmental assessment in the decision-making on the zoning plan. All submitted visions of the SEA will be taken into account. The final zoning plan will be formulated, partly on the basis of the results of the SEA, with consideration for external visions and the advice of

> **The abbreviations: s.e.a. and SEA**
>
> This document uses the abbreviations s.e.a. and SEA. These abbreviations are generally used to distinguish between the procedure for environmental impact assessment and the actual environmental impact assessment:
>
> - The s.e.a. refers to the procedure of environmental impact assessment (s.e.a.) for the plan (in this case, revision of the zoning plan).
> - The SEA refers to the Strategic Environmental impact Assessment (SEA) formulated for a planning procedure. The document at hand is therefore the SEA.

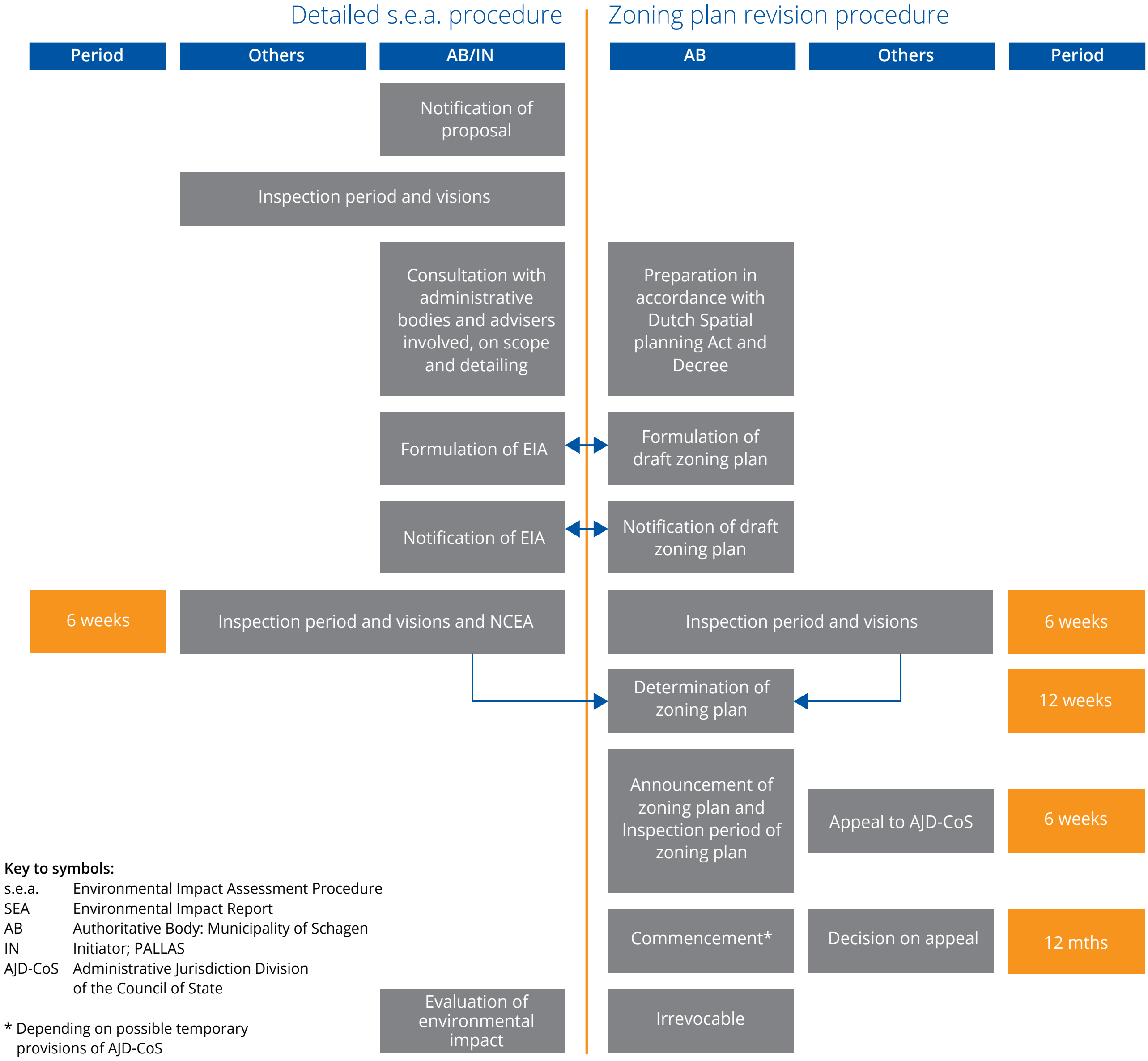


Figure 4 Detailed s.e.a. procedure linked to zoning plan revision

the NCEA. There will subsequently be opportunity for appeal against this decision, to the Administrative Jurisdiction Division of the Council of State.

1.2.4 Definition: SEA versus EIA

Besides revision of the zoning plan, permits are required for realization of the PALLAS-reactor. The most important permit is the Dutch Nuclear Energy Act permit (KeW permit). Both the zoning plan revision and the Dutch Nuclear Energy Act permit require an s.e.a. procedure to be undertaken. The former requires a SEA, and the latter an EIA. Figure 5 gives the general relationship between the procedures (plan and permit) and the types of SEA. They are explained hereafter.

SEA

An s.e.a. procedure is undertaken and a SEA formulated for the purpose of zoning plan revision. The s.e.a. procedure serves as support for the decision-making process on the zoning plan. As the design of the nuclear island has only been specified in general terms in this phase, the environmental impact assessment is conducted at a great level of abstraction. The SEA describes the environmental impact of the maximum possibilities offered by the zoning plan.
The SEA visualizes the proposal in accordance with the EU Directive 2014/52/EU, explaining why it is desirable and essential to make space available for this purpose and whether the proposal is feasible from a planning point of view. The SEA also maps out the environmental consequences of the variants, insofar as these are important from the planning point of view. The SEA studies those environmental consequences which may form considerable risks for the project, and which may therefore be determining factors for the feasibility of the proposal.
The environmental consequences have been studied in terms of various aspects of importance to the surrounding area and residents, see also the correlation table in appendix D.
A number of important aspects are given hereafter:

- Nuclear safety: Can the PALLAS-reactor comply with the

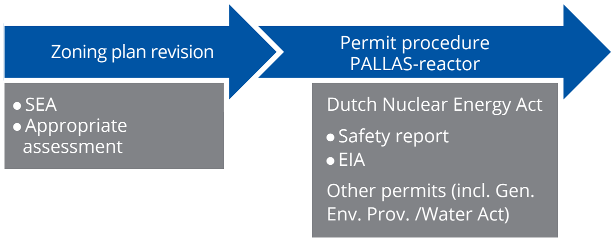


Figure 5 Relationship between zoning plan revision and PALLAS permit procedures

applicable legislation, in order to guarantee nuclear safety now and in the future?
- Groundwater: What will be the impact of changes in the groundwater regime during construction and operation of the PALLAS-reactor, and will these remain within the legislative limitations?
- Water safety: Will the safety of the coastal defenses (dikes and dunes) be safeguarded following interventions in the primary flood defense as a result of the proposal?
- Nature: Will the construction of the PALLAS-reactor with cooling facilities, and its use result in a (permanent) detrimental impact on nature in the Natura 2000 areas?
- Recreation and tourism: This aspect will look at the impact of the proposal on the recreational usage possibilities and experiential value.

Finally, this SEA also provides points of attention for further planning, i.e. for the future permit applications and the EIA to be formulated for that purpose. The regulations of the zoning plan are pre-conditional for the further design.
The dismantling of the HFR is outside the scope of the zoning plan and therefore not included in this SEA, for the following reasons:
- The dismantling process will almost certainly take place after the 10-year period to which the new zoning plan will apply.
- The HFR location is outside the location covered by the new zoning plan.
- The dismantling of the HFR is subject to its own permits process.

EIA
In a following permit phase, an EIA procedure will be undertaken and an EIA formulated. The location-specific research for the EIA is described in the following paragraph (§1.2.5), but is not included in this SEA. After all, the permit applications, and in particular the Dutch Nuclear Energy Act permit application, can only be formulated once the design of the PALLAS-reactor is more detailed. Based on that detailed design, the EIA will take a more in-depth look at the environmental impact of the actual construction, integration and use of the PALLAS-reactor. The environmental impact must fall within the scope of the proposed zoning plan and must comply with the applicable legislation. The EIA will also discuss the impact of decommissioning and dismantling of the PALLAS-reactor.

Start of EIA procedure and s.e.a. procedure
The EIA procedure for the Dutch Nuclear Energy Act permit was started on 26 May 2015 [8] upon submittal of the communication memorandum to the Ministry of Infrastructure and the Environment, and publication of the communication memorandum[2] on 3 June 2015. The s.e.a. procedure was also started in January 2016.
The technical details required for the Dutch Nuclear Energy Act permit and accessory EIA are not yet known. The technical details for the PALLAS-reactor are not yet required for the zoning plan and the SEA. Based on realistic assumptions concerning the design characteristics of the PALLAS, insight is being gained into the impact it may have and any preconditions or research assignments for the following planning phase (including the Dutch General Environmental Provisions Act (Wabo) and the Dutch Water Act permit and the EIA). The SEA procedure will be concluded sooner than the EIA procedure.

1.2.5 Location-specific research included in the EIA: site characterization
In the Neutral Energy Act permit application, PALLAS must prove that the PALLAS-reactor can be constructed and operated safely. The Preliminary Safety Analyses Report (PSAR) will be formulated as support for the application, containing design information, safety information and accessory proof of stability and robustness.
In order to protect the general public and surrounding area from radiological consequences of radioactive emissions as a result of potential incidents, PALLAS will conduct diverse and extensive research into location-specific circumstances which may influence this. This research is also known as site characterization. Think in terms of research into circumstances of natural causes such as flooding, earthquakes and climatic influences but also of human cause, such as storage and transport of chemical substances. There is specific attention for circumstances which may influence:
- The safety of the reactor.
- The impact of radioactive material on the surrounding area.
- The possibility for implementation of emergency measures.

In order to gain a complete overview of all circumstances which could play a role, PALLAS has applied an international guideline by the International Atomic Energy Agency (IAEA). This guideline [9] gives an overview of all possible circumstances and combinations of circumstances which can occur anywhere in the world.
The guideline also establishes requirements for the research to be conducted per subject. The IAEA sometimes also has specific guidelines, per subject, with requirements regarding the research.
The research conducted by PALLAS complies with the requirements of these guidelines. Table 1 gives a brief summary of the most important subjects, and paragraph 5.4 also includes the areas of attention again.
In the end, the results of all these studies, the degree to which

2 This was made available for inspection from 4 June 2015 through 15 July 2015. During this period of inspection, interested parties could submit their vision regarding the communication memorandum.

the circumstances can be formed and the degree to which significant negative impact for the surrounding area can be prevented, is an important condition for the final viability of the proposal. The results of the studies into location-specific circumstances are used in order to further formulate requirements and acceptance criterion for the design of the PALLAS-reactor. The design is subjected to safety analyses, in order to check the design's resilience to the specific local circumstances. Within the scope of the Dutch Nuclear Energy Act permit granting process, these safety analyses will prove in detail that the PALLAS-reactor to be constructed is resilient to the location-specific circumstances. The application for the Dutch Nuclear Energy Act permit for construction of the PALLAS-reactor, the accessory Safety report and SEA project will prove, for example, that the proposed reactor design is safe and resilient to the specific local circumstances. The following figure is a schematic representation of this process.

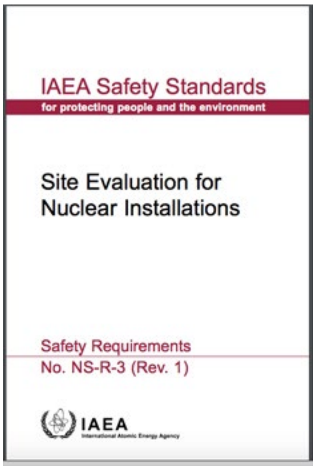


Figure 6
The NS-R-3 Rev.1 guideline

1.2.6 Decisions to be taken

During the phase following the zoning plan revision, PALLAS will undertake various permit procedures. The statutory principles for the most important permit obligations are given hereafter:

- The Dutch Nuclear Energy Act for design and operation of the PALLAS-reactor. Two permits will be granted for the PALLAS-reactor. A Dutch Nuclear Energy Act permit for realization of the reactor. And a Dutch Nuclear Energy Act permit for rendering and maintaining the reactor operational. Besides the EIA (environmental impact assessment), another important component of the Dutch Nuclear Energy Act permit application is the Safety Report (SR, described briefly hereafter).
- The Dutch Water Act for all direct water discharges and works in and around primary flood defenses, and the water extraction for cooling.

Table 1 Summary of location-specific research

Subject	Description
Earthquakes and surface faults	The research focuses on ground movements and subsidence as a result of an earthquake. Research was conducted into any impact of (1) the active fault zone in Limburg, (2) possible impact of regional oil and gas extraction and (3) the known local historic fault line in the deep subsurface. With regard to the active fault zone in Limburg and the oil and gas extraction, monitoring data is available for actual earthquakes, which formed the basis for determination of a possible earthquake magnitude for the site. However there is no such data for the local fault line. The fault line must therefore be more effectively mapped out in order to determine or exclude any possible impact of this fault line on the proposed construction location (gaps in knowledge). An initial study has been undertaken to map out the local fault line, using the monitoring data gathered in the past for the purpose of oil and gas extraction. This data shows a fault resolution in the upper layers of the soil surface, therefore requiring supplementary field research.
Meteorology	A study has been conducted into the extreme values of all possible meteorological circumstances, including wind (and tornadoes), snowfall, temperature and lightning.
Flooding	Studies have been conducted, including modeling, into flooding due to one or more natural causes, including waves, storm surge, tsunamis. Also studied was the way in which the water would flow at the Research Location Petten in the event of significant flooding.
Geotechnical risks	Studies have been conducted into various risks associated with the local subsoil. Think in terms of instability, ground subsidence on slopes, and as a result of soil composition.
Aviation incidents	Based on the new Dutch safety requirements, a study is being conducted into the methodology regarding determination of aviation incidents. Besides the impact of such a crash, there will also be attention for resultant fire and explosions.
Chemical explosions	All activities and storage units in the vicinity of the construction location have been mapped out, including the related risk contour.
Ministry of Defense firing range	There is a Ministry of Defense firing range close to the Research Location Petten. The risk contour of transport of munitions has been determined and there will be further consideration for the actual process of firing practice.
Dissemination of nuclear material and public exposure	A study has been conducted into the circumstances which play a role in the dissemination and possible ingestion of radioactive material. Think in terms of meteorological conditions, dissemination via groundwater and surface water, the use of land and water in the region, and the scope and composition of the local and regional population. Where not available, models were developed with which any dissemination can be calculated.

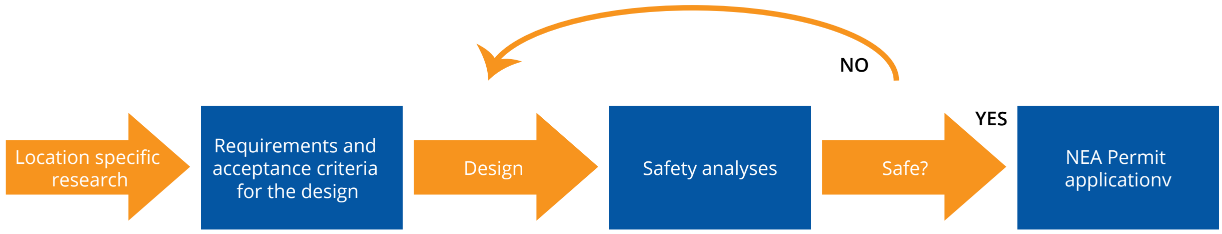


Figure 7 Use of the location-specific studies

- The Dutch General Environmental Provisions Act for location-based activities, such as construction, installation and operation.
- The Dutch Nature Protection Act for the protection of the countryside (Natura 2000).

Figure 8 is a schematic representation of the above, including the planning as currently proposed.

1.2.7 Parties involved

The following parties are involved in the s.e.a. procedure and in establishment of the zoning plan, each with their own role:

Initiator
Foundation Preparation PALLAS-reactor
PO Box 1092
NL-1810 KB ALKMAAR

Authoritative body
The Authoritative body for establishment of the zoning plan and the s.e.a. procedure is the Municipal Council of Schagen.
Municipality of Schagen
PO Box 8
NL-1740 AA Schagen

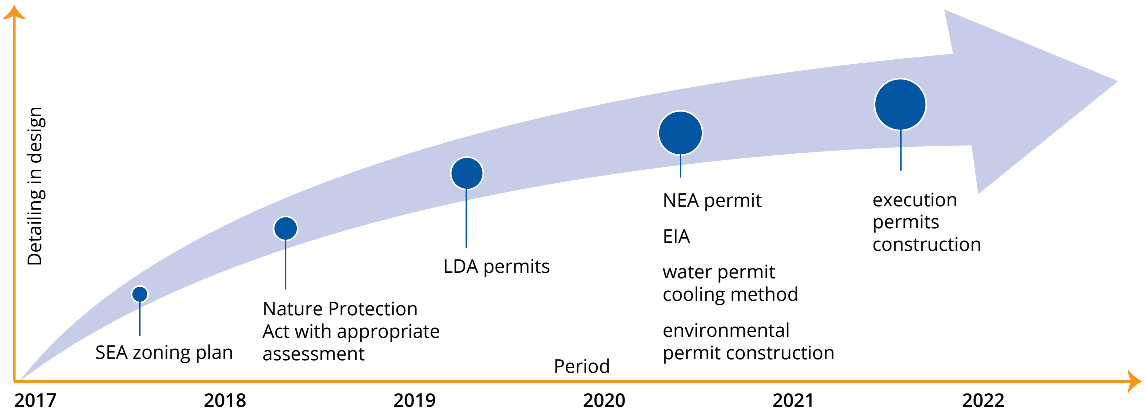


Figure 8 Schematic overview of procedures in relation to degree of design detail

1.3 Cross-border information

This project is not expected to have any (significant) detrimental cross-border environmental consequences (see also the background report on Nuclear Safety, Appendix F2). A cross-border consultation is therefore not required within the scope of the Espoo convention.
As a cautionary measure, the municipality of Schagen has decided to inform all 56 countries who ratified the Espoo convention, of the proposal. An English-language communication of the proposal and an English translation of the communication memorandum of the SEA has therefore be sent to these countries. Appendix B includes an overview of the countries informed. Those countries have been informed regarding the SEA procedure.

Espoo convention

On 25 February 1991, the UN convention on cross-border environmental impact assessment was established in Espoo (Finland). The key aspect of the Espoo convention is that in the event of a possible cross-border environmental impact, the general public and authorities in neighboring countries are involved in the s.e.a. procedure in the same manner and timescale as the authorities and general public in the Netherlands. The convention came into effect on 10 September 1997, and has been further developed into the European directive 'regarding the environmental assessment of certain public and private projects' (97/11/EC2) and the European directive 'regarding the assessment of the environmental impact of certain plans and programs' (2001/42/EC). Both the convention and the appropriate articles of the European directive has been implemented in the Dutch Environmental Management Act.

2 Objective, purpose & necessity

This section discusses the purpose and necessity of the PALLAS-reactor. Paragraph 1 defines the objectives of PALLAS. It also discusses the decision-making on replacement of the current High Flux Reactor (HFR) and the choice of the Petten location. Paragraph 2 deals with the social relevance of medical isotopes. It describes the importance of these isotopes for research and for treatment of patients, and looks at the international markets and demand and supply of isotopes. Appendix G discusses the subject of "Medical isotopes" in more detail. Paragraph 3 deals with (possible) alternative production methods. In the fourth and final paragraph, a description is given of the nuclear infrastructure and economic aspects.

2.1 Decision-making on and objective of PALLAS

2.1.1 Objective of PALLAS

The Foundation Preparation PALLAS-reactor (hereinafter PALLAS) was assigned by the Ministry for Economic Affairs and the province of Noord-Holland to ensure the realization of a modern and safe reactor, in order to safeguard the continuous supply of medical isotopes. Furthermore, the new reactor will be used for the production of industrial isotopes and for the conducting of technological nuclear research.

The statutory definition of the objective of PALLAS [10] is as follows:

a The design and realization of a high flux reactor intended for the production of medical and industrial radio-isotopes, and technological nuclear research in the municipality of Schagen.

b Operation of the PALLAS-reactor.

2.1.2 Decision-making regarding replacement of the High Flux Reactor

The current High Flux Reactor (HFR) is more than 50 years old by now and is approaching the end of its economic life cycle. This means that maintenance programs become more expensive and intensive, and that the risk of (unplanned) production downtime increases. Production stops result in a serious risk of the international supply certainty of medical isotopes. During the 2007-2010 period, such a stop in Petten, in combination with production problems in Canada and Belgium, resulted in large global shortages in hospitals. The diagnosis and treatment of patients became delayed, and choices sometimes had to be made for deployment of alternatives and sub-optimum solutions which were less patient-friendly.

Partly as the result of these events, the Dutch cabinet took the decision in spring 2012, to replace the High Flux Reactor, whereby the municipality of Schagen was designated the location for the new PALLAS-reactor. The explicit requirement thereby was that the HFR was not to be decommissioned until a new reactor was fully operational. According to the cabinet, this would otherwise result in "a global problem for the supply of medical radio-isotopes and a void in the nuclear knowledge infrastructure" [11].

In 2013, the Ministry for Economic Affairs and the Province of Noord-Holland reached agreement on establishment of the independent entity 'Foundation Preparation PALLAS-reactor'. PALLAS is responsible for realization of the design, tender for the construction of the reactor and gaining the necessary permits. A further task for PALLAS is to attract private financing for construction and operation of the reactor.

The principle of the cabinet policy is that the construction and operation of a new reactor will become a market matter in due time and must be financed with private funds. The Ministry for Economic Affairs and the province of Noord-Holland have jointly granted a loan of 80 M€ for completion of the initial design and permits phase. This initial phase will take approximately 5 years, and will be dictated mainly by the tender, design and permits process. Meanwhile, a solidly underpinned business case must enable PALLAS to attract private parties who can earn back the cost of constructing the reactor via income from the production of medical radio-isotopes and nuclear research. The second project phase concerns the construction and commissioning of the new reactor.

The scope of the reactor, the specifications and the thermal capacity will be designed in accordance with the intended use of the PALLAS-reactor. They can be divided into four market segments:

- The production of molybdenum-99/technetium-99m, the main medical isotope for diagnosis of cancer and heart disease.
- The production and development of other, mainly therapeutic, medical isotopes.
- The reactor will also be deployed for production of industrial isotopes, used for example for the monitoring of welding seams in pipelines.
- The fourth area of application is technological nuclear research, for example research into fissile material and material for existing and new nuclear installations. This also concerns research into reactor safety and (final) disposal of nuclear waste.

2.1.3 Choice of location

A number of factors play an important role in the cabinet decision to designate Petten in the municipality of Schagen as the location for the new reactor:

- The Netherlands is the only country in Europe to have a dedicated and complete infrastructure, in Petten, for the production (irradiation) and processing of medical isotopes. The isotopes are not only produced but also processed at the Research Location Petten. Curium, formerly Mallinckrodt Medical, processes and distributes the isotopes, making them available for medical applications in hospitals. The combination of all these activities and an effective logistics infrastructure at the Research Location Petten prevents valuable time being lost. This is important when considering the shelf life and quality of the isotopes (see further section 2 on half-life).
- The Netherlands has traditionally had a strong nuclear knowledge infrastructure, which contributes to the innovative and competitive strength at the international level. The Petten reactor plays a crucial role in this, not only when it concerns applied research into forms of nuclear energy generation and the careful use of nuclear materials (including radioactive waste) but also for the development of new (medical) isotopes (see also paragraph 4). Petten therefore already has a number of relevant permits which are required for the HFR operation.
- At the regional and local levels, the activities in Petten are an extremely important source of quality employment in this area of Noord-Holland (see also paragraph 2.4.3).

2.2 The social relevance of the PALLAS-reactor; the demand for medical isotopes

Medical isotopes play an important role within medical diagnostics and as an application for therapy and pain relief. Currently, 80% of the medical isotopes used in Dutch hospitals are produced by the reactor in Petten [12].
The PALLAS-reactor will produce not only the diagnostic isotope molybdenum-99, but also a range of therapeutic isotopes. This paragraph discusses the demand for diagnostic isotope molybdenum-99 (paragraph 2.2.1). Insight will then be provided into the suppliers (paragraph 2.2.2) and into the development of demand for diagnostic isotopes (paragraph 2.2.3). The final section discusses the demand for diagnostic isotopes in more detail (paragraph 2.2.4).

2.2.1 Isotopes for diagnostics; molybdenum-99 and technetium-99m

Radio-isotopes are extremely important for diagnostic purposes in oncology, cardiology and neurology. Estimates are that more than 10,000 hospitals use radio-isotopes worldwide. The best known isotope for diagnostic purposes is technetium-99m. This isotope is used annually in more than 40 million diagnostic examinations worldwide, half of which take place in the USA and approximately 7 million in Europe. Technetium-99m is used annually in around 250,000 cases in the Netherlands. Technetium-99m is the decay product of molybdenum-99. Molybdenum-99 is therefore known as the mother isotope of technetium-99m (see hereafter).

2.2.2 Supplier of molybdenum-99 and international developments

The Netherlands is the world's largest producer of medical radio-isotopes. The Dutch molybdenum-99 is currently produced by NRG in the High Flux Reactor (HFR) in Petten. The HFR in Petten can meet approximately 70% of European demand, and more than 30% of the global requirement. Under the responsibility of Curium and IRE (Institute of Radioelements), molybdenum-99 is prepared for delivery to hospitals all over the world, where it is used in nuclear medicine.
The majority of the medical isotopes are currently produced worldwide in 6 reactors, 5 of which are more than 45 years old [12]. Since the discontinuation of the NRU reactor in Canada, which no longer produces for the market, the High Flux Reactor in Petten is the most important supplier, followed closely by the BR2 reactor in Belgium. A smaller share in the production is held by the Safari reactor in South Africa and the OPAL reactor in Australia, though the latter is mainly focused on supplying the Australian and Asian markets. The Maria reactor in Poland and the LVR15 in the Czech Republic mainly serve as so-called spare capacity. Russia has reactors for its domestic market, in much the same way as the RA3 mainly supplies the domestic market in Argentina.
Two older reactors have recently stopped production: OSIRIS (France) has been decommissioned and the NRU (Canada) is only on 'hot stand-by', which means that the reactor can only produce in emergency situations. Until recently, this facility in Canada was the world's largest supplier of molybdenum-99.

Diagnosis using isotopes: how it works

Most isotopes are unstable (radioactive) and are therefore referred to as radio-isotopes. The term radionuclides is also used. There are radio-isotopes which have favorable chemical but also favorable radioactive properties for use in hospitals. They can be safely and effectively applied for diagnosis by means of a scan, or for the administration of therapy. Each year, medical isotopes are administered more than 400,000 times for diagnostic purposes in Dutch hospitals [12]. Nuclear physicians use this radioactive material to discover whether organs function well or to detect cancerous growths in an early stage. A small amount of radioactive material is injected into the patient. By subsequently detecting the radiation, doctors can determine whether anything abnormal is going on. The radioactive substances used for this purpose are medical isotopes. In order to ensure that they are transported to the appropriate organ, the isotope is coupled to another (non-radioactive) substance, known as a tracer. After administering this combination to the patient, a special camera is used to trace the 'trail' of radiation, which enables the nuclear specialist to determine how the organ is functioning and whether a cancerous growth is active.

There are various plans for new reactors worldwide, but there is no certainty whether any of them will actually be realized. Moreover, not all of these reactors will primarily produce medical isotopes, as most of them are intended for research and for training purposes.
Following the sudden production limitations of, among others, the High Flux reactor and the NRU reactor in the 2007 – 2010 period, international consultation took place under the leadership of the NEA (Nuclear Energy Agency of the OECD) on how to react more effectively to such disruptive events. In 2014, the leading countries – including the Netherlands – agreed to a common declaration of the policy which must result in increased supply certainty of medical isotopes. The cooperation between producers has improved, so that the available international production capacity is now more effectively geared. Agreements have been reached on the development of spare capacity and possibilities of increasing production at other facilities in the case of unforeseen stops. Finally, the countries have worked to increase production capacity [13].
With a view to the supply certainty for patients, the OECD-NEA recommends achieving a certain level of overcapacity, internationally, in order to accommodate loss of production.
Despite these agreements, decommissioning of the HFR or discontinuity in the production would still result in major international problems from 2017 on, especially since the Canadian reactor stopped production of molybdenum-99 in 2016. A letter by the Minister for Economic Affairs dated 30 September 2016, concludes that decommissioning of the HFR "would result in serious availability problems for the medical

> ### Mother and daughter: molybdenum-99 and technetium-99m
> Radioactive substances are subject to decay. A radioisotope is not stable and over the course of time, a nuclear reaction occurs in which radiation is emitted and the original isotope changes.
> Half of the atoms in each isotope decay over a certain period of time, the so-called half-life. Only half is left after 1 half-life therefore, only a quarter after 2 x half-life, etc.
> Molybdenum-99 has a half-life of 66 hours. Over that period of time, molybdenum-99 decays and a new isotope is formed: technetium-99m. Molybdenum-99 is therefore known as the mother isotope of technetium-99m. Thanks to the relatively long half-life of molybdenum-99, it can be transported over a relatively long distance, and hospitals only need to be supplied around once a week in practice. In the hospital, it is used as technetium-99m, through the use of a generator.
> The technetium-99m is namely 'milked' from a generator which has been loaded with the mother isotope molybdenum-99 by the producer. The generator is a heavy duty cylinder containing a bottle of liquid. Upon milking, also known as elution, chemical separation takes place. The main advantage of this process is that the generator can be used for a longer period of time to create a shorter living isotope, thanks to the long half-life of the mother isotope. Hospitals therefore need not order the shorter living isotopes on a daily basis, but can instead use molybdenum-99 as a longer lasting source of isotopes.

isotopes molybdenum-99/technetium-99m, iridium-192 and possibly also iodine-131" [14].
In a report published in July 2017, the RIVM indicates that "the market for isotopes (for both diagnostic and therapeutic purposes) will remain fragile until 2020 at least and probably until 2025. Shortages can arise upon outage of only one reactor. There is still great uncertainty regarding the situation post-2025. That will depend on new reactors or alternative production facilities becoming available" [12].

2.2.3 Development of demand for molybdenum-99
The Nuclear Energy Agency of the OECD (OECD-NEA) expects the demand for molybdenum-99 to increase slightly in the future (1% per annum) in the Western world. A more significant increase of approximately 4-5% is expected for emerging countries in Asia and other continents [15]. Other sources are accounting for even stronger growth in emerging countries, in excess of 10% over the next 10 years [16]. The Dutch Institute for Public Health and Environment (RIVM) expects a stable or slightly increasing demand for technetium-99m. This Institute foresees strong global growth for this market, with a view to the predictions of great economic growth in Asia and South America [12].
Reasons for the forecast increased demand also include global population growth, increased prosperity in the emerging countries and continents (and thereby enhanced levels of health care) and aging of the population.

2.2.4 Therapeutic isotopes
There are great expectations regarding the development of therapeutic isotopes. Therapeutic applications are rapidly gaining importance, and nuclear medicine is discovering more and more innovative possibilities for treatment. The RIVM

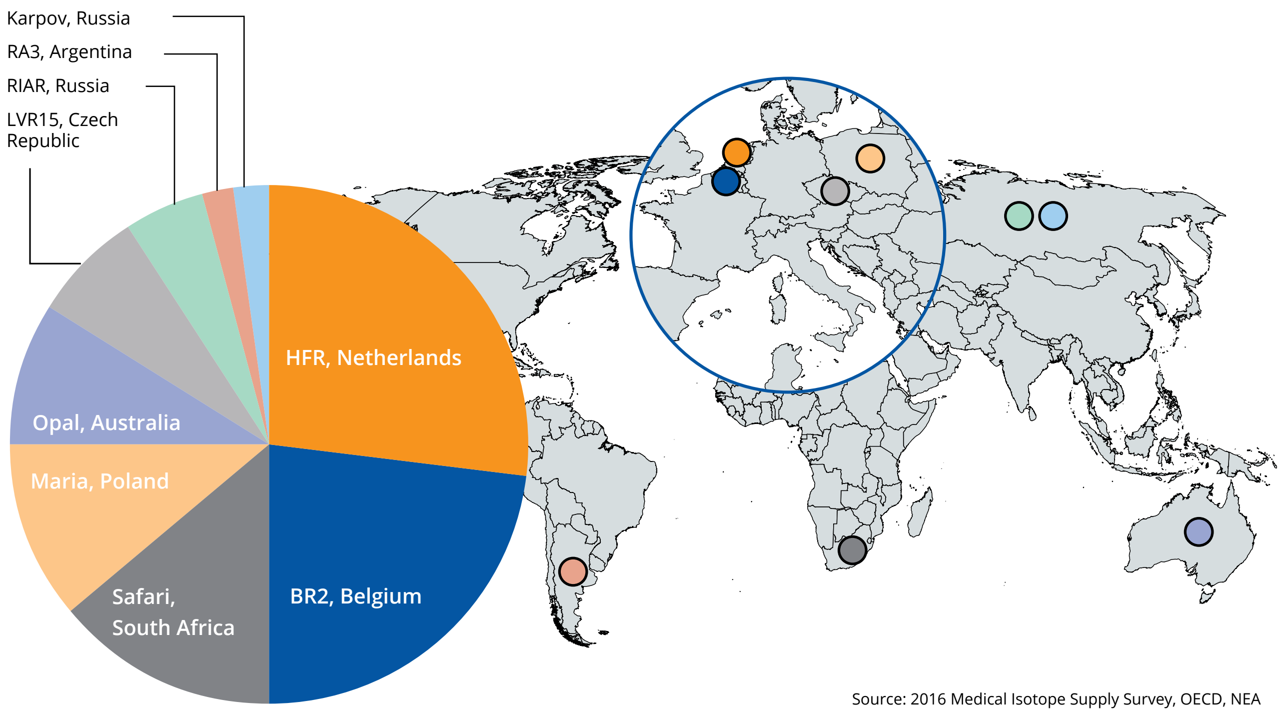


Figure 9 Overview of the producers of molybdenum-99 worldwide

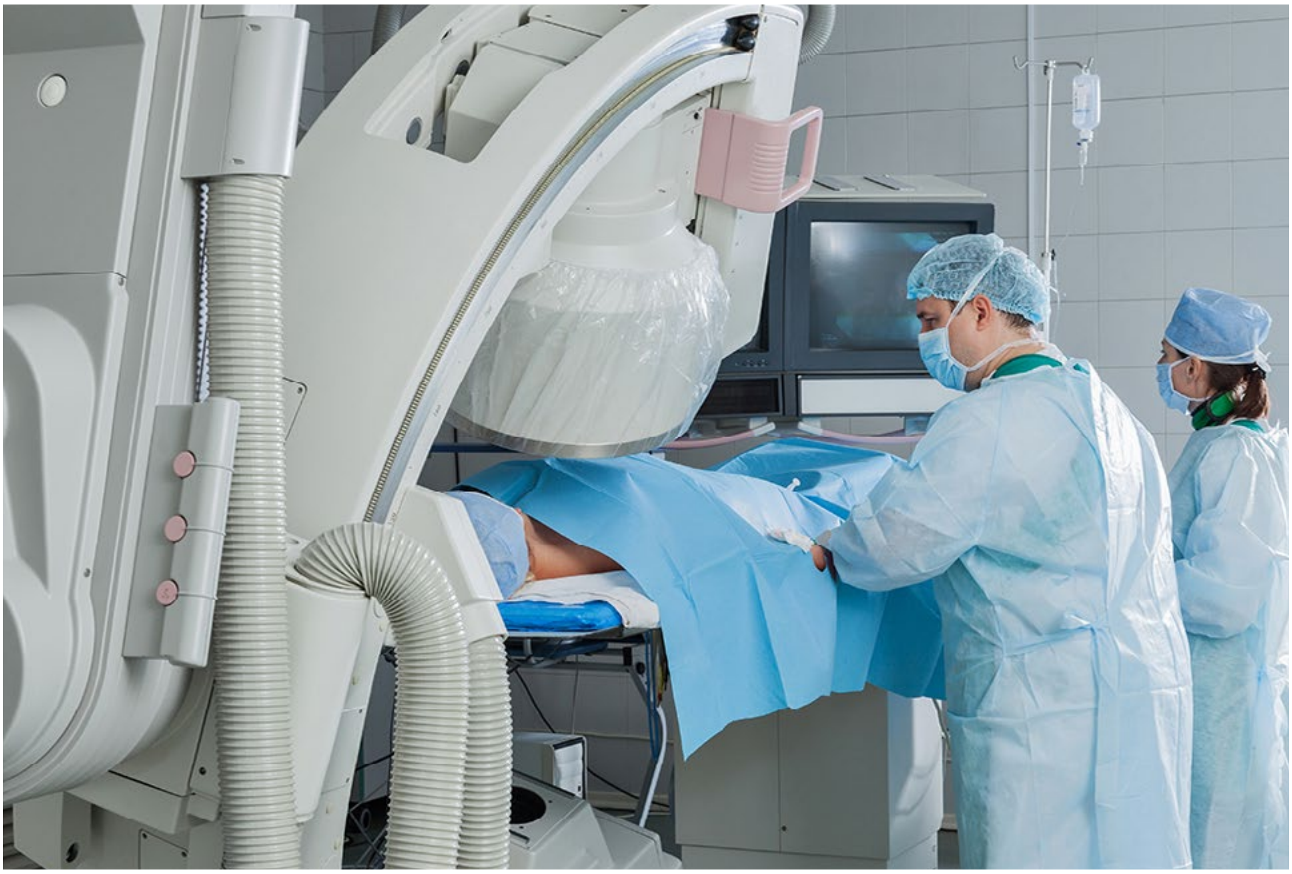


Figure 10 An example of using SPECT camera. Multiple two-dimensional images are processed by a computer to give a three-dimensional image. SPECT scans nearly always use technetium-99m.

foresees increased use of isotopes for therapeutic purposes. According to this Institute, "a slight increase, stable demand and considerable increase is expected for iodine-131, iridium-192 and lutetium-177, respectively. These three isotopes are produced in reactors. In many cases, expectations are for (considerably) increased demand for other radioisotopes such as gallium-68, rubidium-82, zirconium-89, yttrium-90, holmium-166 and radium-223. These isotopes are also mainly produced in reactors" [12].

NRG in Petten has already become an international trendsetter with isotopes such as iridium-192 and lutetium-177. PALLAS will continue this trend through research into new therapeutic isotopes, thereby reacting to the international tendency towards personalized medicine. The production of and research into new therapeutic isotopes is an integrated component of the PALLAS business case.

Isotope therapy can be subdivided into radiotherapy, nuclear medicine therapy (including brachytherapy[3] and palliative therapy. Radiotherapy works using external radiation sources, while patients are administered a medical isotope in nuclear medicine therapy. Both treatments are aimed at destroying specific tissue. Palliative therapy is aimed at curbing tumor growth and combating pain. Patients are administered a medical isotope which slows down progression of the illness, thus reducing pain and improving quality of life.

By linking the appropriate medical isotope to a suitable tracer, nuclear physicians are able to administer the medical isotopes to exactly the right spot in the body, in order to limit damage to healthy cells while effectively destroying unhealthy. The administered radiation dose is much higher than in the case of diagnostics. In fact, patients are often even regarded to be temporarily radioactive.

An example of a therapeutic isotope is the reactor product lutetium-177, which is used to treat neuro-endocrine tumors, a rare and extremely malignant form of cancer. Lutetium-177 treatment of patients with these tumors extends their average life expectancy by no less than 4 years, with a relatively good quality of life. This treatment was developed in the Netherlands and is nowadays very successfully applied all over the world. Expectations are that the number of patients that can be treated with lutetium-177 will increase greatly.

Iridium-192 is mainly used for the treatment of prostate, breast, gynecological and head/neck tumors. A report by the Institute for Public Health and Environment (RIVM, July 2016) [13] states that stopping the current HFR production would result in far-reaching consequences for the patients who require this isotope. The two other producers cannot accommodate such a deficit and this product can only be manufactured in very small volumes in cyclotrons.

The most commonly used nuclear medicine therapies in the Netherlands are:

- Iodine-131 for thyroid disorders, whereby patients are administered a capsule containing radioactive iodine. The iodine collects in the thyroid gland, where the radiation is

3 Brachytherapy is a specific method of administering the radio-isotope, whereby the isotope is applied via a catheter or needle to the location of the disorder, where it treats the unhealthy tissue using radiation for various lengths of time.

emitted (therapy).

- Iridium-192 for the treatment of prostate, breast, gynecological and head/neck tumors (brachytherapy).
- Radium-223 (Xofigo®) for the treatment of prostate cancer and bone metastases (nuclear medicine therapy).
- Lutetium-177, for the treatment of neuro-endocrine tumors and for the experimental treatment of prostate cancer (nuclear medicine therapy).
- Strontium-89, rhenium-186 or samarium-153 for pain control in metastasized bone cancer (nuclear medicine therapy).
- Yttrium-90 for the treatment of liver cancer (radio-embolization) and for certain rheumatic disorders.
- Holmium-166 for the treatment of liver cancer (radio-embolization).

2.2.5 Isotopes for industrial applications

Besides the development and supply of medical isotopes, the PALLAS-reactor will also provide services for industrial applications. This will mostly comprise the irradiation of iridium plates ('sources') used in equipment for non-destructive testing. The Ir-192 isotopes produced by irradiation in these sources, enable the inspection of welding seams in pipelines, for example. Iridium sources are also used in cameras for neutron radiography, which generate a type of x-ray image, but then within metal objects. The demand for iridium sources is currently stable, but demand for other isotopes such as selenium-75 is also expected in the future.

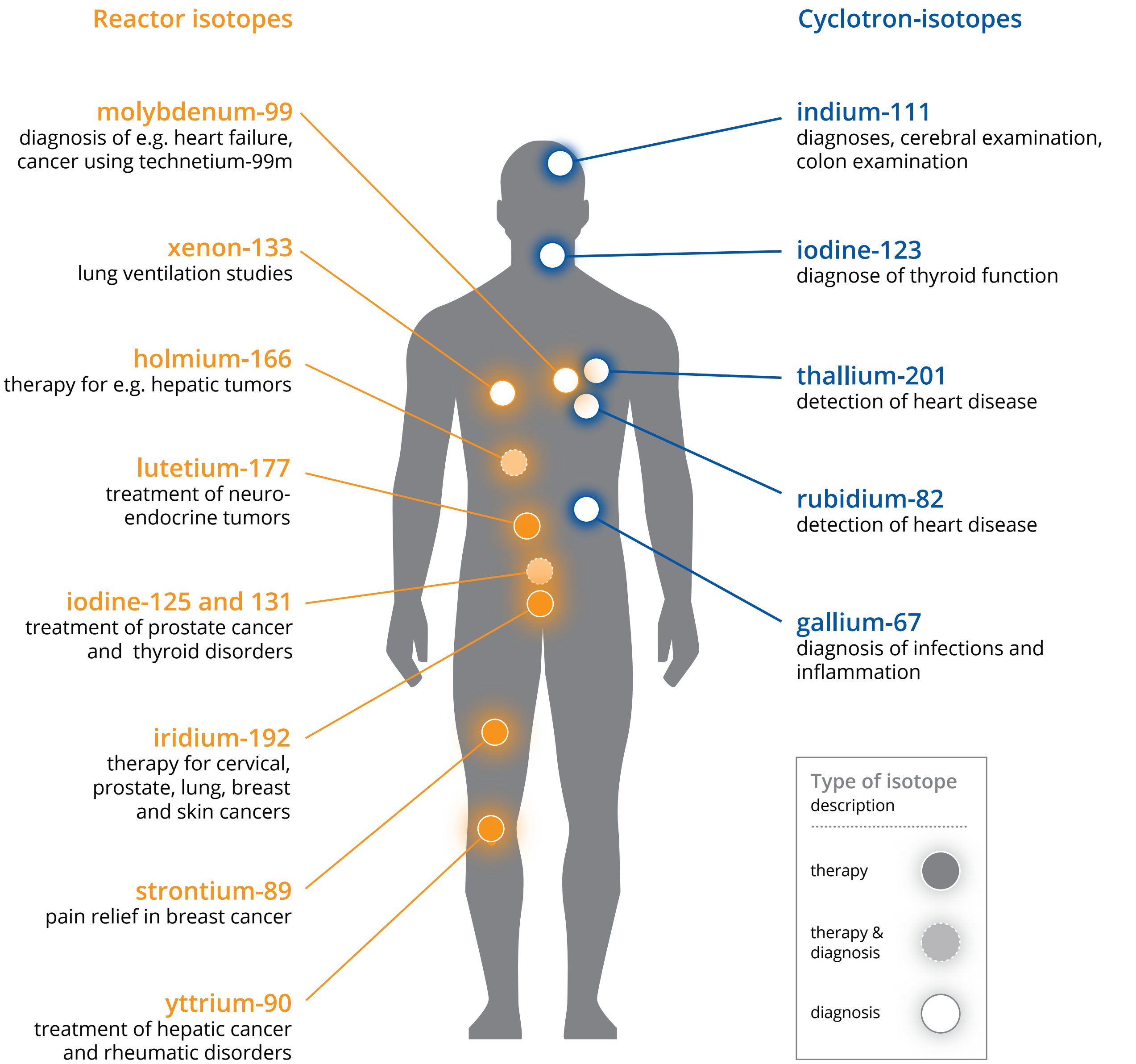


Figure 11 Isotopes from Petten

2.3 Alternative production methods of medical isotopes

During the decision making regarding construction of the new reactor, the question regularly arises whether medical isotopes could not be fully produced in cyclotrons (particle accelerators). The advantage of the use of cyclotrons is that it would result in less nuclear waste, as they do not work on the basis of fissile material. Nuclear fission results in waste products which remain radioactive for a long period of time, which is not the case for cyclotrons[4].
A distinction can be made between cyclotrons and linear accelerators. Cyclotrons are so-called circular accelerators, while straight accelerators are described as LINACs, linear accelerators. They both work by the same principle, i.e. the acceleration of charged particles.
This paragraph discusses various alternative production methods. Which isotopes can be/are made using reactors, and which using cyclotrons and linear accelerators? Why should a new reactor be built rather than using alternative production methods? It also deals with the Lighthouse initiative by ASML.

> ### Significance of decay time for the supply process
> Medical isotopes are radioactive. The level of radioactivity decreases due to so-called radioactive decay, which means that the medical isotopes product loses its strength over time. The half-life is the time in which the level of radioactivity is halved. This half-life ranges from a number of hours to a number of days for many medical isotopes. Due to the amount of product therefore quickly decreasing, it is crucial that the supply chain is well organized. This means that the time at which the medical isotopes are required in the hospital is calculated accurately backwards to the time of production. It also means that the time lost throughout the logistics chain must be minimized wherever possible.

2.3.1 How reactors and accelerators work: a comparison

A nuclear reactor uses fissile material, for example uranium. A slow neutron is absorbed by a uranium nucleus, which splits into two lighter nuclei of more or less the same size. This reaction releases a number of new free neutrons, which then split other uranium nuclei, resulting in a chain reaction. Neutrons are uncharged nuclear particles. It is relatively simple to place a large rack of targets in the nucleus, in order that the material be activated through collision with neutrons. Nuclear reactors are designed for a massive number of nuclear reactions to take place per second. Large research reactors can achieve a rate of 10^{14} (one hundred thousand billion) neutrons per second and per square centimeter. A reactor therefore has a very high production rate, allowing a great diversity of medical isotopes to be produced in extremely large volumes. Nowadays, the best known and most commonly used isotope produced in a reactor is molybdenum-99.
In accelerators, charged particles (protons) are accelerated in a combination of a magnetic field and electrical field, after which they collide with a target. This activates the material in the target, converting it into a radio-isotope as it were. A relatively low number of particles can be accelerated per second versus a reactor, so that the production capacity of accelerators cannot match that of reactors. The half-life of most products from an accelerator is extremely short, generally only a few hours. An accelerator must therefore always be located close to the hospital where the products are to be used.
A particle accelerator produces other products than a reactor. Well known isotopes produced using a cyclotron are oxygen-15, fluorine-18, iodine-123 and iodine-124, carbon-11, nitrogen-13, zirconium-89Zr, gallium-68 and rubidium-82. Non-radioactive oxygen-18 can be exposed to protons to convert it into radioactive fluorine-18, a commonly used accelerator isotope. Fluorine-18 is used for diagnostic purposes with PET cameras. Appendix G covers in further detail PET and SPECT cameras and which isotopes are required for which type of camera.
Besides molybdenum-99, reactors produce isotopes such as strontium-99, yttrium-90, iodine-125 and iodine-133, xenon-133, samarium-153, holmium-166, erbium-169, lutetium-177, rhenium-186 and 188, and iridium-192 (Ir-192).

Other particle accelerators
A special application of the accelerator technology is the so-called Lighthouse initiative by ASML, in which a special, intense electron accelerator is used to generate extremely high-energetic light (photons) via a converter. This light is then shone on enriched molybdenum (Mo-100), which in turn forms molybdenum-99. This production technology does not require the use of uranium, but rather only enriched molybdenum.
Lighthouse is not yet a proven technology and is only in a very early stage of development. Should the project prove viable, it will take a further 5 to 10 years to produce molybdenum for the market [12]. In the case of Lighthouse, this would only concern the diagnostic isotope molybdenum-99, with no possibility of producing therapeutic isotopes.

2.3.2 Cyclotron and reactor isotopes are complementary

Not all medical isotopes produced in a reactor can also be produced using an accelerator. This applies in particular for therapeutic isotopes. Vice versa, the same applies: not all medical isotopes produced in an accelerator can be produced using a reactor.
Reactors and cyclotrons are complementary to one another,

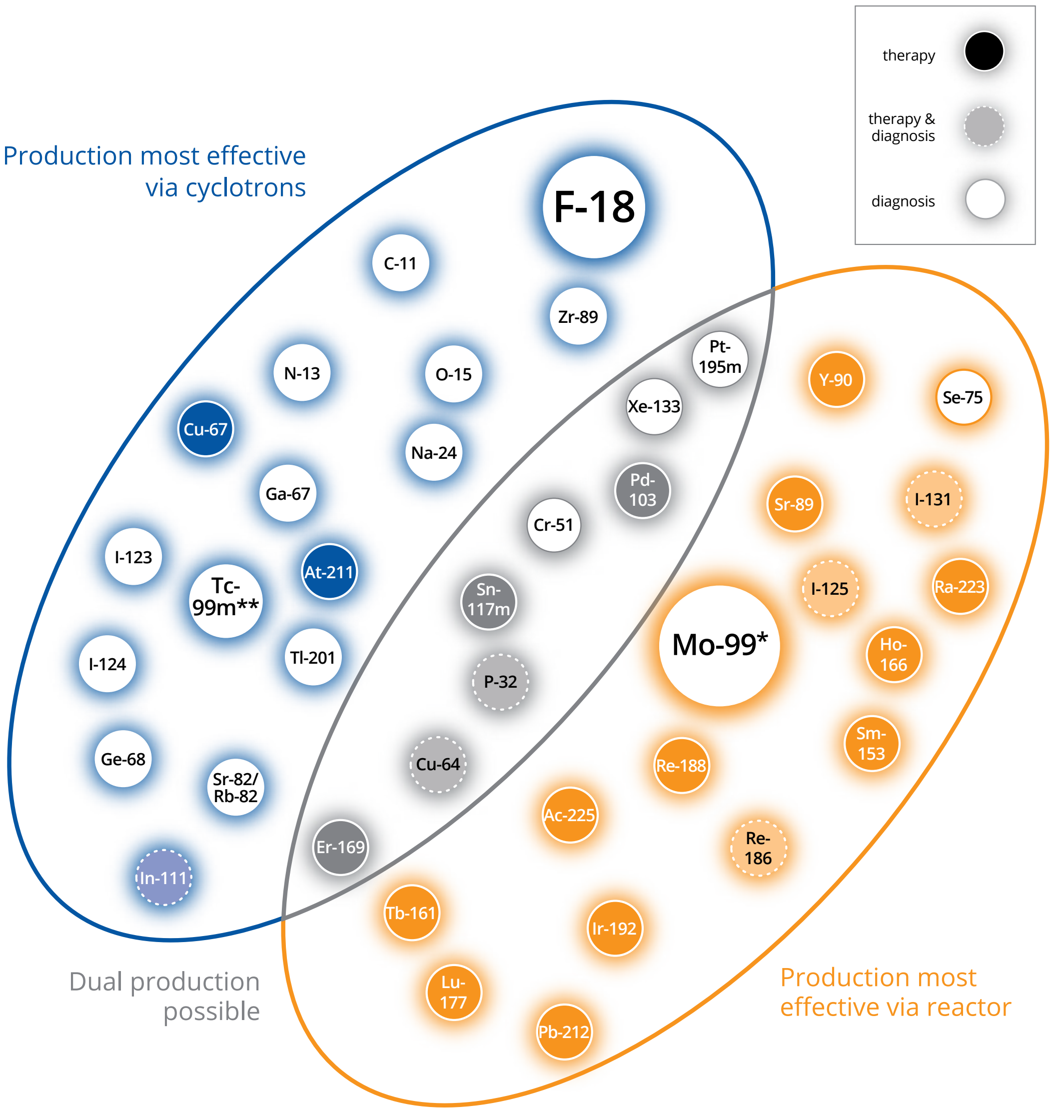
4 Moreover, it is a myth that the use of a cyclotron does not result in nuclear waste. Particle accelerators cause nuclear reactions, and cyclotrons therefore also produce nuclear waste, just like nuclear reactors. However, the volume of waste produced can be limited due to the technical design of the cyclotron and smart choice of targets. Generally speaking, a cyclotron produces much less radioactive waste than a reactor (also when calculated per volume of supplied product). Just like a nuclear reactor, a cyclotron is operational day in day out for a number of decades. The installation itself, and parts of the building in which the installation is housed, therefore become radioactive due to its use. The amount of radioactivity and the level of radiation caused by a cyclotron, is much lower than that of a reactor. However, a great deal of radioactive waste is also released when a cyclotron is dismantled, which still needs to be stored for more than 100 years, as is apparent from compilations and the experience gained in dismantling former medical cyclotrons such as the Cyclotron BV at the VU University Hospital in Amsterdam. Source: RIVM July 2017

but cannot replace each other. The Research Location Petten therefore houses not only a reactor but also two cyclotrons for the production of medical isotopes.
Although various research projects are underway (particularly in Canada) to look into the production of technetium-99m using accelerators, large-scale and commercial production are still a long way away. The developments in Canada will determine the further progress (see box on Canada).
In the Netherlands, accelerators can be found in or near to hospitals in Amsterdam, Eindhoven, Petten, Alkmaar, Groningen and Rotterdam. None of the owners of these cyclotrons currently have plans to use them to produce technetium-99m [12]. The cyclotrons presently used in the Netherlands, are largely deployed for the production of fluorine-18, which is used for PET scans (see appendix G for an explanation of PET and SPECT scans).
However, a crucial fact is that many isotopes simply cannot (yet) be effectively manufactured using cyclotrons or accelerators. This especially concerns the therapeutic isotopes; so far, they can only be produced using reactors.

Canada

As an alternative for the construction of a new multipurpose research reactor, the Canadian government chose to make 35 million CAD available for the 'non-reactor-based isotope Supply Contribution Program' (NIP) in 2009, followed in 2011 by 25 million CAD for research in the so-called 'Isotope Technology Acceleration Program' (ITAP). The developments within these Canadian programs focus on the production of technetium-99m by cyclotrons. Recent scientific publications and public reports on their progress show that work is still under way on this solution for Canada. Despite the many investments, there is still no approved and certified producer using cyclotrons for the production of technetium-99m. They are currently working on the admission requirements for registration.

If a transition is made to the use of cyclotrons only, a number of therapeutic isotopes can no longer be supplied. This



* Research into various production routes for Mo-99
** Research into direct production of Tc-99m via accelerators

Figure 12 Overview of the most important isotopes would mean that isotopes such as iridium-192, lutetium-177 and holmium-166, used for lung, ovarian, liver and neuro-endocrine tumors, among others, would no longer be available to hospitals. This would result in major national and international problems in the treatment of patients suffering from these types of cancer. The 2016 RIVM report to which we refer explicitly indicates a foreseeable increase in the number of deaths from gynecological cancers, for example, due to a shortage of iridium-192 if the HFR were to be decommissioned [13].

The PALLAS objectives can only be met through the construction of a reactor, and not using alternative production methods such as accelerators. Experiments are underway for the production of technetium-99m via cyclotrons but it will take ten years before there is any certainty whether this can result in actual, adequate (commercial) production. Great uncertainty also still surrounds the 'Lighthouse project', and large-scale production must therefore be excluded for the coming ten years. Should the project prove viable, it could be a valuable addition in supplying the global demand for technetium-99. Reactors will in any case remain necessary for the production of therapeutic isotopes. Risks cannot be taken regarding the supply certainty of medical isotopes. The construction of a new reactor in Petten guarantees continuous availability of a wide range of medical isotopes, so that patients in the Netherlands, Europe and a large part of the world can continue to rely on the required diagnosis and treatment.

2.4 Quality knowledge infrastructure and employment

2.4.1 The nuclear knowledge infrastructure

The nuclear knowledge infrastructure can be subdivided into a nuclear chain, from mining through to storage of nuclear material, and a knowledge chain which mainly concerns research work.
The nuclear chain comprises six activities:

- The mining of raw materials for nuclear applications forms the basis.
- Preprocessing focuses on all processes which precede a nuclear reaction. This includes the enrichment of elements, such as uranium.
- Conversion concerns all activities in which a nuclear reaction takes place, for example the conversion into energy for the production of electricity or conversion into a neutrons flux for the production of (medical) isotopes.
- Finishing covers all activities following the nuclear reaction. This includes the separation of specific radio-isotopes from the reaction product, for medical applications, among others.
- Application can concern the application of doped semiconductors in industry, for example, or the application of medical isotopes in nuclear medicine or in medical imaging equipment (after further processing by pharmaceutical companies).
- Storage refers to the temporary and long-term storage of radioactive material (waste). In the Netherlands, nuclear waste is stored at the COVRA in Zeeland.

In turn, many nuclear material applications result in radioactive waste which needs to be collected and stored. In the Netherlands, nuclear waste is stored at the COVRA in Zeeland. With the exception of the mining process, all these activities take place within the Netherlands, and the country is therefore widely active in the nuclear chain.

2.4.2 Importance of Petten for the nuclear infrastructure

The Research Location Petten represents considerable economic and social interests. The Research Location Petten is an essential link in the chain of applied nuclear research. This concerns, for example, research into reactor safety and (final) disposal of nuclear waste, and research with the aid of nuclear technology, such as material research for energy storage.
The nuclear chain is closely knit in the Netherlands. There is a great degree of collaboration between the various players; the Reactor Institute Delft (the Higher Education Reactor), URENCO in Almelo, NRG as operator of the High Flux Reactor) and the Central Organization for Radioactive Waste (COVRA) in Zeeland. A number of the cooperative relationships concerns the production of medical isotopes or the development of new techniques for more accurate diagnosis or therapy for the treatment of even more types of cancer. DIVA (Dutch Isotopes Valley) is a cooperation between TU Delft, URENCO and NRG.
The European Commission is the owner of the current High Flux Reactor. The European Commission's Joint Research Centre (EC-JRC) is located at the Research Location Petten.
The Dutch organizations within the nuclear knowledge infrastructure are involved in various international organizations. There are numerous international contacts, for example within the OECD, the IAEA, Euratom and in consortia of European

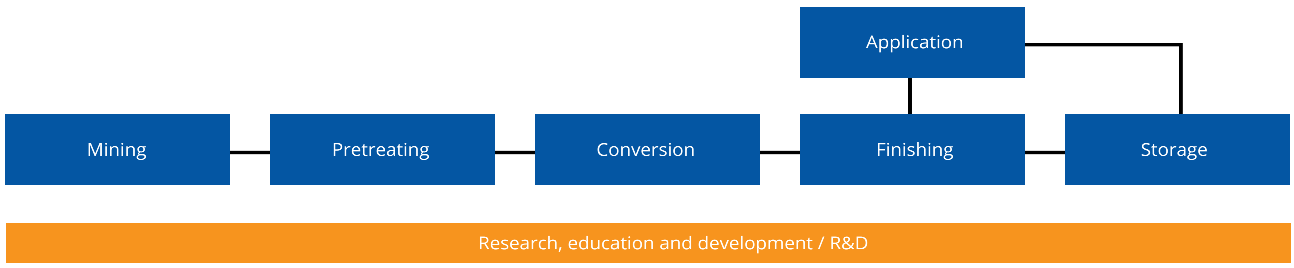


Figure 13 Components of the value chain

policy programs for research and innovation.
The scientific quality of nuclear research in the Netherlands is highly qualified, with leading researchers and also a state-of-the-art research infrastructure, thanks to the reactor of TU Delft, for example. There is also a good range of (academic) education and training.
The Technopolis agency estimates the total income within the nuclear knowledge infrastructure to be around 1 billion euros per annum (report dated 18 July 2016) [17].

2.4.3 Quality employment

The nuclear knowledge infrastructure brings employment and thereby economic growth to regions with otherwise limited employment possibilities. NRG, Curium (formerly Mallinckrodt) and EC-JRC in Petten provide many jobs in the Noord-Holland province. Moreover, these are organizations and companies which attract and retain academic employees for the region.
'Petten' is currently good for approximately 1,600 (mostly) highly-qualified jobs. Besides the HFR, there is a specialized nuclear infrastructure of laboratories for research, treatment, processing and the eventual transport of the nuclear material. The amassed nuclear knowledge and expertise makes this a unique bundling of activities at a single location.
The isotopes are not only produced but also processed at the Research Location Petten. Curium processes the isotopes, making them available for medical applications in hospitals. The combination of all these activities and an effective logistics infrastructure prevents valuable time being lost. And so Petten has a complete infrastructure for the production and processing of medical isotopes.
The construction and operation of the PALLAS-reactor will provide yet another impulse for employment and economic activities in this area of Noord-Holland.

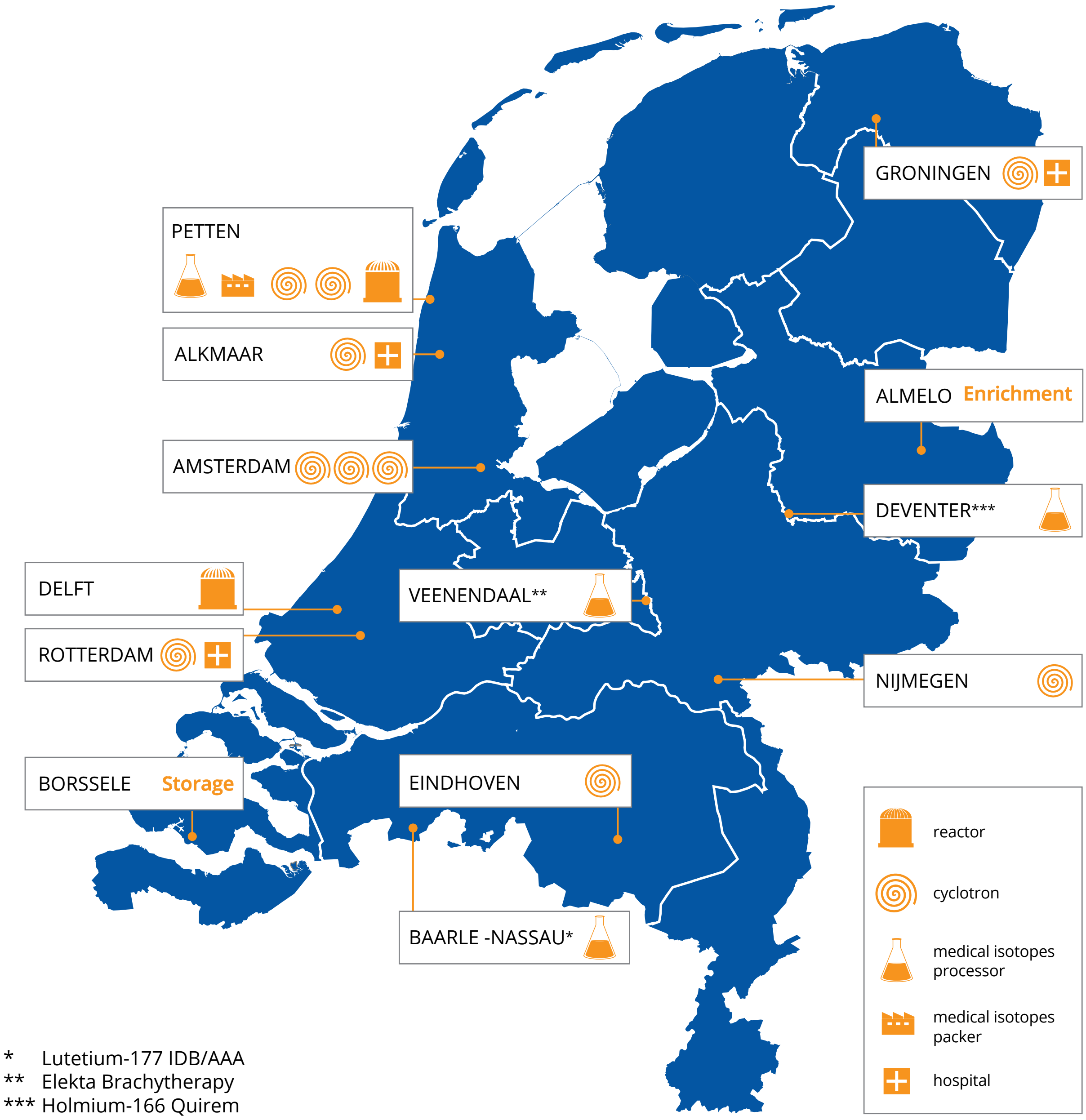


Figure 14 Netherlands nuclear value chain for medical isotopes

3 Proposal and variants

The purpose of the PALLAS project is the realization of a multifunctional ('multipurpose') reactor suitable for the production of medical isotopes, industrial isotopes and conducting technological nuclear research, as well as the construction of all facilities required for this purpose.

Section 3 describes the proposed activity. Paragraph 3.1 shows where the PALLAS-reactor will be located at the Research Location Petten. Paragraph 3.2 gives a general idea of the expected appearance of the PALLAS-reactor and facilities, and the principles applied in further detailing of the concept. Paragraph 3.4 gives the variants considered in this SEA.

3.1 Location at the Research Location Petten

A number of locations are available at the Research Location Petten, within the existing zone classification of "industrial estate – exceptional industrial estate", which are all located in the lower lying area, not in the dune area. Figure 16 shows all available undeveloped area or area available within the zone classification of "industrial estate – exceptional industrial estate".
The eastern cluster of the Research Location Petten includes the Hot Cell Laboratory[5] (HCL) building [18] and other existing buildings for the production of radionuclides and for conducting technological nuclear research. With a view to safety, security and transport of nuclear material, it is desirable to cluster the nuclear activities on the site. Only those locations in the eastern cluster of the Research Location Petten have therefore been considered in more detail.
Of all the available locations in the eastern cluster, only the proposed PALLAS location (see Figure 3) offers sufficient surface area (approximately 1.7 hectares) to be able to realize the reactor with accessory buildings and functions.

Possible layout of PALLAS site
The PALLAS-reactor will be located on a secure site. A separate reception area will be built at the Research Location Petten, from which access is gained to the PALLAS site. Figure 17 shows the possible layout of the PALLAS site.

Figure 15 Undeveloped area or area suitable for building in the zoning plan

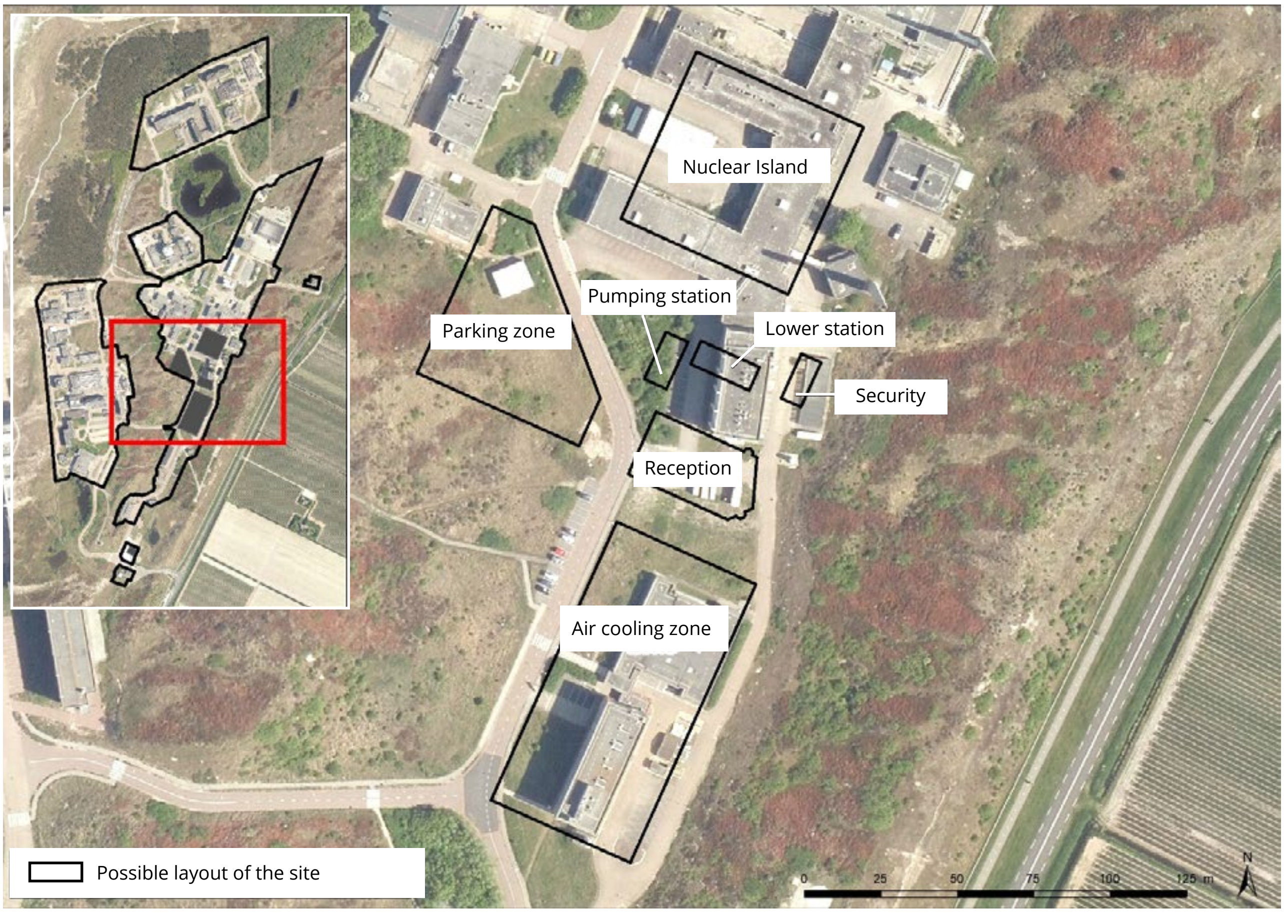


Figure 16 Possible layout of the PALLAS site at the Research Location Petten

5 This laboratory is deployed for post-irradiation research: radioactive materials irradiated in the High Flux Reactor can be processed in this laboratory for further research and production (source: https://www.nrg.eu/over-nrg/bedrijf/nucleaire-faciliteiten.html)

3.2 Design framework, reactor, position in chain

3.2.1 Design framework

The exact layout and technical detailing of the PALLAS-reactor and the reactor site are not yet known. This SEA therefore works on the basis of a design framework (see appendix C). Realistic assumptions have been made regarding the design characteristics of the reactor, within which the proposed activity can take place. The design framework was formed for the benefit of the SEA and the zoning plan, and therefore has a corresponding level of abstraction.

The design framework provides a conservative yet realistic estimation of the proposed activity. It is based on the characteristics of the site at the Research Location Petten, on policy and legislative preconditions and on know-how gained at the current HFR.

The exact location is as yet unknown for some components, such as the possible routes for cooling water pipelines or the temporary LDA. In such cases, the design framework works with a search area, for which the impact and possible obstacles are visualized in this SEA. These can then be taken into account wherever possible in further detailing of the design. This further detailing of the design is assessed within the scope of the EIA.

3.2.2 PALLAS-reactor

Type of reactor

PALLAS has opted for a pool type reactor. A commonly used differentiation is a tank-in-pool type reactor, see Figure 18

The water basin provides room for fissile elements and control rods. The fissile elements are responsible for generation of the neutrons in the nuclear fission process. The PALLAS-reactor will be designed to operate using low-enriched uranium, which means that the volume of uranium-235 (^{235}U) is less than 20% of the total volume of uranium used (largely ^{238}U). The control rods serve to control the capacity of the reactor, by absorbing neutrons. The advantages of a 'pool type' reactor are that the water basin provides sufficient protection for the safe conducting of experiments and isotope irradiation in or adjacent to the reactor core during normal operation, and that there is a good view of the experiments due to the transparency of the water. The high density of the concrete walls of the basin also functions as a protective measure for safe operations.

Cooling the reactor (primary cycle)

Fission of the uranium atomic cores generates heat, which is dispersed by cooling the reactor core. The heat is transferred into cooling water which flows through the reactor basin. The cooling water is pumped around the so-called primary cycle, which transfers the heat absorbed from the cooling water to a secondary system, via a heat exchanger. The reactor core and the fissile material used also transfer heat to the basin water. This basin water is cooled in a similar manner to the cooling water, namely using a primary cycle which transfers heat to the secondary cooling system via a heat exchanger.

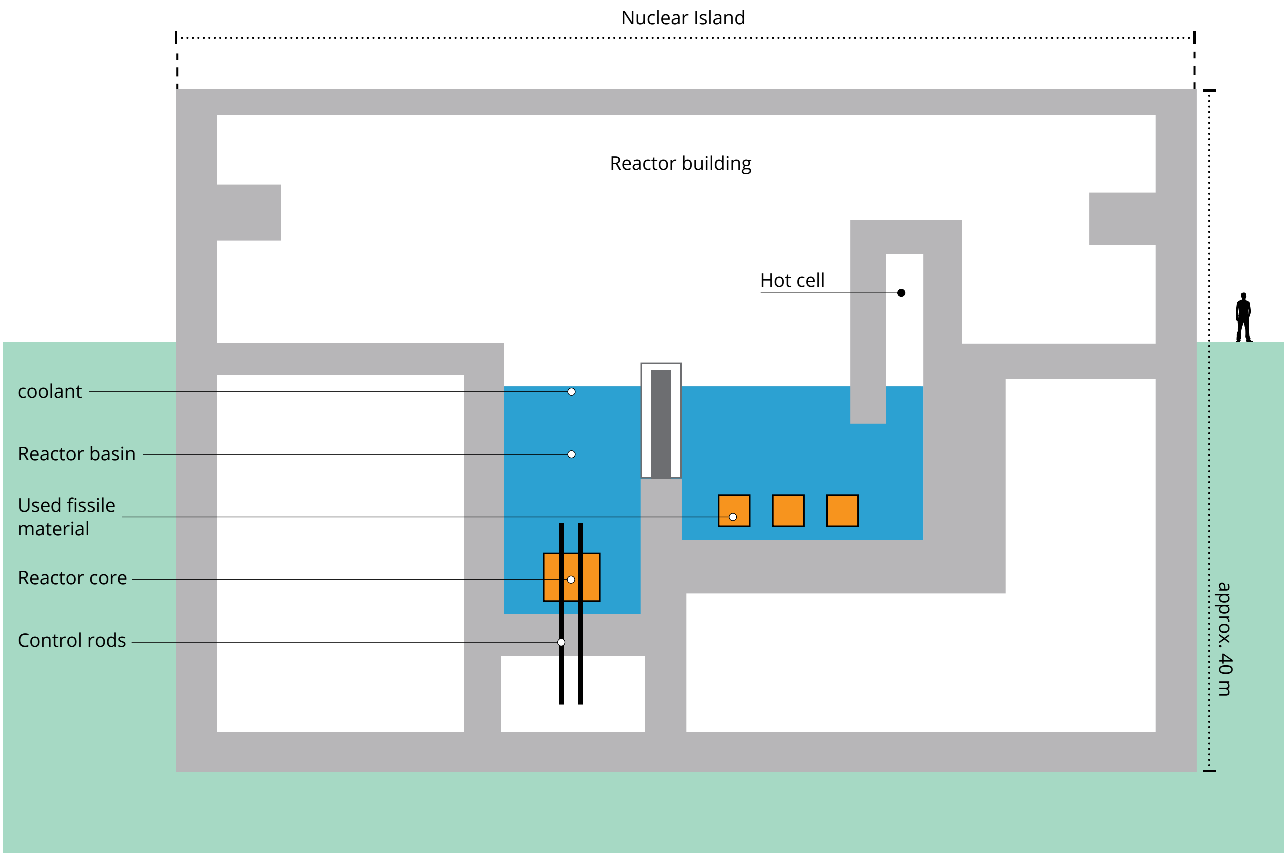


Figure 17 Schematic representation of a pool-type reactor

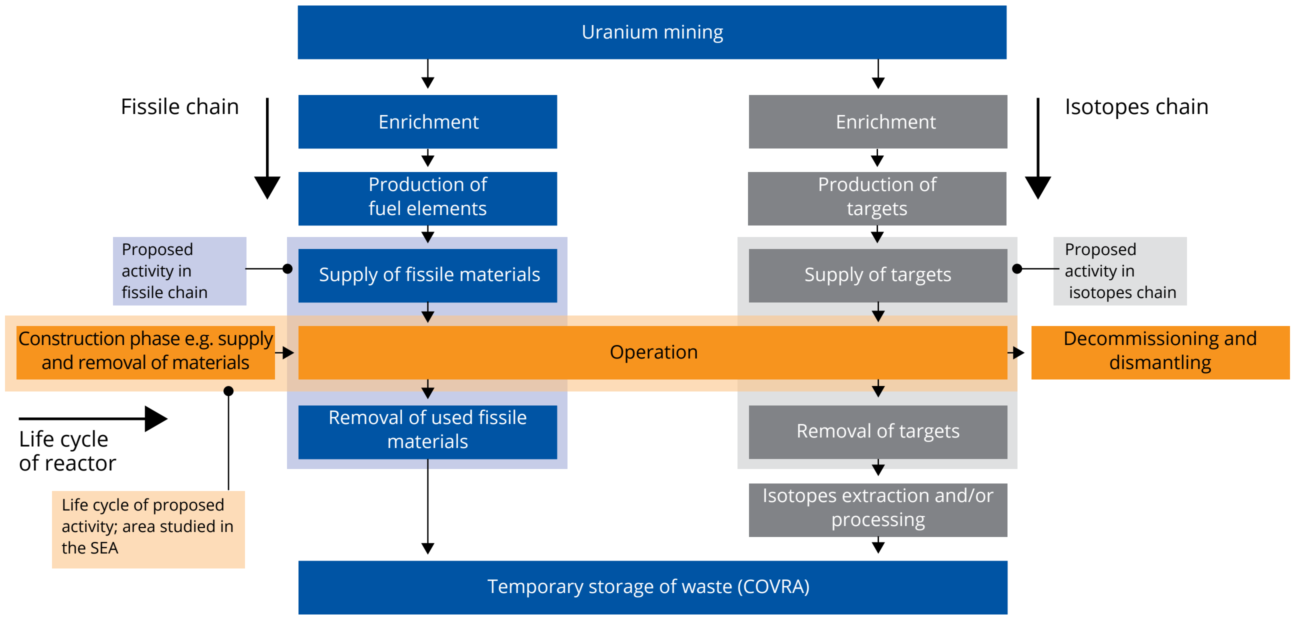


Figure 18 Schematic representation of the fissile chain and isotopes chain (green area is discussed in this SEA)

Nuclear island
The nuclear island comprises the location of the reactor. An important function of this nuclear island is that it provides a physical barrier, in order to seclude radioactive material and fissile material. The process of preventing or limiting the emission of radioactive material to the environment is also known as confinement[6]. The assumed dimensions of the nuclear island are 40 m (width) x 60 m (long) x 40 m (height).

Reactor safety
Nuclear reactors must be operated safely. There is extensive international and national legislation for this purpose. In other words, people and the environment will be sufficiently protected against the harmful influence of ionizing radiation throughout the life cycle of a nuclear reactor. This is subject to strict monitoring. The life cycle of a nuclear reactor concerns its design, construction, commissioning, operation and eventually decommissioning and dismantling.
A nuclear reactor must essentially comply with the three following safety functions:
- Control of the reactivity.
- Cooling the fissile material.
- Confinement of the radioactive or fissile materials.

These three safety functions apply to all phases of the life cycle of a nuclear reactor. If the safety functions are not met, a Dutch Nuclear Energy Act permit will not be granted. The safety functions are further underpinned in the application for the Dutch Nuclear Energy Act permit and the accessory EIA.

3.2.3 Position of PALLAS in the fissile chain and in the isotopes chain

The PALLAS-reactor is a component in the fissile chain and in the isotopes chain. Figure 4 gives a schematic representation of the two chains. Appendix C (Design framework) pays detailed attention to the (impact of the) steps prior to and following the steps in the chain for which the PALLAS is to be deployed.

Fissile chain
The fissile chain starts with mining and enrichment, followed by the production of fissile elements. The mining and production of the fissile elements does not take place in the Netherlands. There is an enrichment plant in the Netherlands, though this will not be (directly) deployed by PALLAS. The fissile elements are purchased on the international market, whereby the supplier determines the source of the enriched material. This material will then be transported in containers to the PALLAS-reactor, and will be deployed as fuel in the PALLAS-reactor, for operation of the reactor. These elements generate neutrons, which are required for irradiation of the experiments. The fissile material thus used will need to be periodically replaced. When spent, the used fissile elements are discharged from the reactor core and temporarily stored under water (for a number of years) in the water basin.
After around 2 years, the heat production decreases to such an extent that the fissile elements can be transported in a special container. The fissile elements are transferred from the water basin into a specially designed container, which is then transported to COVRA (Central Organization for Radioactive Waste).

Isotopes chain
The isotopes chain is very comparable with the fissile chain, though a number of components deviate. This too is an international chain, with some stages (activities) taking place in the Netherlands, and others further afield. A target is a piece of material, often made from aluminum, which contains uranium. Targets are transported to the PALLAS-reactor in the Netherlands from abroad (from France, for example).
Using special equipment, the targets are placed in special

6 Confinement: The prevention or limitation of the emission of radioactive materials to the environment during normal operations and during any incidents which may occur.

target holders, which in turn are installed in or alongside the reactor core of the PALLAS-reactor. The neutrons generated in the fission process in the reactor irradiate the targets. Following a preset irradiation period, the targets are removed and placed in a container.
Following irradiation, the targets are transported in specially designed containers for further processing, for the production of medical isotopes or conducting technological nuclear research. Most of these activities take place at the Research Location Petten.
During processing and following use at the hospitals or research institutions, the waste materials are radioactive, and are transported to COVRA in specially designed containers, where they are stored according to the Dutch policy.

3.3 Project phases

The realization and operation of the PALLAS-reactor can be divided into three project phases: the construction phase, the transition phase and the operating phase. These phases are explicitly described in the environmental assessment of this SEA.

3.3.1 Construction phase

The PALLAS-reactor, the related systems and the related infrastructure modifications are realized during the construction phase, which will take approximately 4 years. The activities undertaken during the four years are generally as follows:

- Preparation of the site and the LDA, this phase will take approximately 4 months.
- Construction of the reactor and the nuclear island, this phase will take approximately 44 months.
- Construction of the secondary cooling water system, this phase will take approximately 31 months and will be undertaken simultaneously with the reactor construction work.
- Construction of the other buildings and facilities (sewer/car park, etc.) on the site. This phase will take approximately 36 months and will be undertaken simultaneously with the reactor construction work.

Within the scope of the SEA, particularly relevant factors are the excavation and ground moving for the purpose of the reactor and the realization of the secondary cooling water system. Also relevant is that a temporary LDA of approximately 50,000 m² must be formed (the search area is given in appendix C design framework). Excavated ground and construction materials will be transported in and out using trucks. The principle is that construction work must give the least possible hindrance for the surrounding area. Safety and accessibility are other important aspects, especially because the Research Location Petten has limited accessibility for security reasons.
A construction pit is necessary for realization of the nuclear island, as this nuclear island is partially underground. When considering the depth in particular, the realization of such a construction pit is not without risk. There are two main risks, namely the installation of construction pit walls, and subsidence in the surrounding area. Both aspects will affect the level of the ground and the neighboring buildings.

3.3.2 Transition phase

During the transition phase, the PALLAS-reactor will be gradually put into operation. The reactor core will be put in place and used to test the installation. The first transport of fissile elements will also take place in this phase. As soon as the PALLAS-reactor is ready for operation, it is likely that the HFR activities will be gradually discontinued. As it is still uncertain exactly when the operator will phase out the HFR, our description of the environmental impact assumes a transition phase in which both reactors will be operational.

3.3.3 Operational phase

During this phase, the PALLAS-reactor will be commissioned. The reactor will be safely operated and maintained according to the specifications described in the permit granted.

3.4 Variants

The SEA considers and compares variants which are relevant for the planning of the PALLAS-reactor. This relates to variants for:

- The height of the reactor (paragraph 3.4.1).
- The secondary cooling water system (paragraph 3.4.2).

3.4.1 Variants for the height of the reactor

This SEA considers three variants for the construction height and depth of the nuclear island. The variants and reasons for the choice of these variants are described hereafter.

1. Construction height variant B1:
   17.5 m above ground level and 29.5 m below ground level. In this variant, the deeper foundation of the nuclear island results in a total height of 47 m instead of 40 m. This variant is constructed using the caisson method and will be determined by the height of the buildings in the current zoning plan (21.0 m NAP). A large part of the nuclear island will therefore be constructed underground.

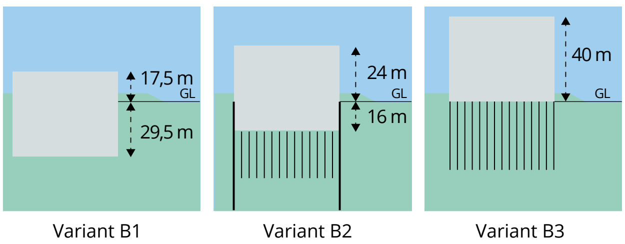


Figure 19 Construction variants for the nuclear island

2. Construction height variant B2:
   24 m above ground level and 16 m below ground level. Variant B2 is determined by the maximum permissible height

in the current zoning plan, which is 24 m above ground level (27.5 m NAP). A limited part of the nuclear island will therefore be constructed underground.

3 Construction height variant B3: 40 m above ground level and 0 m below ground level. Based on a nuclear island of 40 x 60 x 40 m, this building will be 40 m above ground level (43.5 m NAP).

The construction height variant B1 falls within the construction height possibilities of the current zoning plan. Construction height variant B2 can only be realized within the current zoning plan under the facility of derogation. The maximum construction height of the zoning plan would need to be modified for construction height variant B3.

3.4.2 Variants for cooling the reactor

Adequate cooling is an important basic condition for safe operation of the PALLAS-reactor. This is needed to remove the heat generated by the operation of the reactor. The PALLAS-reactor has primary and secondary cooling water systems (see paragraph 3.2).
The general choices are between cooling by water or by air. The possibilities given in the BREF for cooling systems have been compared[7] in a technical study (Arcadis, 22 September 2016: Secondary cooling system, technical studies LEOPS). On the basis of this study, the following variants have been chosen for the secondary cooling water system, and are considered in this SEA:

1 Cooling variant K1: Extraction from the Noordhollandsch Kanaal and discharge into the North Sea (freshwater-saltwater variant).
  This variant is derived from the current practice at the HFR. The secondary cooling system of the HFR extracts water from the Noordhollandsch Kanaal, which is freshwater. After having cooled the primary system, the water is discharged into the North Sea. This is once again an option for cooling the PALLAS-reactor. This variant would require a new extraction point to be constructed in the Noordhollandsch Kanaal, as well as a new discharge point in the North Sea. A cooling water pipeline would also be constructed between the reactor, the extraction point and the discharge point.
2 Cooling variant K2: Extraction from the North Sea and discharge into the North Sea (saltwater-saltwater variant).
  The proposed location of the PALLAS-reactor is in the vicinity of the North Sea, making it possible to also use saltwater from the North Sea as cooling water. In this variant, the water is extracted and then discharged again into the North Sea after having been used to extract heat from the primary system. The extraction and discharge points can be realized at approximately 300 m (at a depth of 5 m) and 700 m (at a depth of 10 m) from the coast, respectively. The choice mainly depends on the volume of sand and fish suction and possible growth of organic material in the extraction station. The extraction station with pumps will be constructed on a platform in the sea.
3 Cooling variant K3: Air cooling / hybrid cooling.

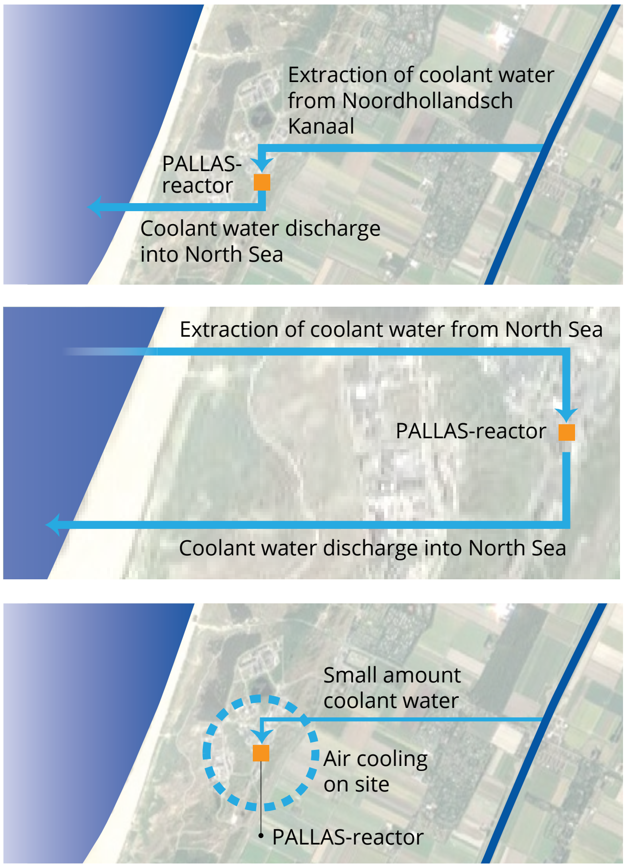


Figure 20, 21 and 22 Schematic representation of cooling variants K1 (top), K2 (center) and K3 (bottom)

  In this variant, the cooling water is air cooled after having been used to extract heat from the primary system. As the water can be largely reused once it has cooled, this variant requires considerably less water than the water-cooled plants. The water supply will be mains water or water from the Noordhollandsch Kanaal.
  Depending on the type of cooling units, they will require a surface area of maximum 5000 m² on the site. The principle is that the cooling units may never be higher than 11 m.

The exact location of the cooling water pipelines for the cooling variants has yet to be determined. Figure 24 shows the search areas for these cooling water pipelines from the Noordhollandsch Kanaal / North Sea and to the North Sea.

Eliminated cooling variants

A number of variants have been eliminated, following motivation in the technical study.

- EA variant with cooling using salt North Sea water extracted wholly or partially further at sea (far shore, 5 km) than in the K2 cooling variant (near shore, 300 m). This was due to the great environmental impact:
  - The collision risk by ships is greater in a far shore variant than in a near shore installation.
  - A longer pipeline requires more treatment to prevent organic material growth (preventative chlorination), with a greater risk that such substances are dispersed in a

7 BREF stands for BAT Reference Documents and is a description of the Best Available Techniques (BAT) which must be applied by industrial companies subject to the European Directive on industrial emissions (2010/75/EU). The BREF for cooling systems describes the best available techniques for industrial cooling systems using air and/or water as their cooling.

higher dose to the environment.
- The 5 km long pipelines must be installed in the seabed, therefore affecting the seabed more than a near shore installation.

- An air cooled variant without any use of water has also been eliminated. The reason was that this so-called dry cooling requires a temperature difference for the transfer of energy, in order to cool the cooling medium. However the required temperature difference of 6°C or more is not available in summer months (the air temperature would need to be 25 – 6 = 19°C or lower).

Figure 23 Search area for cooling water pipelines route and proposed location of PALLAS-reactor

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4 Approach to environmental assessment

This section describes the approach to the environmental assessment. Paragraph 4.1 begins by discussing the project phases distinguished in the project and in the environmental assessment, as well as the reference situations used in the environmental assessment of the proposed activity and variants. Paragraph 4.2 deals with the design framework. Paragraph 4.3 gives an overview of the assessment framework and the type of environmental impact (paragraph 4.3.1) to be visualized, the scoring method (paragraph 4.3.2) and a general overview of the relevant environmental impact per project phase (paragraph 4.3.3).

4.1 Reference situation and project phases

Construction variants for the height of the PALLAS-reactor and for the cooling system have been assessed in comparison with the reference situation. The reference situation is the current situation plus the autonomous development. The time horizon is set at ten years after the zoning plan becomes irrevocable. Autonomous development means the future development of the plan and study area, if the PALLAS-reactor were not to be realized. This takes account of two types of developments:

1. Autonomous developments resulting from changes caused by economic developments and by climate change.
2. Established plans and projects which influence the plan or study area, in which there are intervention-impact relationships for the relevant environmental themes.

Each section of Part B of the SEA features a paragraph titled 'Current situation and autonomous development', which describes the current situation and any relevant autonomous developments in the impact assessment of a particular environmental aspect.
One important development is uncertain within the autonomous developments, namely the planning of the closure of the current HFR. The most realistic scenario is that it is decommissioned once the PALLAS-reactor is fully operational. This is necessary in order to guarantee the supply certainty of isotopes. This study assumes that the HFR and the PALLAS-reactor will be simultaneously operational until the isotope production has been entirely transferred.
Should the HFR be decommissioned before the PALLAS-reactor is operational, this would result in an exceptional (and undesirable) situation. In order to visualize the impact which would then occur due to realization of the PALLAS-reactor and cooling facilities, a special analysis has been made of the impact with regard to a second type of reference situation. This is defined in a sensitivity analysis at the end of part B, in section 18.

Relevant project phases
The environmental impact of the PALLAS-reactor are described for three phases, namely:

- The construction phase.
- The transition phase (during which both the HFR and the PALLAS-reactor will be operational).
- The operational phase (in which only the PALLAS-reactor is operational).

The phases are schematically represented in Figure 24.

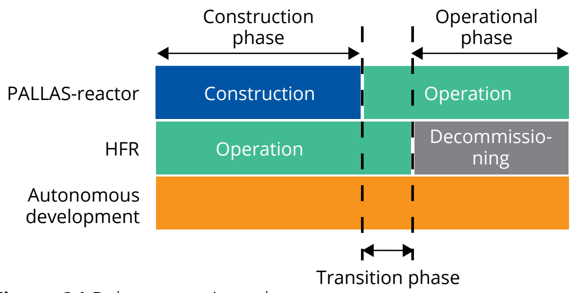

Figure 24 Relevant project phases

As it is the intention that the PALLAS-reactor takes over production from the HFR, a transition phase is assumed, in which PALLAS increases its activities and the HFR decreases its activities. In assessing this transition phase, it has been assumed that both reactors will be fully operational, in order to give a worst-case scenario regarding the impact. This provides insight into the cumulative impact of the HFR and the PALLAS-reactor.
It should be noted that decommissioning of the HFR need not immediately result in its dismantling. This has not been assessed in the current SEA, as dismantling of the HFR is not part of the PALLAS project.

4.2 Design framework

IThe environmental assessment describes the impact of the proposed activity. Due to the precise design and technical detailing of the reactor and the reactor site not yet being known, this proposed activity is based on a design framework (Appendix C).
The design framework makes realistic assumptions regarding the design characteristics of the reactor. Assumptions and principles have also been detailed for the three construction height and cooling variants, in the design framework. These are based on the characteristics of the site at the Research Location Petten, on policy and legislative preconditions and on know-how gained at the current HFR. The design framework provides a conservative and realistic estimation of the proposed activity.
The SEA maps out the impact of the maximum usage possibilities. As far as the capacity of the reactor is concerned, for example, a maximum reactor capacity of 55 MW is assumed. The actual capacity will be 55 MW or less. The cooling capacity assumed in the SEA has in turn been derived from the maximum capacity.
The SEA will therefore always describe the maximum impact as a result of the reactor capacity. The exact location is as yet unknown for some components, such as the possible routes for cooling water pipelines or the temporary LDA. In such cases, the design framework works with a search area, for which the impact and possible obstacles are visualized in this SEA. These can then be taken into account wherever possible in further detailing of the design. The design framework is described in Appendix C.

4.3 Environmental assessment method

4.3.1 Type of environmental impact

Part B of this SEA describes a detailed impact assessment per assessment criterion, based on the following assessment framework (see Table 2).

When formulating the background reports and translating these basic results into part B of this SEA, there was some degree of deviation from the original layout of the impact assessment framework, as defined in the communication memorandum of the PALLAS SEA and in the guidelines of the municipality of Schagen. This concerns the renaming of criteria[8], the classification of criteria under a different aspect[9] or a further division within criteria[10], due to extra insight having been gained regarding description of the dose-impact relationship. All in all, this SEA does not contain less information than prescribed in the NRD/guidelines, but it has become more logically classified as the process progresses.

The impact is studied at a general level in the SEA, in keeping with the level of detail of the zoning plan and the decision-making process within the scope of the zoning plan. The quantitative impact has been determined whenever possible, which has then been translated into a qualitative assessment scale 4.3.2. In those cases where it was not otherwise possible or useful, the qualitative impact has been determined on the basis of expert judgment.

A synthesis has been formulated in section 5, based on the total impact, and allowing conclusions to be drawn for the decision-making process on zoning plan revision.

Table 2 SEA Assessment framework

Aspect	Criterion	Assessment criterion
Radiation protection and nuclear safety	Radiation protection	Effective dose as the result of • Direct radiation • Radioactive emissions to air • Radioactive emissions to water • Radioactive waste
	Nuclear safety	Radiological requirements for postulated incidents: Effective dose for local residents Admissible risk as a result of incidents: Individual risk Group risk
Soil and water	Groundwater	Vegetation
		Buildings
		Dunes as part of the coastal defense
		Agriculture
		Groundwater extraction or infiltration systems
		Mobile contaminants
	Water quality	(physical) chemical water quality
		Biological water quality
	Cooling water extraction and discharge	Cooling water extraction
		Cooling water discharge
	Soil quality	Soil quality
Water safety		Realization of construction and increased/decreased water safety
		Intersections with primary defenses and regional defenses
		Impact of access road through the inner (secondary) dune ridge
Air quality	Impact on NO_2	Impact of PALLAS-reactor on nitrogen dioxide in the air
	Impact on PM_{10} and $PM_{2.5}$	Impact of PALLAS-reactor on fine particular concentrations in the air
Noise	Noise hinder for housing	Noise hinder for housing, other noise-sensitive buildings and noise-sensitive sites

8 For example Water quality instead of Surface water. The impact on freshwater supply (water quantity) has been discussed under a different criterion, namely cooling water extraction and discharge.

9 For example: geological values are discussed under Landscape and Cultural history rather than under Soil and water, Water safety has been 'promoted' to become a separate aspect (and therefore a specific section in part B) while Noise hinder in nature is now classified under Nature.

10 For example: the relationship between groundwater and six functions dependent upon groundwater, further division of dose-effect relationships with regard to protection of the region (Dutch Nature protection act and NNN) and species protection (Dutch Nature protection act).

Aspect	Criterion	Assessment criterion
Light	Direct incidence of light in housing	Direct incidence of light in housing in the direct vicinity of the Research Location Petten
Nature	Regional protection Dutch Nature Protection Act	Surface area loss/mechanical impact
		Disturbance
		Nitrogen deposition
		Suction of fish
		Hydrological changes
		Thermal changes in the surface water
		Chemical changes in the surface water
	NNN	Surface area loss/mechanical impact
		Disturbance
		Hydrological changes
	Species protection Dutch Nature Protection Act	Surface area loss/mechanical impact
		Disturbance
		Suction of fish
		Hydrological changes
		Thermal changes in the surface water
		Chemical changes in the surface water
Spatial quality, landscape and cultural history	Physical degradation of landscape characteristics/values	Influencing of valuable landscape elements and patterns (points, lines, planes)
	Physical degradation of historic geographical elements	Influencing of historical and geographical valuable elements and patterns (points, lines, planes)
	Physical degradation of historic (urban) architecture	Influencing of objects and ensembles with historic (urban) architecture values
	Experiential value	Influencing of the visual-spatial characteristics of landscape and cultural history
	Usage value	Influencing of the use or suitability for activities in the landscape
	Future value	Influencing of the sustainability of the landscape (adaptive capacity)
Recreation and tourism	Recreational usage possibilities	The degree of influence on the recreational use of the Research Location Petten surroundings.
	Recreational experiential value	The degree of influence on recreational activities by the spatial perception of the proposed activity.
	Accessibility	The degree of influence on access roads to and parking facilities at recreational day activities.
	Economic value	The degree of influence on employment and income in the area (as a result of tourist spending).
	Identity	The degree of influence on the reputation and identity of Petten and Sint Maartenszee as a tourist area and the possibilities for (further) development in that sense.
Archeology	Damage to areas with expected archaeological value	Quantitative assessment takes place if the impact can be defined through quantification (for example the number of hectares or square meters) and/or if there are other generally accepted quantitative methods for determining the impact.
	Physical or indirect damage to archaeological evidence (known archaeological value)	Quantitative number of known values, including assessment (qualitative)
Traffic	Traffic safety	Road design complies with the Sustainable Safety principles
	Traffic movements	Increased traffic (perceptual and absolute) versus maximum (desirable) intensity
	Vibrations due to traffic	Increase in vibration hinder

4.3.2 Scoring method

An assessment table is formulated per aspect (see column 2 of Table 2), to summarize the possible environmental impact. Per assessment criterion, the table then indicates whether there is a positive impact, negative impact or no impact expected. A five-point scale is used for this purpose. Table 3 gives a schematic representation of this scoring. The reference situation is always scored neutrally (0).

Table 3 Assessment scoring

Score	Meaning	Explanation
++	Extremely positive impact	A strong decrease of the impact on the environment versus the reference situation.
+	Positive impact	A limited decrease in the environmental consequences versus the reference situation.
0	No impact	No significant change in the impact on the environment versus the reference situation.
-	Negative impact	A limited increase in the environmental consequences versus the reference situation. These consequences comply with the criteria of the assessment framework.
- -	Extremely negative impact	A strong increase in the environmental consequences versus the reference situation. These consequences exceed the criteria of the assessment framework.

4.4 Results: negative and/or differentiating environmental impact

The following three paragraphs summarize the impact, as described and underpinned in Part B of the SEA. The focus lies on:

a Those assessment criteria for which any impact at all may occur in the specific project phase. Not all impacts will occur in each phase[11]. A motivation is provided in part B, as to why certain assessment criteria have not been assessed.

b Those assessment criteria for which the assessment is not neutral. Part B shows that the lion's share of the assessment criteria will be dropped. In other words, many assessment criteria will show no impact versus the reference situation (score 0) and these are therefore not discussed in part A. Appendix E of part B includes the complete impact assessment table for verification purposes.

c Those assessment criteria which have a negative impact or differentiating environmental impact between the various variants. After all, this provides valuable information for the purpose of decision-making on the PALLAS zoning plan:

- Insofar negative impacts occur: the severity of the environmental impact and whether it can be mitigated.
- Insofar there are differences between variants (for construction and cooling): the extent to which this difference should play a role in the choice of the variant.

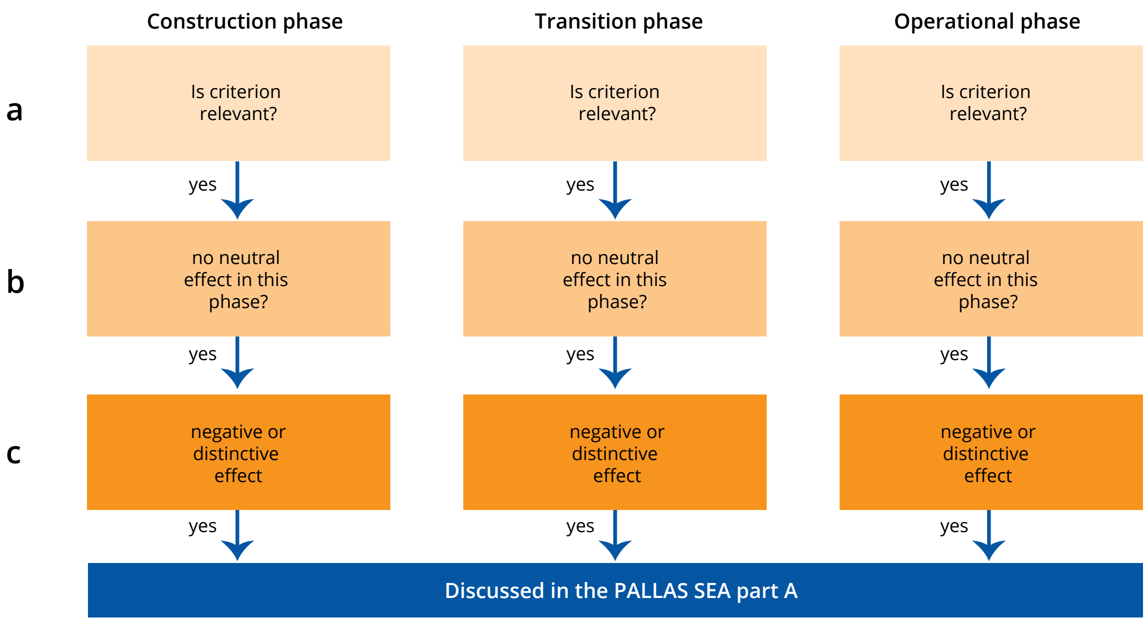

Figure 25 Relevance of assessment criteria for part A of the SEA

11 In the construction phase for example, the PALLAS-reactor is not yet in operation, and there is therefore no extraction and discharge of cooling water.

4.4.1 Negative impact and differentiating impact between variants – Construction phase

Negative impact
Non-differentiating negative impacts apply during the construction phase, for the following assessment criteria:

- Recreation and Tourism: Influencing of recreational usage possibilities

Section 5 discusses this assessment and the possibilities/requirements for mitigating measures.

Differentiating impact between variants
Table 4 gives an overview of the assessment criteria and assessments, when there are differentiating impacts between the variants. Section 5 discusses the conclusions which can or must be drawn, in more detail.

Table 4 Assessment criteria with differentiating results between the variants in the construction phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Nuclear safety						
Radiological requirements for postulated incidents	-	-	-	0	0	0
Admissible risk as a result of incidents	-	-	-	0	0	0
Soil and Water						
Groundwater						
Vegetation	0	0	0	- -	- -	n/a
Agriculture	0	0	0	-	-	n/a
Mobile contaminants	0	0	0	- -	- -	n/a
Noise						
Noise hindrance for local residents due to construction activities	- -	- -	- -	-	0	0
Indirect noise hindrance for local residents	-	-	-	n/a	n/a	n/a
Light						
Increased light intensity in light-sensitive objects	-	-	-	- -	0	0
Nature (following mandatory measures)						
Natura 2000 area	0	0	0	-	-	0
Protected species	0	0	0	-	-	0
NNN	0	0	0	-	-	0
Red List species	0	0	0	-	-	0
Recreation and Tourism						
Influencing of recreational experiential value	-	-	-	-	-	0
Identity	-	-	-	-	-	0
Landscape and Cultural history						
Experiential value	-	-	-	0	0	0
Archeology						
Expected archaeological values	- -	- -	- -	- -	-	0
Known archaeological values	-	-	-	-	-	0
Traffic						
Road design according to the Dutch Sustainable Safety principles – if the Zeeweg is used.	-	-	-	0	0	0

4.4.2 Negative impact and differentiating impact between variants – Transition phase

Negative impact

Non-differentiating negative impacts do not apply to any of the assessment criteria during the transition phase.

Differentiating impact between variants

Table 5 gives an overview of the assessment criteria and assessments, when there are differentiating impacts between the variants. Section 5 discusses the conclusions which can or must be drawn, in more detail.

Table 5 Assessment criteria with differentiating impacts between the variants in the transition phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Radiation protection						
Effective dose	-	-	-	0	0	0
Nuclear safety						
Radiological requirements for postulated incidents	-	-	-	0	0	0
Admissible risk as a result of incidents	-	-	-	0	0	0
Soil and Water						
Groundwater						
Groundwater extraction or infiltration systems	-	-	0	0	0	n/a
Cooling water extraction and discharge						
Cooling water extraction	n/a	n/a	n/a	- -	0	0
Water safety						
Water safety	0	+	+	0	0	0
Noise						
Noise hindrance for local residents due to installation	0	0	0	0	0	- -
Noise hindrance for local residents due to construction activities	0	0	0	0	0	- -
Nature (following mandatory measures)						
Natura 2000 area	0	0	0	-	-	0
Recreation and Tourism						
Influencing of recreational usage possibilities	0	0	0	0	-	-
Influencing of recreational experiential value	0	-	- -	0	- -	-
Identity	0	-	-	0	-	-
Landscape and Cultural history						
Physical degradation of landscape characteristics/values	0	0	0	-	-	0
Experiential value	0	-	- -	0	- -	-

4.4.3 Negative impact and differentiating impact between variants – Operational phase

Negative impact

Non-differentiating negative impacts apply to any of the assessment criteria during the operational phase.

Differentiating impact between variants

Table 6 gives an overview of the assessment criteria and assessments, when there are differentiating impacts between the variants. Section 5 discusses the conclusions which can or must be drawn, in more detail.

Table 6 Assessment criteria with differentiating impacts between the variants in the operational phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Nuclear safety						
Radiological requirements for postulated incidents	+	+	+	0	0	0
Admissible risk as a result of incidents	+	+	+	0	0	0
Soil and Water						
Groundwater						
Groundwater extraction or infiltration systems	-	-	0	0	0	n/a
Cooling water extraction and discharge						
Cooling water extraction	n/a	n/a	n/a	0	++	++
Water safety						
Water safety	0	+	+	0	0	n/a
Noise						
Noise hindrance for local residents due to installation	0	0	0	0	0	- -
Noise hindrance for local residents due to construction activities	0	0	0	0	0	- -
Nature (following mandatory measures)						
Natura 2000 area	0	0	0	-	-	0
Recreation and Tourism						
Influencing of recreational usage possibilities	0	0	0	0	-	-
Influencing of recreational experiential value	0	-	- -	0	- -	-
Identity	0	-	-	0	-	-
Landscape and Cultural history						
Physical degradation of landscape characteristics/values	0	0	0	-	-	0
Experiential value	0	-	- -	0	- -	-

5 Conclusions for environmental assessment

This section is the central section of the SEA. Paragraph 5.1 briefly explains which variants have been assessed for the nuclear PALLAS-reactor and the cooling system. This is followed by a synthesis of the environmental assessments conducted. These environmental assessments are described in more detail in part B of this MER. Three questions serve as the starting point for this synthesis:

- Can the authoritative body take a positive decision regarding the proposed zoning plan revision, on the basis of the results of the environmental assessment (paragraph 5.2)?
- What mitigating measures can or must PALLAS take (paragraph 5.3)?
- To what extent does this SEA invoke extra questions for the EIA (paragraph 5.4)?

5.1 Variants for construction height and cooling system

The following conditions have been considered:

- Variants for the nuclear island height
  - Construction height variant B1: 17.5 m above ground level and 29.5 m below ground level.
  - Construction height variant B2: 24 m above ground level and 16 m below ground level.
  - Construction height variant B3: 40 m above ground level and 0 m below ground level.
- Variants for cooling the reactor
  - Cooling variant K1: Extraction from the Noordhollandsch Kanaal and discharge into the North Sea (freshwater-saltwater variant).
  - Cooling variant K2: Extraction from the North Sea and discharge into the North Sea (saltwater-saltwater variant).
  - Cooling variant K3: Air cooling / hybrid cooling.[12]

The environmental impact is described and explained in more detail in part B of this SEA. For full background information, please refer to the background reports which have been formulated per aspect.

5.2 General assessment: negative, positive and differentiating impact

Paragraph 4.4 gives the main results of the impact assessment. In approximately half of the criteria, the reactor and cooling system have no impact. The focus of paragraph 4.4 lies on those criteria which result in relevant, negative impacts or which differentiate between variants. We shall take a closer look at each project phase in more detail in the following paragraphs.

5.2.1 Construction phase

The construction of the PALLAS-reactor and the cooling system will result in a number of negative impacts. The construction process has a neutral/negligible impact for half of the criteria. There is no positive impact. In a number of cases, there is differentiation between the impact of the different variants, but this is not always the case.
In terms of the zoning plan, it is important that the plan is viable. As far as construction is concerned, the question is whether it can take place, technically speaking, in such a way to sufficiently limit the hinder and whether PALLAS complies with the statutory requirements.
The impact as a result of construction of the installation does not represent an obstacle to the establishment of the zoning plan.
The opposite would only be the case if it was already clear upon establishment of the zoning plan, that realization of the construction work would inevitably result in serious physical damage to third parties.
The construction of the reactor and installation of the cooling facilities can take place within statutory frameworks. Insofar as supplementary obligations must be made for this purpose, this is indicated in the table in paragraph 5.3.

Construction of PALLAS-reactor

The construction of the PALLAS-reactor results in negative impacts in a limited number of aspects, which however can be largely mitigated by means of specific measures. The main impact can be found in the aspects of:

- Nuclear safety
- Noise
- Recreation
- Archeology

The construction activities can entail risks for other nuclear activities and the Research Location Petten, due to subsidence and vibrations, for example. As a mitigating measure therefore, PALLAS has opted for a construction method which considerably limits the risk of vibration hinder and possible subsidence problems. It includes low-vibration installation of slurry walling for the construction pit walls (drilling instead of pile driving). This has therefore also been a principle of the impact assessment. In the following project phase of the Dutch Nuclear Energy Act permit with accessory EIA, PALLAS will give a more detailed description of the way in which nuclear safety remains safeguarded during construction work.
During construction of the PALLAS-reactor, there will be noise hinder for local residents, as well as indirect hinder caused by construction traffic. The concrete plant is the most critical aspect, and can result in the directive values for the evening and night periods being temporarily exceeded. One possibility for reducing the hinder lies in the choice of the LDA. With a view to the large search area for the LDA, there is sufficient space to situate the plant further away from housing. Screening of the concrete plant is also an option. Traffic measures are possible, including a temporary lower speed limit, in order to limit the indirect hinder from construction traffic (2 dB (A) increase in noise level) for local residents. Further detailing will take place in the next phase. The construction of the reactor is therefore not expected to involve any noise hinder which cannot be mitigated.
The construction phase will have various negative impacts on recreational usage possibilities, recreational experiential value and identity. Negative impacts by the construction process can be limited by limiting views of the reactor LDA where possible.
Construction of the reactor may have a negative impact on archeology. There is no alternative location at the Research Location Petten. Further archaeological studies will allow for further detailing, integration and the permits required for that purpose, according to the policy advice by the municipality of Schagen. Archaeological aspects therefore offer no restriction for the zoning plan revision.

Construction of cooling facilities

Construction of the cooling water system for the PALLAS-reactor will have a negative impact on a limited number of

12 A number of other cooling variants have been defined specifically for the noise aspect. This will be worked out in more detail in part B, under Noise.

aspects, which are however local and limited in scope, and can also be largely mitigated by means of specific measures. The main impacts can be found in the nature aspect.
Temporary drainage facilities will be required for installation of the cooling water pipelines (cooling variants K1 and K2). These can have local negative impacts on natural vegetation, agriculture and mobile contaminants. The precise impacts will need to be determined prior to the permits procedure. Within the scope of the drainage plan, the choice can be made for that method which has the least impact or even no impact at all.
Installation of the cooling water pipeline from the Noordhollandsch Kanaal (cooling variant K1) will result in noise hinder to nearby residents. The 24-hour value of 60 dB(A) may be exceeded due to pile driving work for the pump building. The maximum exposure duration of the Dutch 2012 Building Decree is not expected to be exceeded. This can be achieved through a smart location choice or by applying mitigating measures when pile driving.
Installation of the cooling water pipeline K1 from the Noordhollandsch Kanaal may result in light hinder of 30 lux in a holiday park. This is much higher than the norm, and will occur extremely locally.
There are mitigating measures available in order to comply with the norm, such as limitation of lighting, the use of low light masts with directional fittings, and LED lighting. Installing the pipeline itself at least 30 m from the holiday complex is also an option. Such mitigating measures will need to be considered, should PALLAS opt for cooling variant K1. These will be discussed in further procedures for permits.
The construction phase may have a negative impact on nature due to installation of the cooling water pipelines through the dune area and at sea, i.e. in cooling variants K1 and K2. The dune area will be subject to temporary loss of surface area, traffic impact, dehydration and disturbance. Noise will be the main factor of disturbance. There will also be disturbance in the North Sea. The visual disturbance will be the main factor above water, and noise under water. The construction process will also result in nitrogen deposition. The Dutch PAS program for control of nitrogen takes account of damage to nature due to nitrogen. A package of mitigating measures can limit the impact due to installation of the cooling water pipelines (K1 and K2) to such an extent that these exclude significant impacts as defined in the Dutch Nature Protection act.
The construction phase will have a negative impact on recreational usage possibilities, recreational experiential value and identity. For installation of cooling water pipelines K1 and K2, construction activities can be moved outside of the beach season. The impact of the working strip for the K1 cooling water pipeline in the polder landscape can be limited when carefully integrated.
The archaeological information is missing for the cooling variants K1 and K2. This knowledge void will be filled at a later stage. For the time being, it is not relevant to the zoning plan which determines the location of the reactor.

5.2.2 Transition phase

The simultaneous operation of the PALLAS-reactor and the HFR will result in a number of negative impacts. This phase has a neutral/negligible impact for nearly half of the criteria. One positive impact has been determined. There will sometimes be differentiation in the various impacts of the variants. This paragraph does not cover any negative impact occurring in the transition phase but which is purely attributed to the PALLAS-reactor, this is discussed in paragraph 5.2.3. After all, simultaneous or non-simultaneous operation of the HFR is not relevant to this impact.
Taking this into account, the difference between the transition phase and operational phase lies in the impact on Radiation protection, Nuclear safety and Cooling water extraction criteria.
In terms of the zoning plan, it is important that the plan is viable. As far as the transition phase is concerned, the question is whether simultaneous operation of the PALLAS-reactor and HFR can take place, technically speaking, in such a way to sufficiently limit the hinder and to comply with the statutory requirements.
The simultaneous operation of both reactors will result in an increased dose and increased risk, for radiation protection and nuclear safety. However, both reactors comply with the statutory norms of the Dutch Nuclear Energy Act permit, which applies individually to the two installations. In the current situation, further agreements have been reached between the nuclear companies, which has enabled them to comply with the lower limiting value of 0.04 mSv per annum for direct radiation, for the individual companies (see also the NRG Safety report). It seems logical to assume that the PALLAS-reactor will also be able to comply with a comparable limiting value.
Cooling variant K1 doubles the volume of cooling water from the Noordhollandsch Kanaal. This was assessed extremely negatively for the cooling water extraction aspect. However, in case of drought, both the PALLAS-reactor and the HFR can be switched off. Within a few seconds, the required cooling capacity can be reduced to 10% and even further if necessary.
The simultaneous operation of the PALLAS-reactor and the HFR for a certain period of time does not represent an obstacle to the establishment of the zoning plan.
After all, such simultaneous operation can take place within statutory frameworks. Insofar as supplementary obligations must be made for this purpose, this is indicated in the table in paragraph 5.3.

5.2.3 Operational phase

The operation of the PALLAS-reactor and the cooling system instead of the HFR will result in a limited number of negative impacts. There are also a number of positive impacts however. For most of the criteria, operation of the PALLAS-reactor instead of the HFR will have a neutral/negligible influence. There is differentiation in the impacts of the variants for a number of specific criteria.
In terms of the zoning plan, it is important that the plan is viable. As far as operation is concerned, the question is whether it can take place, technically speaking, in such a way to sufficiently limit the hinder and whether PALLAS complies with the statutory requirements.
Operation does not represent an obstacle to the establishment of the zoning plan.

After all, exploitation of the PALLAS-reactor including cooling facilities can take place within the statutory frameworks. Insofar as supplementary obligations must be made for this purpose, this is indicated in the table in paragraph 5.3.

Operational PALLAS-reactor

Due to improved technology and the PALLAS-reactor being subject to stricter requirements than the existing HFR, the reactor has been positively assessed for nuclear safety.
A disadvantage of the B1 and B2 construction variants is that they result in various negative impacts relating to the groundwater. The scope of all the impacts is extremely limited. There are no statutory restrictions, such as the Dutch Nature Protection Act.
The higher construction variants (B2 and B3) are positive for water safety due to the positive sand balance. They were however negatively assessed for the experiential value and identity. This negative impact can be mitigated through careful design of the color, shape and image quality, but this cannot prevent the visibility of the mass.

Cooling the PALLAS-reactor

Each of the cooling variants has its advantages and disadvantages, and all options are still open following this SEA. The cooling method is not arranged via the zoning plan, for which this SEA has been formulated.
The freshwater supply is an important issue when it comes to cooling water extraction. Due to the freshwater supply being under pressure, particularly due to climate change, ceasing extraction from the Noordhollandsch Kanaal would be a positive factor. This is the case for K2 (extraction from the North Sea) and K3 (air cooling). While the extraction of cooling water by cooling variant K1 is indeed comparable to the current HFR extraction from the Noordhollandsch Kanaal, it is less desirable from a freshwater management point of view.
One problem of air cooling (K3) is that it results in noise hinder exceeding the 24-hour value of 50 dB(A) in housing. This noise hinder can be partially limited by applying technical measures.
Suction of fish and thermal pollution in habitat H1110B (permanently flooded sandbanks in the North Sea coastal zone), are disadvantages of cooling variants K1 and K2.
The pipelines for cooling variants K1 and K2 will degrade the seabed structure. The platform for cooling water extraction for K2 is negative for the experiential value and K3 is negative for the experiential value due to formation of condensation in the winter. The scope and impact on the landscape characteristics/values remain limited however.

5.3 Mitigating measures

5.3.1 Overview of mitigating measures

Following the impact assessment, mitigating measures were sought in order to render a number of negative impacts less negative or even neutral.

Radiation protection and nuclear safety

The PALLAS-reactor is fitted with various safety provisions in order that the reactor complies with dosage limits and risk criteria for incidents, as defined in the assessment framework with regard to radiation protection and nuclear safety, whereby the ALARA principle must always be applied. No additional mitigating measures are therefore required within the scope of the zoning plan.

Groundwater

The precise impacts of the trench drainage on the phreatic water table in the dune area have yet to be determined. This will be done in combination with the drainage plan, once the route, depth, duration and construction technique are known. The impact on the phreatic water table can be largely or wholly prevented by excavating the trench within sheet piling, down to the poorly permeable Holocene deposits.

Cooling water extraction and discharge

In the event of drought, the cooling capacity of PALLAS and the HFR can be reduced to 10% of the maximum within a number of seconds, after which the cooling capacity can be gradually further downscaled if necessary. This will also guarantee that there is sufficient cooling water from the Noordhollandsch Kanaal during the transition phase. Switching off in this manner will however affect production capacity.

Noise

The following mitigating measures are possible for the various noise sources:

- Cooling variant K3: The deployment of quieter cooling units, a different type of cooling with a lower noise emission, the installation of dampers and/or realization of a protective screen between the cooling units and the nearest housing. Deployment of these measures will reduce the noise in variant K3 by at least 7 dB(A) for the nearest housing. This means that the total source capacity of the cooling units to be deployed may not exceed 105 dB(A). However, a screening wall will probably not be a realistic option when deploying cooling units with a larger source height, as currently envisaged for variant K3.
- Concrete plant: The concrete plant can be screened off from the nearest housing, while the location and (evening and nighttime) working hours of the concrete plant can also be taken into account. The impact will be limited if the concrete plant is located sufficiently far away from the nearest housing.
- Pile driving work: Mitigating measures include the use of a pile driving shield, the drilling of piles (instead of driving) or the projection of the concrete plant and public buildings at a relatively large distance from the housing. This will probably allow compliance with the maximum exposure duration of the Dutch 2012 Building Decree.

Application of the aforementioned measures can limit the impact of the construction phase and cooling variant K3 to 'negative' (instead of extremely negative) and the impact can be sufficiently reduced to comply with the statutory limiting values.

Light
Negative impacts can be prevented by applying 30 m as the minimum distance from the light source to the housing, in realization of the LDA and construction of the cooling water pipelines.
The following measures can be taken to further reduce the light hinder in the surrounding area:

- The light masts must not be too high.
- The radiation direction of the fittings must be positioned as far away as possible from the housing and nature area
- The use of LED lighting is a possibility, as LED lighting is spot lighting with less radiation to the surrounding area.
- Lighting should be omitted wherever possible.

It is simple enough to find a location for the LDA and cooling water pipelines within the search area, thus preventing any light impact. The light impact following the mitigating measures has therefore been assessed as 'neutral' (instead of (extremely) negative).

Nature
The mitigating measures result in the following areas of attention for the design and realization of construction work:

- In order to avoid the resultant mixing zone reaching the North Sea seabed, there must be attention for the design and depth of the cooling water outlet in the North Sea for the various variants (variants K1 and K2).
- Design and location of the water extraction point in the Noordhollandsch Kanaal, including facilities for limitation of fish intake (variant K1).
- Design, location and construction method of North Sea water extraction point (variant K2).
- Routing of the cooling water pipelines (variants K1 and K2) in the dune area in relation to the prevention of the impact on protected habitats and species.
- Prevention of dehydration impact upon construction of the cooling water pipelines, by deploying alternative realization methods or installation of sheet piling.
- Route structure for work in the dunes.

Following mitigation, the transition and operation of PALLAS will not have significant negative consequences for the NNN, The impact assessment has therefore been adjusted to neutral for all variants during all phases (instead of slightly negative).

Landscape and cultural history
There are various options for integration of the LDA, such as basing it on existing plot structures, shielding it with greenery, limiting the light emission and ensuring storage facilities and constructions are low level.
The negative visual image of the nuclear island can be reduced through its architectonic design, color scheme, etc. There are also possibilities to make the nuclear island less visible in its surroundings, by raising the dunes around it. However, this would require careful gearing with the ecological values and would need to be done in close cooperation with Staatsbosbeheer, which is responsible for management of the nature reserves.
In terms of the cooling variants, attention must be paid to integration of the pumping station (or preferably a gravity flow water supply, as this only requires an inlet) for cooling variant K1, and integration of the inlet platform for cooling variant K2. If the cooling water pipelines are aligned with existing pipeline routes, it would be sensible to follow the existing topography, resulting in disturbance of the geological values.

Traffic
The Zeeweg is not a suitable route for construction traffic (heavy goods vehicles). The proposal is therefore to forbid the use of this road for construction traffic. It is proposed that construction traffic be diverted via the N9 and the N502 (via Petten). The N503 and N502 can be used when approaching from the north. The N502 would already be the most logical choice when coming from Alkmaar via the N9. Finally, the goods transfer facility can be moved in order to minimize the diverted driving distance for heavy goods vehicles.

5.3.2 Method of legal safeguarding of mitigating measures

Part B and the SEA Appendices describe the mitigating measures. The zoning plan to be established must sufficiently safeguard those mitigating measures required in order to comply with statutory norms. This can be done either by including a conditional obligation, or by indicating that this must be regulated in the permits process. A summary of this is given in Table 7.

Table 7 Overview of mitigating measures and means of legal safeguarding

Aspect and cause	Mitigating measure(s)	Legal safeguarding
Construction phase		
Nuclear safety – Vibration and subsidence problems due to construction of reactor	Specific low-vibration construction method	Yes, for the prevention of serious physical damage; inclusion of conditional obligation in zoning plan regulations
Noise due to construction of reactor	• Situation of LDA and concrete plant further away from housing • Screening off concrete plant • Lower speed limits for construction traffic	
Water table changes upon construction under ground level	Installation of a drain to mitigate this effect.	Yes, via the permits process

Aspect and cause	Mitigating measure(s)	Legal safeguarding
Damage to recreational usage possibilities, recreational experiential value and identity due to appearance of LDA	LDA to be kept out of sight where possible	Yes, via the permits process
Archeology due to construction of reactor	Continuation of study	Yes, include archeology as an extra value zone in zoning plan regulations, including environmental permit system for installations and work.
Nature due to temporary drainage for construction of cooling water pipelines (variants K1 and K2)	Formulation of drainage plan	Yes, via the permits process
Agriculture due to temporary drainage for construction of cooling water pipelines (variants K1 and K2)	Formulation of drainage plan	Yes, via the permits process
Mobile contaminants due to temporary drainage for construction of cooling water pipelines	Formulation of drainage plan	Yes, via the permits process
Noise due to pile driving work for cooling water pipeline pump building variant K1	• Choice of location • Alternative construction method for pile driving	Yes, via the permits process
Light hinder in holiday park due to construction of cooling water pipelines variant K1 and LDA	• Keep a distance of 30 m from light-sensitive objects. Further reducing measures can also be taken. • Limit incidence of lighting • Low level light masts • Directional fittings • LED lighting	Yes, distance via the permits process Not necessary
Nature due to temporary loss of surface area in dunes for construction of cooling water pipelines (variants K1 and K2)	Package of mitigating measures as included in the Nature Background document	Yes, via the permits process
Nature due to temporary traffic impact in dunes for construction of cooling water pipelines (variants K1 and K2)	Package of mitigating measures as included in the Nature Background document	Yes, via the permits process
Nature due to temporary disruption (mainly noise) in dunes for construction of cooling water pipelines (variants K1 and K2)	Package of mitigating measures as included in the Nature Background document	Yes, via the permits process
Nature due to temporary dehydration impact in dunes for construction of cooling water pipelines	Package of mitigating measures as included in the Nature Background document	Yes, via the permits process
Nature due to temporary visual hinder at sea for construction of cooling water pipelines (variants K1 and K2)	Package of mitigating measures as included in the Nature Background document	Yes, via the permits process
Nature due to temporary noise hinder underwater at sea for construction of cooling water pipelines (variants K1 and K2)	Package of mitigating measures as included in the Nature Background document	Yes, via the permits process
Nature due to temporary nitrogen deposition at cooling water pipelines (variants K1 and K2)	Package of mitigating measures as included in the Nature Background document	Yes, via the permits process
Damage to recreational usage possibilities, recreational experiential value and identity due to cooling water pipelines (variants K1 and K2)	• For K1, the LDA in the polder must be kept out of sight where possible • For K1 and K2, work outside the beach season	Not necessary
Traffic safety on the N502 and Zeeweg roads	Close roads to construction traffic	Yes, traffic order to be made
Transition phase		
Radiation protection and nuclear safety due to simultaneous operation of the PALLAS-reactor and HFR	Compliance with lower limiting value as a result of mutual agreements	Not necessary

Aspect and cause	Mitigating measure(s)	Legal safeguarding
Doubling of cooling water extraction from the Noordhollandsch Kanaal due to simultaneous operation of the PALLAS-reactor and HFR for cooling water pipeline variant K1	Switch off reactors	Yes, via the permits process
Operational phase		
Experiential value and identity due to the higher construction variants B2 and B3	Soften color, design and image quality	Not necessary
Noise due to air cooling variant K3	Package of mitigating measures as included in the Nature Background document	Yes, traffic order to be made
Nature due to suction of fish and thermal pollution in cooling variants K1 and K2	Technical measures, such as: • Deployment of quieter cooling units • A different type of cooling system with a lower noise emission • Noise dampers • Protective measures	Yes, via the permits process
Seabed structure in cooling variants K1 and K2	• Design and location of the water extraction point in the Noordhollandsch Kanaal, including facilities for limitation of fish intake (variant K1) • Design, location and construction method of North Sea water extraction point (variant K2)	Yes, via the permits process
Seabed structure in cooling variants K1 and K2	In order to avoid the resultant mixing zone reaching the North Sea seabed, there must be attention for the design and depth of the cooling water outlet in the North Sea (variants K1 and K2).	Yes, via the permits process
Experiential value due to the platform for cooling water extraction in cooling variant K2	None	Yes, via the permits process
Experiential value due to condensation formation in the winter in cooling variant K3	None	Yes, via the permits process
Radiation protection and nuclear safety due to the PALLAS-reactor	• Safety provisions • Apply ALARA principle	Yes, via the permits process
Phreatic water table in dune area due to trench draining	• Formulation of drainage plan • By excavating the trench within sheet piling, down to the poorly permeable Holocene deposits	Yes, via the permits process
Landscape/cultural history due to dominance of pipelines	Cooling pipeline routes in the polder must be parallel to existing structures where possible	Not necessary

5.4 Recommendations and points of attention for the EIA

As indicated in paragraph 1.2.4, an EIA will be formulated for the Nuclear Energy Act permit, following on from this SEA for the zoning plan. The contextual assessments have now been conducted (and are summarized in the previous paragraph 5.2). This provides greater clarity on those issues which require further attention in the EIA. Paragraph 1.2.5 (specifically, Table 1) describes the EIA location-specific research.
In addition to paragraph 1.2.4 and in line with Table 1, the following specific issues have become apparent which are relevant to the EIA:

- The assessment of Radiation protection and Nuclear safety, and compliance with the criteria can only take place quantitatively once the design of the PALLAS-reactor and accessory analyses are complete. These will become available at a later phase of the project. The quantitative assessment will be a component of the EIA to be formulated at that point.
- The Water Authority for Northern Holland (HHNK), the Authority on Nuclear Safety and Radiation Protection (ANVS) and the Noord-Holland Noord Safety Region (VRNHN) have requested attention for climate change, which will affect the freshwater supply in the future. In the event of sporadic scarcity, the freshwater supply of the HFR currently has 3rd priority, following the drinking water supply and polder water level maintenance. The scenario of a possible decrease in the freshwater buffer in relation to the PALLAS extraction in the future has not been explicitly considered in this SEA, but does deserve attention in the EIA. There should also be consultation with the Water Authority for

this purpose, before making any further choices regarding the form of cooling.

- The calculated mixing zone of the cooling water discharge remains under the critical level, and therefore does not require a model study within the scope of the Dutch Water Act. The mixing zone must not come in contact with the seabed, due to possible impact on seabed life. This exit point has not yet been detailed in the design. The discharge point will require further detailing in due time, for the purpose of the EIA and the permits.
- There is not expected to be a significant impact on nature, within the scope of the Dutch Nature Protection Act. However, a Nature Protection permit will be required, and an appropriate assessment will therefore be made at a later stage. All the possible consequences will then be reviewed in terms of maintenance targets. In the assessment in this SEA, the cooling system in variants K1 and K2 is particularly an issue, especially considering the thermal impact on the North Sea and the hydrological impact upon construction of the pipelines in the dunes.
- The EIA will require further detailing for the K3 air cooling variant, regarding the conditions and duration of condensation formation based on various weather conditions (temperature, humidity, wind, light/dark, et cetera)
- Further archaeological studies will be required for construction of the B1, B2 and B3 construction height variants, in terms of the further detailing, integration and the permits required for that purpose (according to the archeology policy of the municipality of Schagen [19]). If opting for the K1 and K2 cooling variants, further studies will be required should the surface area under assessment be exceeded (according to the policy advice by the municipality of Schagen) in the form of an archaeological desk study to begin with. This will determine whether further research is required.
- The fault line must be more effectively mapped out in order to determine or exclude any possible impact of this fault line on the proposed construction location. To this end, an initial study has been undertaken, using the monitoring data gathered in the past for the purpose of oil and gas extraction. This data shows a fault resolution in the upper layers of the soil surface, therefore requiring supplementary field research.
- Since the Dutch safety requirements are updated, a study into the methodology regarding determination of aviation incidents is required. Besides the impact of such a crash, there will also be attention for resultant fire and explosions.
- Following on from the determination of the risk contour of the transport of munition (when considering the location of the Ministry of Defense firing range close to Research Location Petten), further investigation is required into the firing practice process on the site.

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Part B

6 Further explanation of part B

Sections 4 and 5 of part A summarize and compare the environmental impact of the variants.
This part B of the SEA provides further explanation and detailing of the underlying analyses and impact assessments. Part B has been formulated on the basis of the background reports, which were drawn up per aspect. They have been included as appendices to the SEA.
As an overview, a brief description of the common principles for all impact assessments is given hereafter.

6.1 Reference situation

Construction variants for the height of the nuclear island and for the cooling system have been assessed in comparison with the reference situation. The reference situation is the current situation plus the autonomous development. The time horizon is set at ten years after the zoning plan becomes irrevocable. Autonomous development means the future development of the plan and study area, if the PALLAS-reactor were not to be realized. This takes account of two types of developments:

1. Autonomous developments resulting from changes caused by economic developments and by climate change.
2. Established plans and projects which influence the plan or study area, in which there are intervention-impact relationships for the relevant environmental themes.

Each section of this Part B of the SEA features a paragraph entitled 'Current situation and autonomous development', which describes the current situation and any relevant autonomous developments in the impact assessment of a particular environmental aspect.

One important development is uncertain within the autonomous developments, namely the planning of the closure of the current HFR. The most realistic scenario is that it is decommissioned once the PALLAS-reactor is fully operational. This is necessary in order to guarantee the supply certainty of isotopes. This study assumes that the HFR and the PALLAS-reactor will be simultaneously operational until the isotope production has been entirely transferred.

Should the HFR be decommissioned before the PALLAS-reactor is operational, this would result in an exceptional (and undesirable) situation. In order to visualize the impact which would then occur due to realization of the PALLAS-reactor and cooling facilities, a special analysis has been made of impact with regard to a second type of reference. This is defined in a sensitivity analysis at the end of part B, in section 18.6.

6.2 Project phases

The PALLAS project has three phases (see Figure 1). An explanation is given under the figure, of how these phases are included in the SEA, and particularly the relationship of the HFR and the PALLAS-reactor during those project phases.

Construction phase

The PALLAS-reactor is to be built during the construction phase. There will be a temporary building site. The HFR is still in operation.

Transition phase

Both the HFR and the PALLAS-reactor will be operational during the transition phase. In this transition phase, it is assumed that both reactors will be fully operational. This provides insight into the cumulative impact of simultaneous operation of the HFR and the PALLAS-reactor.

The impact of the transition phase does not differ from the impact of the operational phase for all environmental aspects. The transition phase will therefore only be separately described for those aspects which differ from the operational phase. This concerns the following aspects:

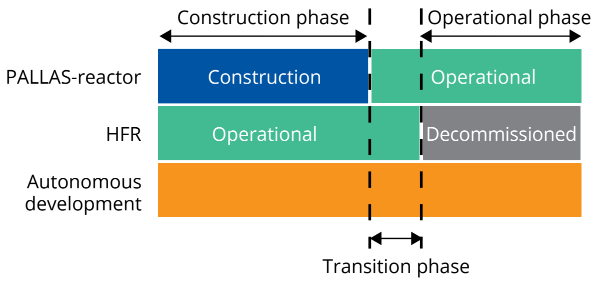

Figure 1 Schematic representation of project phases

- Radiation protection and nuclear safety
- Cooling water.
- Water quality.
- Nature.

Operational phase

In the operational phase, the PALLAS-reactor will be operational and the HFR no longer operational.

6.3 Variants

Construction variants for the nuclear island

There are three variants for the construction height of the nuclear island: B1, B2 and B3, see Figure 2.

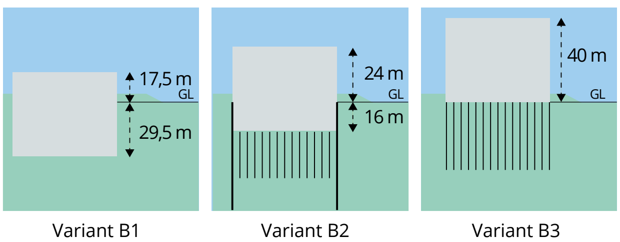

Figure 2 Construction variants for the nuclear island

Cooling water variants
There are three variants for cooling of the nuclear island: K1, K2 and K3, see Figure 3. There are three extra variants for cooling, specifically for the noise aspect. An explanation of these cooling variants is given in section 6, noise.

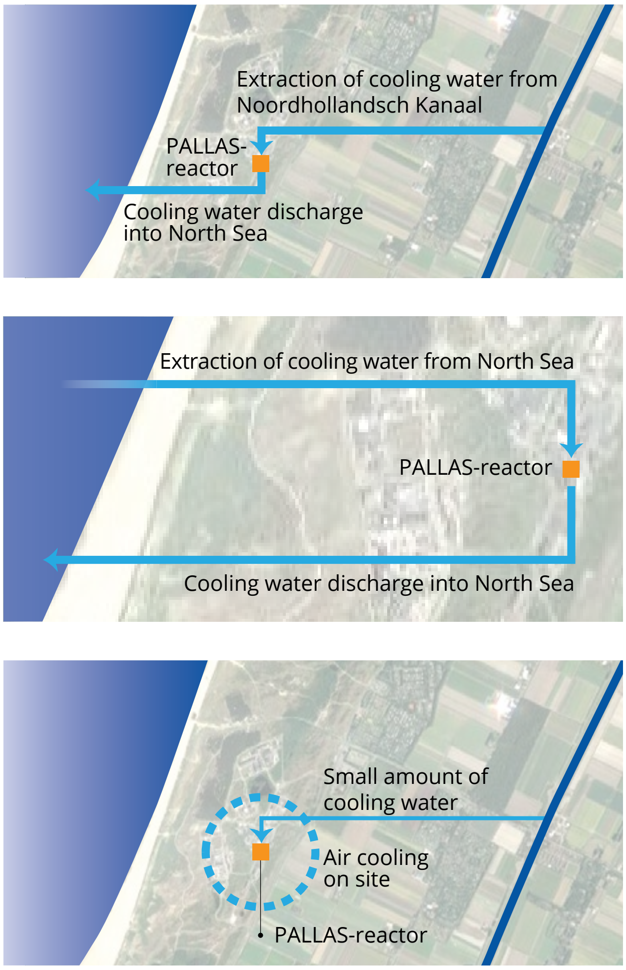

Figure 3 Schematic representation of cooling variants K1 (top), K2 (center) and K3 (bottom)

6.4 Considered aspects and reading guide

This part B assesses the variants in terms of the following aspects:
- Radiation protection & Nuclear safety (Section 7).
- Soil and Water (Section 8).
- Water safety (Section 9).
- Air quality (Section 10).
- Noise (Section 11).
- Light (Section 12).
- Nature (Section 13).
- Recreation and Tourism (Section 14).
- Landscape and Cultural history (Section 15).
- Archaeology (Section 16).
- Traffic (Section 17).

The following is discussed per (environmental) aspect:
- The relevant policy, legislation and regulations.
- The assessment criteria and method, applied in the impact assessment.
- The description of the reference situation.
- The impact of the integral development.
- Mitigating and compensatory measures.
- Knowledge voids and the initial design of an evaluation program.

To provide an overview of the impacts, a table is included giving the scores for each set of criteria. The impact assessments result in scores, which indicate whether an impact is extremely positive (+ +), positive (+), (zero), negative (-) or extremely negative (- -).
The sensitivity analysis (second reference with HFR decommissioned before the PALLAS-reactor becomes operational) is discussed in section 18.

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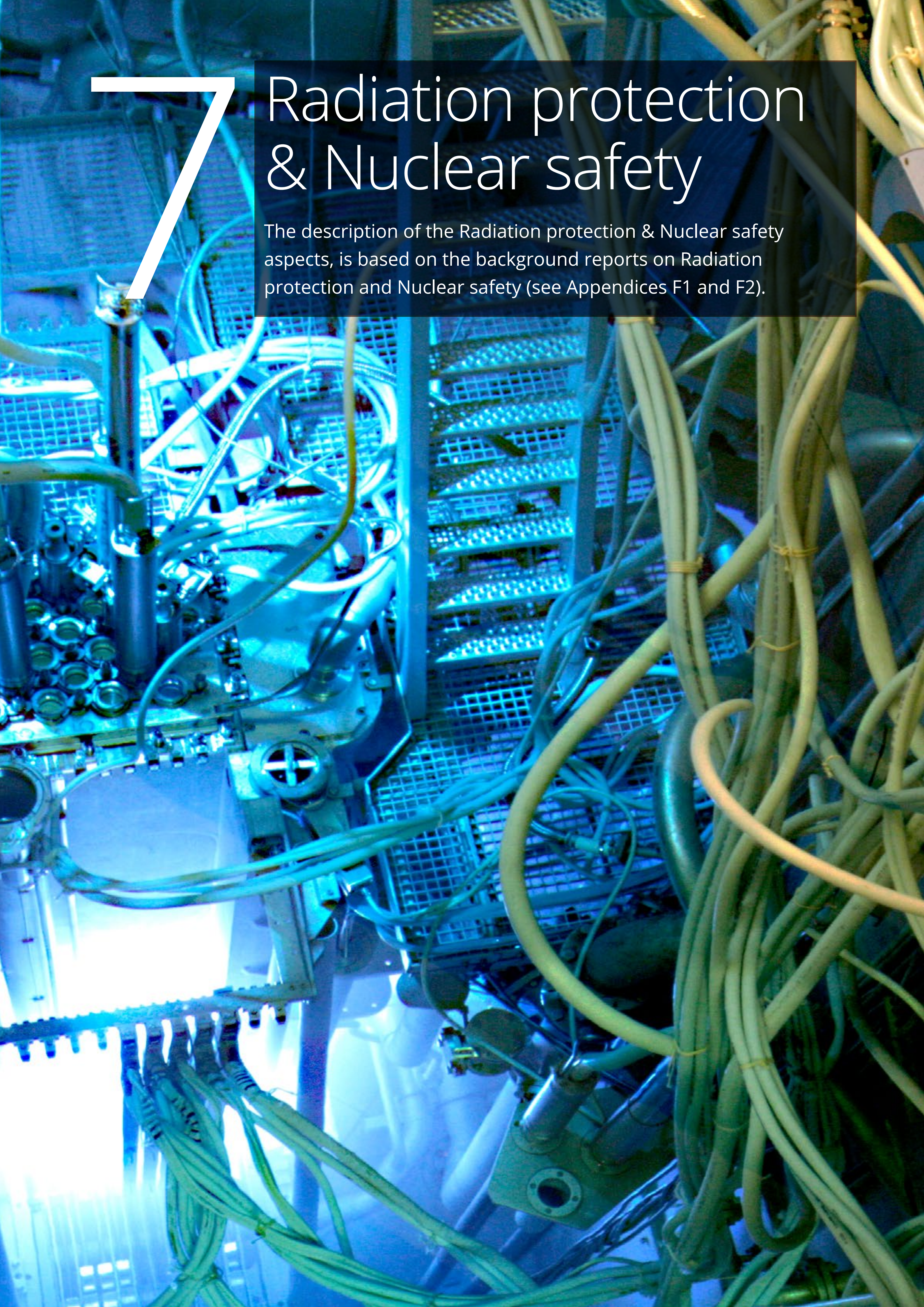

7 Radiation protection & Nuclear safety

The description of the Radiation protection & Nuclear safety aspects, is based on the background reports on Radiation protection and Nuclear safety (see Appendices F1 and F2).

7.1 Assessment framework

7.1.1 Policy framework

Table 1 gives the relevant policy and relevant legislation and regulations for the Radiation protection and Nuclear safety aspects, along with an indication of their relevance for the project. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Radiation protection and Nuclear safety.
The policy framework described above is described in more detail for the PALLAS-reactor hereafter.

Safety objective and safety functions

Nuclear reactors must be safely operated, and so too must the PALLAS-reactor. In other words, people and the environment will be sufficiently protected against the harmful influence of ionizing radiation throughout the life cycle of a nuclear reactor. The life cycle concerns its design, construction, commissioning, operation and eventually decommissioning and dismantling. In order to meet the objective, the nuclear reactor must essentially comply with the three following safety functions:

1. Control of the reactivity.
2. Cooling the fissile material.
3. Confinement of the radioactive or fissile materials.

These three safety functions apply to all phases of the life cycle of a nuclear reactor. The Defense-in-Depth safety concept gives a general description of how this is achieved. In order to guarantee the safety functions, a nuclear reactor, and therefore the PALLAS-reactor must take measures:

- To control the exposure of people to ionizing radiation and to prevent radioactive substances or (irradiated) fissile material being emitted to the atmosphere.
- To limit the probability of incidents which may result in loss of control of the core in the nuclear reactor, of the nuclear chain reaction, of radioactive sources or other sources of ionizing radiation.
- To mitigate the consequences of such incidents, should they occur.

The Defense-in-Depth safety concept

The nuclear safety of nuclear reactors is based on the concept of layers of safety, (known as 'Defense-in-Depth'). The intention of this safety concept is to prevent incidents or to limit their consequences. The concept is a combination of constructional, technical and organizational provisions. Multiple strategies are applied to guarantee the safety of the PALLAS-reactor under abnormal circumstances and incident conditions. This is achieved through several different levels of protective measures, each with its own strategy. The purpose of each strategy is to deploy the available means to prevent all possible forms of both human failure and equipment failure (prevention) or the most effective limitation of the radiological consequences of that failure (control, mitigation)
The following safety levels with related operational circumstances can be distinguished (see Table 2):

- Safety level 1: normal operation.
- Safety level 2: foreseeable operating issues/ deviating operation.
- Safety level 3a: postulated early incidents with single failure.
- Safety level 3b: postulated early incidents with multiple failure.
- Safety level 4: postulated nuclear meltdown incidents.
- Safety level 5: emission of significant volumes of radioactive substances.

Safety level 3 has two levels, subdivided into a and b, because both levels must comply with the same radiological objectives. Under normal operating conditions, the installation is at safety level 1. At this level, the focus is on prevention of malfunctions in daily operation. The following levels concern foreseen operating issues and also deviating operation (safety level 2), incidents without nuclear meltdown (safety level 3) and incidents with nuclear meltdown (safety level 4). Despite these measures, should there be significant emissions of radioactive substances into the environment, measures will be taken with a view to limiting consequences for people, animals, plants and objects (safety level 5).

Table 1 Policy, legislation and regulations on Radiation protection and Nuclear safety

Policy plan, law, regulation	Description/ Relevance for PALLAS
Nuclear Energy Act	The Dutch Nuclear Energy Act (Kernenergiewet (Kew), geldend op 01-06-2016) is a framework law concerning activities which use ionizing radiation or in which such radiation is emitted. The purpose of this law is to promote good development with regard to the release and use of radioactive substances and of equipment which emits ionizing radiation, and protection against risks linked to the use of radioactive substances and ionizing radiation. This law has been further detailed in the Dutch Nuclear Installations, Fissile Materials and Ores Decree (Dutch National Gazette 1969-403) and the Dutch Radiation Protection Decree (Dutch National Gazette 2001-397) and the accessory regulations. The PALLAS-reactor requires a permit according to the Dutch Nuclear Energy Act.
Dutch Guidelines for the Safe Design and safe Operation of Nuclear reactors	The Dutch Guidelines for the Safe Design and safe Operation of Nuclear reactors (ANVS, October 2015) provide insight into the current level of technology for design and operation of (new) reactors, the purpose being to render the nuclear reactors as safe as possible. The specific preconditions of this Guide are in keeping with the latest insight of in particular the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators Association (WENRA). There are also specific safety requirements for each type of installation These specific safety requirements are given per installation in the Dutch Nuclear Energy Act permit. A Guide theoretically has no legal status and is therefore not legally binding. Due to the Guide being intended for new reactors, and being based on the latest level of technology and science, it will be applied by the Authoritative Body as part of the PALLAS assessment framework.

Table 2 The Defense-in-Depth safety concept

Levels of safety layers	Accessory operating circumstances	Objective	Essential means	Radiological consequences
Safety level 1	Normal operation	Prevention of deviating operation and failure	Conservative design and quality construction and operation, control of main parameters of the installation within defined limits	Within the prescribed operating limits for emissions
Safety level 2	Foreseeable operating issues	Control of deviating operation and failure	Control and limitation systems, and provisions for monitoring	
Safety level 3	Safety level 3a Postulated early incidents with single failure	Control of incidents in order to limit emission of radioactivity and avoid escalation to circumstances which may result in nuclear meltdown	Safety systems, incident procedures	No radiological consequences or only minor radiological consequences outside the site
	Safety level 3b Postulated early incidents with multiple failure		Additional structures, systems and components, and incident procedures	
Safety level 4	Postulated nuclear meltdown incidents	Control of incidents involving nuclear meltdown in order to limit dispersion of radioactivity outside the site.	Complementary structures, systems and components, and incident procedures	Limited protective measures required (area and time)
Safety level 5	Emission of significant volumes of radioactive substances	Limitation of radiological consequences	Emergency measures outside the site Intervention levels	Radiological consequences outside the site, for which protective measures are required.

The Defense-in-Depth concept also includes incidents with multiple failure and nuclear meltdown incidents. This means that the design of a nuclear reactor must be able to withstand postulated incidents with multiple failure and to withstand certain postulated nuclear meltdown incidents, in order to limit the radiological consequences for the surrounding area. In the past, incidents concerning multiple failure and nuclear meltdown incidents were considered to be non-design-based, so that the design particularly accounted for incidents with singular failure. In the new concept (in accordance with the Dutch guidelines for the Safe Design and Operation of Nuclear Reactors) therefore, extra incidents are considered possible within the design of new reactors.
The following types of incidents are taken into account:

- Failure of an internal system, such as a leakage of a cooling system or interruption of the power supply.
- Internal hazards, such as fire.
- External hazards, such as flooding (taking account of climate change), an earthquake or an aircraft crashing into the installation.

Barrier concept

The barrier concept is part of the Defense-in-Depth concept. The aim of the barrier concept is to confine radioactive substances and (irradiated) fissile material in the installation. This concept is based on the presence of multiple successive physical barriers and retention functions. Upon functional failure of one barrier, the following barrier guarantees confinement.

The number of barriers and their form is determined by the type of nuclear reactor, its configuration and its capacity, among other factors. A barrier is taken to understand the cladding of the fuel elements and their containment (confinement normally achieved by the nuclear island). Retention functions are measures or provisions taken to retain radioactive materials. This can be achieved by filtering air, for example, or keeping radioactive material under water, limiting the (air) flow by means of underpressure, building seals, containers, etc.
For the sake of safety, it is important that the barriers function independently of each other. This means that in case of a hazard or an incident, a barrier may not fail just because another barrier failed. If one or more barriers fail anyway, releasing radioactive substances, then the retention functions must ensure the retention or temporary containment of those substances.

Internal and external hazards

A hazard is defined as an incident that could occur inside or outside the facility that has a potential or certain negative impact on reactor safety. Internal hazards are within the facility, while external hazards come from outside the facility. One example of an internal hazard is a fire within the facility. External hazards are either natural or caused by humans, such as lightening, earthquake or risks originating from a nearby industrial park.

7.1.2 Assessment framework and methodology

Table 3 shows the assessment criteria for Radiation protection and Nuclear safety. An explanation of each criterion is then given.

Study area

The study area for radiation exposure relates to the normal operating situation and is determined by the significant locations where the radiation exposure is the greatest. In the case of direct radiation, this is generally at the immediate border of the installation. In the case of radioactive emissions to air and water, this depends strongly on the dispersal, as a result of climatic influences, for example. Models which calculate radiation exposure as the result of emissions generally assume a 25 km radius around a reactor.

The study area for Nuclear Safety relates to incident situations and is determined by the locations with the greatest radiation exposure as the result of incidents. In the case of direct radiation, this is generally at the immediate border of the installation. In the case of radioactive emissions to air and water, this depends strongly on the dispersal, as a result of climatic influences, for example. Models which calculate radiation exposure as the result of emissions generally assume a 25 km radius around a reactor.

Table 3 Assessment framework for Radiation protection and Nuclear safety

Aspect	Assessment criteria
Radiation protection	Effective dose as the result of • Direct radiation • Radioactive emissions to air • Radioactive emissions to water • Radioactive waste
Nuclear safety	Radiological requirements for postulated incidents: • Effective dose for local residents Admissible risk as a result of incidents: • Individual risk • Group risk

Assessment framework

Emissions of radioactive material into the soil are not assessed here. They are prohibited according to the statutory guidelines, and must be prevented by means of technical provisions. The underground sections of the buildings and any underground pipelines, which may contain radioactive and/or hazardous substances, will need to be constructed in such a manner that controlled leakage cannot occur. This means that continuous monitoring takes place, in order to take immediate action in the case of leakage, in order to prevent its further dispersal.

The design for the PALLAS-reactor is not yet available, so that reference incidents cannot yet be determined, nor their quantitative consequences. The HFR can be considered to be a comparable object. The HFR has a comparable reactor capacity (45 MWth nominal and 50 MWth authorized, versus maximum 55 MWth for PALLAS). The technology applied at PALLAS may be assumed to be more advanced than that of the HFR.

Direct radiation and radioactive emissions to air and water

Radiation exposure due to direct radiation and radioactive emissions to air and water are subject to combined criteria, as described hereafter. A distinction is made between criteria for the general public and for employees of nuclear installations who are exposed and not exposed, respectively.

Article 18 of the Dutch Nuclear Installations, Fissile Materials and Ores Decree defines a number of grounds for refusal of a permit application, according to article 15, sub b of the Dutch Nuclear Energy Act. The grounds for refusal in article 18, first paragraph of the Dutch Nuclear Installations, Fissile Materials and Ores Decree concerns conditions regarding justification and optimization, applicable in combination with articles 4, 5 and 6 of the Dutch Radiation Protection Decree, and related dose limits, applicable in combination with article 48 of the Dutch Radiation Protection Decree.

An overview of the dose limits for the general public and (exposed) employees is given in Table 4.

The Dutch Guide for the Safe Design and Operation of Nuclear Reactors refers to the Dutch Radiation Protection Decree for the dose limits, which states that:

Table 4 Overview of the dose limits for the general public and (exposed) employees

Radiation protection under normal operation	Aspect	Dose limit (per calender year)
Population	• Direct radiation • Radioactive emissions to air • Radioactive emissions to water	Together: < 0.1 mSv[1] per source (outside site[2]) < 1 mSv (inside site)
Non-exposed employees	• Direct radiation • Radioactive emissions to air • Radioactive emissions to water	Together: < 1 mSv
Exposed employees	• Direct radiation • Radioactive emissions to air • Radioactive emissions to water	Together: < 20 mSv
	• Radioactive waste	ALARA

1 The sievert (symbol Sv) is the SI unit for the equivalent dose of ionizing radiation to which a person is exposed during a certain period of time, and is equal to 1 J/kg. The sievert depends on the biological impact of radiation. The millisievert (mSv) is a one thousandth part of a sievert.
2 The location or installation concerns the site to which the permit applies, and will usually be enclosed by a fence or building limitation.

- Radiation exposure or contamination of local residents and the surrounding area as a result of direct radiation and emission of radioactive materials must be kept as low as reasonably achievable (ALARA: As Low As Reasonably Achievable).
- Each authorized emission of radioactive materials to the air or water must be controlled, with monitoring and registration of the type and activity of the emission.

Radioactive waste
The Dutch Guide for the Safe Design and Operation of Nuclear Reactors refers to the Dutch Radiation Protection Decree for the dosage limits, whereby the volume and radioactive content of radioactive waste must be kept as low as reasonably achievable (ALARA).

Radiological requirements for postulated incidents
Article 18 of the Dutch Nuclear Installations, Fissile Materials and Ores Decree defines a number of compulsory and possible grounds for refusal of a permit application, according to article 15, sub b of the Dutch Nuclear Energy Act. The grounds for refusal in article 18, second paragraph, sub a, of the Dutch Nuclear Installations, Fissile Materials and Ores Decree concerns the limiting values for postulated preliminary incidents. These are incidents taken into account in design of the installation. In keeping with the risk policy, a dosage limit has been formulated per risk area, for these postulated and radiologically relevant preliminary incidents. This concerns emissions during normal operation, foreseeable operating issues and design-based incidents.
New nuclear reactors are subject to guidelines with more stringent preconditions, which are not directly applicable to existing reactors, in accordance with the Dutch Guide for the Safe Design and Operation of Nuclear Reactors.

Safety levels 1 and 2 dosage limits
The principle of the Dutch Radiation Protection Decree is that exposure to radiation as the result of operations must be kept as low as reasonably achievable[3]. The dosage limits for the general public and employees during normal operations and foreseen operating issues (up to an incident frequency of 10-2 per annum, see Table 5) are identical (in accordance with Table 2)[4]. Please refer to the background report on Radiation protection for further information on radiation protection during normal operation.

Safety level 3 dosage limits
There must be a guarantee that incidents without nuclear meltdown will have little or no radiological consequences for the surrounding area. This means that there must be no need for protective measures such as the issuing of iodide prophylaxes, shelter or evacuation. The lowest intervention limit hereby applies to the shelter protection measure (see Table 6). The risk analyses must therefore prove that the radiological consequences of an incident without nuclear meltdown will remain under the set intervention limits.
Dosage limits are linked to the frequency with which incidents without nuclear meltdown may occur, see Table 5. The greater the risk of an incident without nuclear meltdown, the lower the permissible dose caused by the incident may be.
Such dosage limits for incidents are also stated in the Dutch Nuclear Installations, Fissile Materials and Ores Decree (art. 18.2) as a criterion for refusal of the permit, but these limits are less stringent than the limits given in the Dutch Guidelines for the Safe Design and Operation of Nuclear Reactors.

Table 5 Incident frequencies and dose limits for incidents without nuclear meltdown (ANVS, October 2015)

Incident frequency F per annum[3]	Maximum permissible effective dose per person (over a period of 70 years)
$F \geq 10^{-2}$	0.1 mSv
$10^{-2} > F \geq 10^{-3}$	1 mSv
$F < 10^{-3}$	10 mSv

Safety level 4 dosage limits
The preconditions for safety level 4 require nuclear meltdown incidents, which may lead to premature and/or large-scale emissions, to be practically impossible. The underlying objective is that in the case of a nuclear meltdown incident, the only required protective measures are limited in both time and scope, and that there is sufficient time to implement them. All reasonably feasible solutions which may reduce potential exposure of employees, the general public and the environment, must be implemented.
In the case of a nuclear meltdown incident, containment is the most important barrier for protection of the surrounding area against radioactive material. It is therefore essential that the integrity of the containment be maintained at all times. Extra provisions must also be made in the design in order to limit the consequences of a nuclear meltdown. Consequently, the containment and the nuclear meltdown control systems must therefore be designed in such a manner that emissions can be kept as low as reasonably achievable in the event of a nuclear meltdown. This must comply with the preconditions as summarized in Table 6.
The zones must be combined, as design preconditions, with the Netherlands intervention values. The applicable intervention values (see Table 6 and Figure 4): for shelter and evacuation, there is an intervention value for the effective dose (E) and for the issue of iodine prophylaxes[6], there is an intervention value for the thyroid dose ($H_{thyroid}$) for children (<18 yrs) and for adults (≥18 yrs).

3 Dutch Radiation Protection Decree art. 5, paragraph 1.
4 For the limits of the Dutch Radiation Protection Decree, see art. 35, 48, 49, 76, 77, 78, 79 and 80
5 10^{-2} means once every 100 years, 10^{-3} means once every 1000 years. $F \geq 10^{-2}$ means that the incident frequency is greater than or equal to once every 100 years.
6 The iodine prophylaxis comprises the administering of an iodine tablet in order to protect against thyroid cancer, if radioactive iodine is released from a nuclear reactor. The ingestion of radioactive iodine increases the risk of children and young people developing thyroid cancer. The risk is greatest among children younger than approximately 10 years at the time of ingestion of radioactive iodine. The increased risk of thyroid cancer is extremely limited in adults, and no increased risk of thyroid cancer has been noted above 40 years (M. Leenders, Y. Kok, H. Reinen and C. Zuur, "Iodine prophylaxis following nuclear accidents, 348804004/2004," RIVM, 2004).

Table 6 Design preconditions for postulated nuclear meltdown incidents (ANVS, October 2015)

Protective measure	Evacuation zone (< 3 km)	Shelter zone (< 5 km)	Outside the Shelter zone	Intervention value
Permanent evacuation	No	No	No	
Evacuation	Can be necessary	Nee	No	E ≥ 100 mSv
Shelter	Can be necessary	Can be necessary	No	E ≥ 10 mSv
Iodine prophylaxis	Can be necessary	Can be necessary	No	$H_{Thyroid, <18 yrs}$ ≥ 50 mSv $H_{Thyroid, ≥18 yrs}$ ≥ 100 mSv

Admissible risk as a result of incidents
In terms of the individual (location-based) risk, the risk analysis must prove that the risk of a person who is present outside the installation in question, permanently and unprotected, dying as the result of an incident (therefore not only a non-design-based incident as referred to in article 18.3 of the Dutch Nuclear Installations, Fissile Materials and Ores Decree) is less than 10^{-6} per annum (see Table 7). In terms of group risk, the risk analysis must prove that the risk of a group of at least 10 persons becoming direct victims killed by an incident, outside the institution in question, is less than 10^{-5} per annum (or the risk is n^2 times smaller for n times more direct victims killed).

To summarize, the criteria in Table 5, Table 6 and Table 7 are the applicable criteria for the assessment framework for Nuclear safety.
The PALLAS-reactor must comply with the strict requirements set for the purpose of Radiation protection and Nuclear safety. This is also feasible (and therefore realistic) when making use of the modern day technology. The EIA will provide proof that there is compliance with these requirements. This is absolutely essential, of course. After all, should the reactor not comply with these requirements, no permit can be granted. This is a principle of the assessment given hereafter.

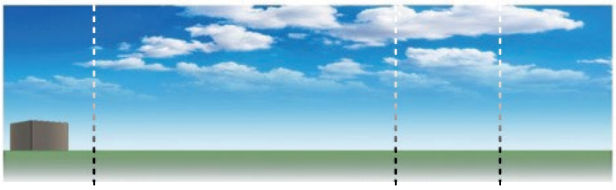

Figure 4 Schematic representation of zones and intervention values in case of postulated nuclear meltdown incidents (ANVS, October 2015)

Table 7 Admissible risk as a result of incidents (ANVS, October 2015)

Type of risk	Admissible risk
Individual (location-based) risk	≤ 10^{-6} per annum
Group risk 10 victims 100 victims 1000 victims	 ≤ 10^{-5} per annum ≤ 10^{-7} per annum ≤ 10^{-9} per annum

Relevant phases
All phases (construction phase, transition phase and operational phase) are relevant for Radiation protection and Nuclear safety. The impact assessment evaluates both the construction height variants and the cooling variants.

SEA assessment scale
The assessment scale defined in Table 9 will be used with regard to Radiation protection.

Table 8 Scoring of assessment of Radiation protection

Score	Meaning	Explanation
++	Extremely positive impact	Great improvement of the protection against radiation due to decreased radiation exposure of the surrounding area during normal operation.
+	Positive impact	Slight improvement of the protection against radiation due to decreased radiation exposure of the surrounding area during normal operation.
0	No impact	No significant change in the protection against radiation.
-	Negative impact	Slight decrease of the protection against radiation due to increased radiation exposure for the surrounding area during normal operation. These consequences comply with the statutory criteria as described in the assessment framework.
- -	Extremely negative impact	Decrease of the protection against radiation due to increased radiation exposure for the surrounding area during normal operation. These consequences exceed the statutory criteria as described in the assessment framework.

Table 9 Scoring of assessment of Nuclear safety

Score	Meaning	Explanation
++	Extremely positive impact	Great improvement of the nuclear safety due to the decreased risk or consequences of radiological incidents for the surrounding area.
+	Positive impact	Slight improvement of the nuclear safety due to the decreased risk or consequences of radiological incidents for the surrounding area.
0	No impact	No significant change in the nuclear safety.
-	Negative impact	Slight decrease of the nuclear safety due to the increased risk or consequences of radiological incidents for the surrounding area. These consequences comply with the statutory criteria as described in the assessment framework.
- -	Extremely negative impact	Decrease of the nuclear safety due to the increased risk or consequences of radiological incidents for the surrounding area. These consequences exceed the statutory criteria as described in the assessment framework.

7.2 Current situation and autonomous development

7.2.1 Current situation

As the assessment concerns the total environmental impact of the nuclear installations at the Research Location Petten and each installation has its own characteristics with regard to nuclear safety, they have been described in brief hereafter. These installations are operated on the basis of the permit granted under the NEA. This concerns the following installations.

High Flux Reactor (HFR)
Research reactor with an important social function in the production of medical isotopes and in research into energy supply.

Hot Cell Laboratory (HCL) (building 07)
This laboratory is deployed for post-irradiation research. Radioactive materials irradiated in the High Flux Reactor can be processed in this laboratory for further research and production. The HCL comprises a Research Lab and the Molybdenum Production Facility (see hereafter).

Molybdenum Production Facility (MPF)
This facility adjoins the HCL. Here, molybdenum is separated and purified from irradiated uranium, in order to render it suitable for final transport to the hospitals.

Jaap Goedkoop Laboratory (JGL) (building 420)
This modern laboratory offers facilities for research into reducing the life-cycle of radioactive waste and the development of new isotopes or patient treatment. The JGL has been included in the HCL permit.

Decontamination & Waste Treatment (DWT)
This facility is deployed for decontamination of radioactive contaminated materials. Here, materials are decontaminated and the radioactive waste is separated and packaged ready for transport to the storage facility. Radioactive contaminated water from the HFR and the other facilities is decontaminated in this facility, after which the decontaminated water can be discharged into the North Sea.

Waste Storage Facility (WSF)
This storage facility is used for temporary storage of radioactive waste before it is transported to the COVRA (Central Organization for Radioactive Waste) in Borssele.

Low Flux Reactor (LFR)
This reactor has been mainly used for training and schooling of reactor personnel. Materials research was also conducted here, including research to verify the authenticity of paintings.
The LFR was decommissioned in 2011 and is currently being dismantled. The fissile material, fuel rods and the most radioactive part of the reactor were all removed and disposed of in 2013.

curium™
LIFE FORWARD

Curium (formerly Mallinckrodt)
Curium is a supplier of pharmaceutical products. There are two cyclotrons in Petten for the production of radio-isotopes, while materials are irradiated in the HFR.

European Commission

The European Commission's Joint Research Centre (EC-JRC) supports the community policy with regard to both nuclear energy and non-nuclear energy, with a view to sustainable, safe and efficient energy production, distribution and use. EC-JRC in Petten provides customer-centric, scientific and technical support in the design, development, execution and monitoring of EU policy.

Table 10 Incident frequencies and dose limits for incidents (Dutch Nuclear Installations, Fissile Materials and Ores Decree)

Incident frequency F per annum	Maximum admissible effective dose per person	
	Persons from 16 years	Persons up to 16 years
$F \geq 10^{-1}$	0,1 mSv	0.04 mSv
$10^{-1} > F \geq 10^{-2}$	1 mSv	0.4 mSv
$10^{-2} > F \geq 10^{-4}$	10 mSv	4 mSv
$F < 10^{-4}$	100 mSv	40 mSv

Table 11 Maximum doses and risk of representative design-based incidents occurring and the individual risk as a result of design-based and non-design-based incidents for the nuclear facilities at the Research Location Petten [3] [4] [7]

Installation	Design-based incident		(Non-)design-based incident
	Max. dose (mSv)	Risk (1/yr)	Individual risk (1/yr)
HFR	(mSv)	Risk	$2 \cdot 10^{-8}$
MPF	(1/yr)	Individual risk	$9 \cdot 10^{-11}$
HCL[8]	(1/yr)	$1 \cdot 10^{-5}$	$2 \cdot 10^{-10}$
WSF	-	-	$1 \cdot 10^{-9}$
DWT	15	$< 1 \cdot 10^{-4}$	$2 \cdot 10^{-8}$

Environmental impact of the existing nuclear installations

The nuclear activities of the existing nuclear installations described above have been authorized by means of a NEA permit. There is a certain risk of incidents occurring at these installations, whereby radioactive substances may be emitted into the surrounding area. This is subject to the dose limits as given in the Dutch Nuclear Installations, Fissile Materials and Ores Decree (art. 18.2), see Table 10.

Table 11 gives the maximum doses and the risk of design-based incidents occurring at the various nuclear facilities at the Research Location Pettenand also the individual risk as a result of non-design-based incidents.

The table shows the reference design-based incidents at the facilities to comply with the assessment criteria of the Dutch Nuclear Installations, Fissile Materials and Ores Decree. It is also apparent that the risk of reference non-design-based incidents, even when totaled for all installations, remains under the statutory assessment criterion of 10^{-6} per annum.

Calculations for the existing installations show that the occurring doses in the surrounding area, caused by incidents, are so limited that no acute (deterministic) impact is possible which might lead to short-term death of persons. There is therefore no group risk.

The mutual influence of the various facilities as the result of a radiological incident at one of the facilities will be limited to possible evacuation of the facilities.

In such an event, there are provisions in place to ensure the safe decommissioning of the facilities. A domino effect resulting in incidents at multiple facilities is therefore not foreseeable.

Direct radiation

An agreement with the other Dutch Nuclear Energy Act permit holders at the Research Location Petten(NRG, HFR (NRG), EC-JRC and Curium) guarantees that the effective dose for persons outside the facility site, due to exposure to direct radiation and after multiplication by the latest applicable exposure correction factors (in which the expected length of stay is discounted) as a result of actions by all four permit holders together, will not exceed 0.04 mSv per annum (NRG, Veiligheidsrapport Kernenergiewetvergunning NRG-Petten, Part 1 "Algemeen & Centrale voorzieningen", 16 december 2014).

In that same agreement, the effective dose for persons present on the site but outside the facility buildings is limited to 0.1 mSv per annum, taking into account the latest exposure correction factor for roads on an industrial site.

Radioactive emissions to air

The current authorized limit for emissions to air by the nuclear installations of NRG is 200 Re_{inh}[9] per annum (NRG, Veiligheidsrapport Kernenergiewetvergunning NRG-Petten, Part 1 "Algemeen & Centrale voorzieningen", 16 december 2014)(Kernenergiewet-vergunning NRG voor het wijzigen en in werking houden van de HFR, 2005). The average nominal emissions are 10-25% (NRG, Veiligheidsrapport Kernenergiewetvergunning NRG-Petten, Part 1 "Algemeen & Centrale voorzieningen", 16 december 2014)(NRG, Veiligheidsrapport HFR, Stralingsbescherming en radioactief afval (Hoofdstuk 12), 2003) of these authorized limits, taking into account fluctuations resulting from the varying volume of work and research assignments.

7 There is insufficient information available on Curium and EC-JRC in Petten to show in this table.
8 The JGL is included here.
9 The radiotoxicity equivalent Re of a radionuclide is the amount of activity which results in an effective subsequent dose of 1 sievert upon full and direct ingestion or inhalation. By expressing emission limits in terms of radiotoxicity equivalents, the limitation factor is independent of the type of radionuclide. It does however require the emission to be measured specifically per nuclide.

Radioactive emissions to water
The waste water of the existing nuclear installations (NRG and Curium) which is possibly radioactively contaminated, undergoes intensive treatment at the DWT facility before it may be discharged into the sea. Following separation and filtration, the concentration of radioactivity in the effluent water is reduced to such a limit that it can be discharged into the North Sea. This takes place via the more than 4 km long sea discharge pipeline. The Dutch Nuclear Energy Act permit limit for this is 2,000 Re_{ing} per annum (NRG, Veiligheidsrapport Kernenergiewetvergunning NRG-Petten, Part 1 "Algemeen & Centrale voorzieningen", 16 december 2014). The average nominal emission is 10–25% of this authorized limit. The effective dose for members of the public as a result of the authorized emission in the North Sea is 0.04 µSv/yr (NRG, Veiligheidsrapport Kernenergiewetvergunning NRG-Petten, Part 1 "Algemeen & Centrale voorzieningen", 16 december 2014).

Radioactive waste
Radioactive waste from the facilities is disposed of via the DWT. Solid waste or waste produced in the process treatment, is processed and recycled where possible. The radioactive waste is separated from the non-radioactive waste and subsequently conditioned by means of compression and/or cutting before being transported to the COVRA Central Organization for Radioactive Waste. The environmental influence of the storage and processing of the radioactive waste is a part of the impact described earlier (direct radiation and emission).

Radiation exposure as a result of the Research Location Petten
Table 12 shows the maximum effective dose for the surrounding area per annum, as a result of the various exposure paths from the Research Location Petten in comparison with the limit given in the Dutch Radiation Protection Decree. The dose as the result of storage and processing of radioactive waste is part of the dose included in the table.
According to the Dutch Radiation Protection Decree, the dose limit for radioactive emissions, including the contribution by direct radiation, is 0.1 mSv per annum. Thanks to mutual agreements between the nuclear companies (NRG, Curium and EC-JRC) and the application of ALARA, it is possible to meet the much lower limiting value of 0.04 mSv per annum for direct radiation caused by the combined companies, at the site border of the Research Location Petten. In that same agreement, the effective dose for persons present on the Research Location Petten but outside the facility buildings is limited to 0.1 mSv per annum, taking into account the latest exposure correction factor for roads on an industrial site.

7.2.2 Autonomous development
A foreseen autonomous development is the conversion of the MPF installation for the processing of irradiated targets with low-enriched uranium instead of the current targets with high-enriched uranium. A Dutch Nuclear Energy Act permit has been issued for this in May 2017. The conversion is expected to have been completed upon commencement of the proposed activity (planned in 2017). It is not expected to result in significant changes with regard to the nuclear safety at and around the Research Location Petten. Any changes will only concern the permit limits and the statutory criteria.
With regard to the WSF, a large part of the historic radioactive waste stored here will be disposed to the COVRA in the coming years. The disposal is not expected to have been completed upon commencement of the proposed activity (planned in 2023). In the end, this will have a limited positive influence on Nuclear safety at and around the Research Location Petten. Installations will be built for the removal of this waste, intended for separation and packaging of this waste. These installations and the related waste transport may possibly make a limited and temporary contribution to the risk of incidents. This possible contribution will only concern the permit limits of these facilities and the statutory criteria, and will not influence the future permit conditions of PALLAS.
There is contaminated ground at the Research Location Petten, with radioactive material. This contamination is the result of a leak in the drain pipeline from the HFR to the DWT. A decontamination campaign has been underway in recent years, so that the majority of this contamination has been removed. The decontamination of the ground is expected to have been completed upon commencement of the proposed activity (planned in 2019).
With a view to characterization of the location for the PALLAS-reactor, an inventory has been made of the population density and development around the Research Location Petten (LEOPS (ARCADIS/NRG), 2016). The conclusion is that the expected population growth in the province of Noord-Holland (versus 2015) will be 6% in 2025 and 10% in 2040. The considered impact for local residents is partly individually ascertained (effective dose and individual risk) so that population growth has no impact on them. There could be a possible impact on the group risk, but as there is no group risk from the HFR (see previous paragraph), it is unlikely that this will result in statutory criteria being exceeded for the PALLAS-reactor.
More tourists may be found in the vicinity of the Research Location Petten in the near future, as a result of autonomous developments in the recreational sector (for example the apartments in Sint Maartenszee hotel and the Bohemian Estate project). These autonomous developments have been described in detail in the Recreation and Tourism background report (Appendix F9). The EIA phase takes account of this increase in the modeling for determination of the impact on the surrounding area.
To summarize, it can be stated that the various influences of the aforementioned autonomous developments on Nuclear safety will be limited, and will only concern the valid permit limits and statutory criteria. All in all, they will not result in a major change versus the current situation. This aspect is not relevant, as there is no group risk at HFR (see previous paragraph).

Table 12 Maximum effective dose for the surrounding area per annum in comparison with the Dutch Radiation Protection Decree limit

Exposure path	Eff. dose surrounding area E_{max} (µSv/yr)	Limit (µSv/yr)
Direct radiation Emissions to the air Emissions to water	40 2.1 0.04	
Total	42	100

7.3 Environmental impact

7.3.1 Impact description

In terms of the Radiation protection and Nuclear safety aspects, we have considered incidents which are the consequence of internal events (such as leakage in a cooling system, or fire) or of calamities with an external cause (such as flooding, an earthquake or an aircraft crash).
The HFR complies with the dosage criteria stated in the Dutch Nuclear Installations, Fissile Materials and Ores Decree. New reactors are nowadays subject to stricter dose criteria (ANVS, October 2015). Due to the PALLAS-reactor being designed and built according to the latest insight and requirements (in compliance with the Dutch guidelines for the Safe Design and Operation of Nuclear Reactors), it is realistic to state that it will comply with the new stricter criteria. This applies not only to the aforementioned dosage criteria but also for the technical safety requirements such as protection against external threats.
The current regional crisis response plan does not take into account the realization of the PALLAS-reactor. This plan will need to be adapted prior to the PALLAS-reactor being commissioned, in order that it does not hinder the new research reactor. This will be done in consultation with the safety region and according to the applicable guidelines. The future situation for the PALLAS-reactor will not essentially differ from the current situation of the HFR on this point.
The mutual influence of the PALLAS-reactor and the existing nuclear facilities at the Research Location Petten as a result of a radiological incident, will be limited to possible evacuation of the facilities. A direct mutual influence as the result of an incident, causing a subsequent incident in another facility, is unlikely. In such a radiological incident whereby evacuation is necessary, there are provisions in place to ensure the safe decommissioning of the facilities. This will also be the case for the PALLAS-reactor. A domino effect resulting in incidents at multiple facilities is therefore not foreseeable.
With regard to possible cross-border impact and within the scope of the Espoo convention (see also paragraph 1.3 of the SEA), the closest national borders with Germany and Belgium are both at approximately 140 km from the planned location for the PALLAS-reactor. As indicated in the assessment framework, the Dutch guidelines for the Safe Design and Operation of Nuclear Reactors describe zones and intervention values for postulated nuclear meltdown incidents. A design precondition for such incidents is that the maximum consequences for the general population must be limited to such an extent that shelter, evacuation or the issue of iodine prophylaxes is not necessary outside the shelter zone, up to 5 km from the site border. The distance to the national borders is much more than 5 km, so that no cross-border protection measures will be required even in the case of the most severe postulated incidents.
The maximum radiation exposure as a result of radioactive emissions, released during an incident, must comply with the statutory criteria (see assessment framework). The maximum radiation exposure occurs at or within a limited distance of the site border. When considering the great distance to the closest national borders, the scope of radiation exposure there as the result of radioactive emissions and the subsequent environmental impact will be lower than the statutory criteria and therefore insignificant. Similar reasoning also applies regarding the regular emissions during normal operation, for which the radiation exposure is many times lower.

7.3.2 Impact assessment

7.3.2.1 Radiation protection

Table 13 gives the impact assessment for the Radiation protection aspect, for the construction height and cooling variants. Following the table, an explanation of the impact scores is given.
The construction height variants result in a larger or smaller part of the nuclear island being underground. As far as Radiation protection is concerned, the only direct influence is that the degree of protection against ionizing radiation by the ground, will differ per variant.
Seeing as the reactor core will be situated in a water basin, the radiation from the reactor core will be largely shielded by this water. Moreover, the concrete base wall and the thick concrete walls of the nuclear island will provide additional shielding. Due to the radiation exposure depending on the amount of shielding used, the various construction height variants will always be able to comply with the applicable criteria to an equal extent. The choice to be made between construction height variants is therefore not a question of radiation protection but rather simply a technical design question. There is therefore no significant difference between the variants for the construction height, in terms of protection against radiation.
The cooling variants are insignificant for protection against radiation. The cooling system in which cooling water is

Table 13 Impact assessment for Radiation protection

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Effective dose	0	0	0	0	0	0
Transition phase						
Effective dose	-	-	-	0	0	0
Operational phase						
Effective dose	0	0	0	0	0	0

drained to the sea allows radioactive waste water to be discharged (after decontamination) with the cooling water in the sea. The cooling water itself is not radioactive, due to the cooling water cycle being separate from the nuclear system. However, this does not give any actual difference versus the cooling variant with air cooling, as radioactive waste water can then also be discharged in the sea via a separate pipeline, as is the case in the current situation. A separate discharge pipeline may result in higher concentrations very locally (directly at the outlet point in the sea) than when the discharge is diluted with cooling water, but this will not result in a significant difference with regard to radiological exposure of the environment due to dilution being immediate. For that matter, dilution with cooling water may not be used in order to comply with emissions criteria. Prior to radioactive waste water being discharged via the cooling water, the waste water must be sampled in order to define the nature and volume of water being discharged. There is therefore no significant difference between the cooling variants for protection against radiation.

Construction phase
With regard to the project phases, the construction phase of the PALLAS-reactor is irrelevant for radiation protection, as there will be no fissile materials or other radioactive substances present in the installation at that time. The construction height variants and cooling variants therefore score neutral (0) versus the reference situation.

Transition phase
In the reference situation, both research reactors are in operation during the transition phase, so that the sum of the emissions, including the contribution by direct radiation, must be taken into account. Due to each reactor having its own Dutch Nuclear Energy Act permit, the statutory framework is decisive for the admissible emissions to begin with. The applicable condition given in the Dutch Radiation Protection Decree is that the maximum admissible site border dose is 0.1 mSv per annum for each individual installation.
In the current situation, the nuclear companies have reached a mutual agreement which has enabled them to comply with the lower limiting value of 0.04 m Sv per annum for direct radiation, for the individual companies. It seems logical to assume that the PALLAS-reactor will also be able to comply with a comparable limiting value.
As the contribution by direct radiation is dominant, it will be possible to limit the dose at the combined site borders of the nuclear installations to maximum 0.1 mSv per annum (namely maximum 2 x 0.04 mSv/year) even when the HFR and PALLAS-reactor are operating simultaneously. The dose limit given in the Dutch Radiation Protection Decree can therefore also be achieved at the combined site border of the Research Location Petten, for which there is no combined permit, as mentioned earlier.
For that matter, the situation in which both reactors are simultaneously operational, is expected to be limited to a few years. In this situation, the environmental impact of the PALLAS-reactor will be slightly negative (-) versus the reference situation, during that period. As described under the operational phase, there is no significant difference between the various construction height and cooling variants.

Operational phase
As described above, the impact of the PALLAS-reactor is comparable to that of the HFR for the Radiation protection aspect. The PALLAS-reactor has a comparable capacity and it may be assumed that the technology applied in the PALLAS-reactor is comparable or superior to that of the HFR. The construction height and cooling variants therefore score at least neutral (0) versus the reference situation.

7.3.2.2 Nuclear safety
Table 14 gives the impact assessment for the Nuclear safety aspect, for the construction height and cooling variants. Fol-

Table 14 Impact assessment for Nuclear Safety

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Radiological requirements for postulated incidents	-	-	-	0	0	0
Admissible risk as a result of incidents	-	-	-	0	0	0
Transition phase						
Radiological requirements for postulated incidents	-	-	-	0	0	0
Admissible risk as a result of incidents	-	-	-	0	0	0
Operational phase						
Radiological requirements for postulated incidents	+	+	+	0	0	0
Admissible risk as a result of incidents	+	+	+	0	0	0

lowing the table, an explanation of the impact scores is given. The construction height variants result in a larger or smaller part of the nuclear island being underground. This will influence a number of aspects with regard to nuclear safety. A direct consequence of the construction height is that the degree of protection against ionizing radiation by the ground, will vary per construction height variant. Another aspect concerns protection against external threats. However, the design can be sufficiently adjusted in both cases in order to provide sufficient protection. The choice to be made between the variants is therefore not a technical safety question but rather simply a technical design question. There is therefore no significant difference between the construction height variants for nuclear safety.

The operation of the secondary cooling system is mainly of importance for normal operations but possibly also for nuclear safety. The cooling system can be designed in such a manner that the various cooling variants can offer sufficient reliability, in combination with the other cooling systems of the PALLAS-reactor. At this point in time however, it is not possible to determine a preference for a cooling variant from a technical safety point of view. The choice to be made between the variants is therefore not a technical safety question but rather simply a technical design question.

Whether cooling water is discharged into the sea or air coolers are used, radioactive substances will not be emitted unless multiple barriers have failed. As the specific design is not yet available, it is not yet possible to determine a preference for a cooling variant from a technical safety point of view. However, the design can be sufficiently adjusted in both cases in order that the consequences of any emissions during incidents, comply with the statutory criteria. The choice to be made between the variants is therefore not a technical safety question but rather simply a technical design question.

There is therefore no significant difference between the construction height and cooling variants in terms of nuclear safety.

Construction phase

With regard to the project phases, the construction phase of the PALLAS-reactor is irrelevant for nuclear safety of the new reactor itself, as there will be no fissile materials or other radioactive substances present in the installation at that time. However, the construction phase can influence the directly adjacent nuclear facilities, the Hot Cell Laboratory (HCL) and the Molybdenum Production Facility (MPF). This influence cannot yet be determined, due to the exact location of the new reactor and the construction method not yet being known. As part of the permit procedure required for the construction phase, there will therefore need to be proof that any additional risks to neighboring installations are acceptable. This is described in brief hereafter.

With a view to radiation protection, the construction phase may result in risks for the existing nuclear installations. A construction pit is necessary for realization of the nuclear island, as this building is partially underground. Two aspects can be distinguished with regard to these risks. On the one hand, the installation of the construction pit walls, and on the other hand local subsidence as a result of excavation of the construction pit. Both aspects will affect the level of the ground and the neighboring buildings:

The installation of construction pit walls brings with it the risk of vibration hinder and noise hinder. Vibrations can also cause damage to neighboring buildings. With a view to the possible sensitivity of the neighboring brickwork buildings to vibrations, a low-vibration construction method has been chosen. The choice of slurry walling for the construction pit walls will prevent vibrations. The construction pit walls will therefore be formed by digging a trench in the ground, which is filled with concrete.

Excavation of the construction pit will result in subsidence in the surrounding area. The area influenced by subsidence is 1.5 x the depth of the excavation (approximately 30 m), with the greatest subsidence occurring close to the construction pit. Whether or not the directly neighboring buildings are in this scope of influence still depends very much on the exact location of the construction pit. For the time being, the existing buildings are approximately on this borderline. Once again, control measures can be taken in order to limit subsidence.

There is no risk to the HFR, as it is way beyond the scope of influence.

The construction height variants can therefore possibly result in a limited negative impact on the nuclear safety of the Research Location Petten, though this will remain within the statutory criteria, and they are therefore scored negative (-) versus the reference situation.

Transition phase

In the reference situation, both research reactors are in operation during the transition phase, so that the sum of the emissions must be taken into account. Due to each reactor having its own Dutch Nuclear Energy Act permit, the statutory framework is decisive for the admissible risk to begin with. The impact of the proposed activity versus the reference situation is at most a doubling of the risk, due to both reactors being operational. Once again, this situation complies with the statutory dose and risk criteria.

During the transition phase, both reactors may be simultaneously operational, requiring a higher total volume of cooling water. When cooling from the canal (variant K1), the cooling capacity for normal operation could theoretically be jeopardized in the event of low water levels in the canal (see the Soil and Water background report). This will not be problematic, as the volume of cooling water required for safety purposes is much less than during normal operation. After all, the required cooling capacity of two recently switched off reactors is well below the required cooling capacity of one reactor at full power. If in the extreme case that the water level is so low that sufficient cooling water is problematic for safety purposes, the reactors could be switched off for the required period of time. This will therefore never become a safety issue.

For that matter, the situation in which both reactors are simultaneously operational, is only a brief period, and is expected to be limited to a few years.

In this situation, the environmental impact will be slightly negative (-) versus the reference situation for a limited period of time, due to both reactors being simultaneously operational. As described under the operational phase, there is no significant difference between the various construction height and cooling variants.

Operational phase
As indicated earlier, the risk posed by the PALLAS-reactor for local residents can be assumed to be lower than the risk posed by the HFR, due to application of improved technology and compliance with stricter requirements. It will certainly also comply with the statutory dose and risk criteria as described in the assessment framework. The construction height and cooling variants therefore score positive (0) versus the reference situation.

7.4 Mitigating measures

As indicated in the previous paragraphs, the PALLAS-reactor can (and must) comply with statutory dose limits and risk criteria for incidents as defined in the assessment framework, with regard to nuclear safety. A number of safety provisions will be in place at the PALLAS-reactor for this purpose, as foreseen in the Dutch Building Decree.
With regard to radiation protection, the PALLAS-reactor can (and must) comply with dose limits as defined in the assessment framework, whereby the ALARA principle must also be applied. Provisions such as radiation shielding will be in place at the PALLAS-reactor for this purpose. A number of measures which can greatly reduce subsidence and bring it within acceptable limits include the choice of heavier slurry walling, the use of an extra layer of shoring and the pretensioning of shoring. The latter measures will always be determined in combination with predictive calculations, and monitored during the execution period by means of an intensive monitoring program.
Additional mitigating measures are therefore not necessary.

7.5 Knowledge voids and the initial design of an evaluation program

The assessment of Radiation protection and Nuclear safety, and compliance with the criteria can only take place quantitatively once the design of the PALLAS-reactor and accessory analyses are complete. These will become available at a later phase of the project. The quantitative assessment will be a component of the EIA to be formulated at that point.

8 Soil and Water

The following description of the Soil and Water aspect is based on the Soil and Water background report (see Appendix F3).

8.1 Assessment framework

8.1.1 Policy framework

Table 15 summarizes the relevant policy and relevant legislation and regulations for the Soil and Water aspect, along with an indication of their relevance for the project. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Soil and Water.

Table 15 Policy, laws and regulations concerning the Soil and Water aspect

Policy plan, law, regulation	Description/ Relevance for PALLAS
International Atomic Energy Agency (IAEA) requirements	The IAEA requires a study of the groundwater regime and the groundwater quality, in relation to the foundations of the installation. The IAEA also states that modeling of transport routes via groundwater must be part of the Safety Analysis Report. This is not a component of this study, but has been included within the scope of the Dutch Nuclear Energy Act permit and the EIA. Based on the impact report, a description is required of the method of monitoring the impact on groundwater during construction and operation of the installation.
European Water Framework Directive (WFD), 2000 and Groundwater Guideline 2006	The WFD sets requirements for a good quantitative state and good chemical and ecological state of groundwater and surface water. At the European level, standards have been established for the chemical state of water, with regard to a group of priority substances. These standards apply uniformly to all surface waters and have been embedded in the Dutch Water Quality and Monitoring Decree 2009. The Dutch Groundwater Guideline, which came into force at the end of 2006, further specifies a number of chemical aspects for groundwater. The 'Dutch Decree of 15 October 2015 for amendment of the Water quality and Monitoring Decree 2009 and the Water Decree' gives the statutory Dutch limiting values for good chemical condition of groundwater bodies. Construction of the PALLAS-reactor may possibly impact the groundwater flow and the distribution of fresh and salt groundwater. The limiting value for chloride is particularly important, and has been established at 160 mg/L for the NLGW0016 (Dune Rhine West) in 2027, while the groundwater quality must also not deteriorate. Furthermore, there are three surface water bodies (Schermerboezem-North, North NHN dunes, Holland Coastline) located within the study area, or potentially influenced by the proposed activities.
Water Act, Dutch government, 2009	The Water Act permit procedure will assess the impact of extraction (of groundwater and surface water) and discharge (of cooling water) on the surrounding area. There will be attention for the impact on vegetation, subsidence of buildings and on dikes. If warm water is discharged into surface water, the water permit includes requirements concerning this discharge, in order to protect the quality of the surface water. Requirements will primarily concern the maximum heat load of the water to be discharged and the volume of water that may be discharged. The Water Authority for Northern Holland (HHNK) has also indicated its desire to see an assessment of any short-circuit currents which may occur between various aquifers as a result of foundation piles. One of the most important impacts may be the influence on vegetation in the surrounding Natura 2000 area. A significant impact on the conservation targets of Natura 2000 areas would be unacceptable.
Dutch Soil Protection Act , Dutch government, 1986	The Dutch Soil Protection Act only allows excavation work at seriously contaminated locations if a notification has been made to the authoritative body. A further condition is that, in the case of serious soil contamination, the excavation work must be in keeping with a predefined (framework) decontamination plan approved by the authoritative body. Prior to the excavation work, there must be verification whether the serious contamination is located in the supplying and/or receiving soil. Once the decontamination results have been achieved, recovered soil may once again be used at this location. There must, however, be certainty that this is not in violation with the imposed limitations for use and/or after-care obligations.
Covenant on soil development policy and approach to urgent locations, Dutch government, 2009	An important point of the soil covenant is that the authoritative bodies have decontaminated or at least contained the risks at the urgent locations by 2015. Urgent locations are those locations where the presence of soil contamination results in hazards for human health or ecological values or the risk of hazardous dispersal of pollutants in the groundwater. At such locations, the prevailing situation would entail unacceptable risks for human health, the groundwater and/or ecosystems. Urgent locations imply autonomous development, due to there being an active decontamination obligation. Such decontamination processes can be (extremely) costly, which in turn may frustrate the feasibility of spatial developments. Urgent locations are therefore the most significant soil locations and are an important component of the soil covenant.

Policy plan, law, regulation	Description/ Relevance for PALLAS
Soil quality ruling, Dutch government, 2007	The soil quality ruling defines the regulations for excavation of soil and dredged material for deposit or use at other locations. Its purpose is to prevent the use of soil and dredged material from contaminating the receiving soil and therefore forming a hazard for (future) land use. The soil quality ruling also defines product requirements regarding the composition and emission values of stony construction materials (not soil and dredged materials).
Netherlands soil pollution overview (LDB), Dutch government, 2004	The Netherlands soil pollution overview is an inventory of all locations in the Netherlands where the soil is (possibly) contaminated due to (former) industrial activities. Regional and local authorities are the authoritative bodies within the scope of the Dutch Soil Protection Act. The datasets compiled on the basis of the Netherlands soil pollution overview still apply as the reference framework for available (historic) soil quality data in the Netherlands.

8.1.2 Assessment framework and methodology

The Soil and Water aspect is assessed according to the assessment framework given in Table 16. This assessment framework will then be worked out in more detail per sub-aspect.

Study area

The study area for aspects concerning water is much larger than the planning area for the PALLAS-reactor and the cooling water pipelines, due to the groundwater influencing area being larger and due to extraction from the Noord-Hollands Kanaal also having an impact in a larger region, see Figure 5. In terms of the soil, however, the study area is virtually identical to the planning area, namely the location where ground-breaking activities take place and its direct vicinity.

Assessment framework

See Table 16 page 81.

8.1.2.1 Groundwater

Groundwater will possibly be extracted for construction of the PALLAS-reactor, depending on the final design and realization method. Depending on the final design, the construction will be partially underground and will therefore partially block the natural groundwater flow. This will influence the water table and groundwater flow, the hydraulic head and distribution of fresh and salt groundwater. The impact on the groundwater has been assessed for: the construction phase, transition phase and operational phase. The impact is expressed as:

- Changes in the water table and/or hydraulic head.
- Changes in the chloride content of the groundwater.

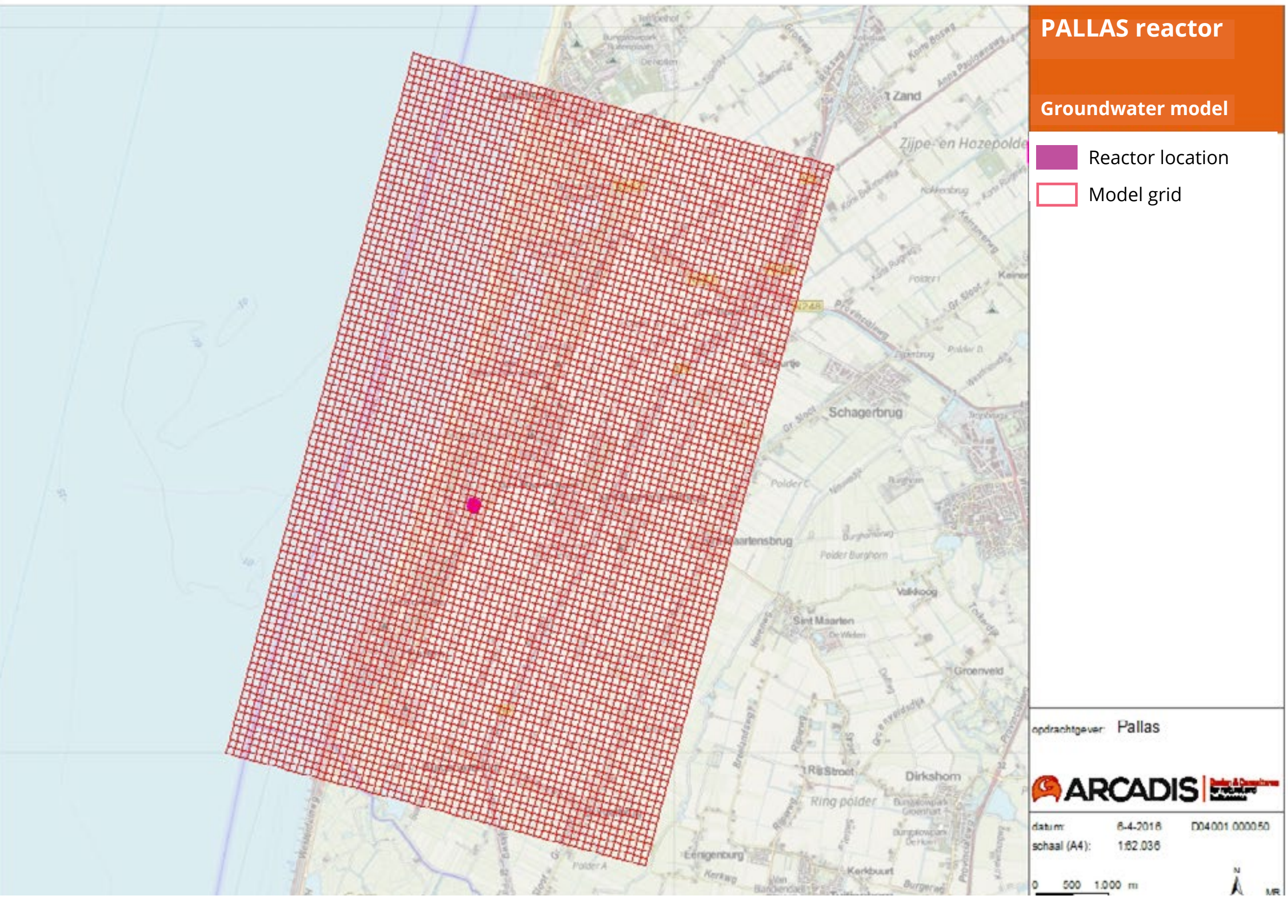

Figure 5 Study area (grid) of groundwater modeling for reactor location

Table 16 Assessment framework Soil and Water

Sub-aspect	Assessment criteria
Groundwater	Vegetation
	Buildings
	Dunes as part of the coastal defense
	Agriculture
	Groundwater extraction or infiltration systems
	Mobile contaminants
Water quality	(physical) chemical water quality
	biological water quality
Cooling water extraction and discharge	Cooling water extraction
	Cooling water discharge
Soil quality	Soil quality

The impact of changes in the groundwater regime has been assessed for:

- Vegetation (dehydration, salinization).
- Buildings (risk of subsidence damage).
- Dunes as a component of the coastal defense (risk of subsidence).
- Agriculture (dehydration damage, salinization damage).
- Groundwater extraction or infiltration systems.
- Mobile pollutants (influence on management).

Aspects can have a negative impact on one assessment criterion, and a positive impact on a different criterion. For example, a lower water table can have a negative impact on vegetation, but may also mean that there is less need for the existing permanent groundwater management system.

Relevant phases

The impact on the Groundwater sub-aspect is described for the construction phase and operational phase. The transition phase has not been separately assessed, as the activities during this phase, in which both the HFR and PALLAS-reactor will be operational, will have no other impact than during the operational phase.

SEA assessment scale

Table 17 shows the translation of the impact into the qualitative assessment scale.

8.1.2.2 Water quality

In the water quality sub-aspect, a distinction is made between two assessment criteria:

1. Influence on (physical) chemical water quality. This criterion assesses the degree to which the Water Framework Directive
   - The priority substances.
   - The general physical-chemical parameters.
   - The other specific pollutants.

   This is based on the norms and targets for these quality elements in the Holland Coastline water body. The assessment considers whether the cooling variants under study will result in exceedance of the norms and targets for the substances and parameters in question.
2. Influence on biological water quality. This criterion assesses the degree to which the Water Framework Directive targets for the relevant biological quality elements are influenced. In the Holland Coastline water body, this concerns phytoplankton and macrofauna. The assessment considers whether the cooling variants under study will impact the targets for these quality elements for the Holland Coastline water body.

Table 17 Scoring of assessment for Groundwater

Score	Meaning	Explanation
++	Extremely positive impact	Does not exist.
+	Positive impact	Stronger shallow seepage to and increased water level of wet dune valleys. Expected improvement of Natura 2000 conservation targets. Soil desalination in agricultural areas. Less groundwater extraction required for groundwater control. Control of the distribution of pollutants.
0	No impact	No impact on the groundwater regime.
-	Negative impact	Slight negative impact on existing groundwater extractions / groundwater use; Slight dehydration / salinization of wet dune valleys. The phreatic water table drops less than 5 cm where there is low vegetation and less than 10 cm where there are woodlands. Slight risk of settlement damage in buildings and the primary flood defense. Slight dehydration/salinization damage to agriculture. Slight negative impact on the distribution of mobile pollutants.
- -	Extremely negative impact	Strong negative impact on existing groundwater extractions / groundwater use. Strong dehydration / salinization of wet dune valleys. Conservation targets are at risk. The phreatic water table drops more than 5 cm where there is low vegetation and more than 10 cm where there are woodlands. Strong risk of settlement damage in buildings and the primary flood defense. Great dehydration/salinization damage to agriculture. Strong negative impact on the distribution of mobile pollutants.

Table 18 Scoring of assessment for Water quality

Score	Meaning	Explanation
++	Extremely positive impact	Strong positive impact with regard to WFD targets, resulting in higher assessment class
+	Positive impact	Limited positive impact with regard to WFD targets, resulting in other assessment class
0	No impact	No significant impact on water quality
-	Negative impact	Limited negative impact with regard to WFD targets, admissible within the criteria for 'no deterioration'.
- -	Extremely negative impact	Strong negative impact with regard to WFD targets, not admissible within the criteria for 'no deterioration'.

Relevant phases
The water quality can only be influenced during the transition and operational phases. This sub-aspect has therefore not been assessed for the construction phase. The transition phase has not been separately assessed, as the activities during this phase, in which both the HFR and PALLAS-reactor will be operational, will have no other impact than during the operational phase. As cooling variant K3 does not extract or discharge any cooling water, this variant has also not been assessed.

SEA assessment scale
These criteria are explained hereafter and translated into the scoring method as included in table 17.

8.1.2.3 Cooling water extraction and discharge

There is a limit to the volume of water which can be extracted from the Noordhollandsch Kanaal. However, this limit cannot be concretely defined, as it depends on rainfall, water requirements by other functions and the volume of water drained from the IJsselmeer lake. A qualitative approach has therefore been chosen, in which a larger extraction volume is negatively assessed and a smaller extraction volume positively assessed.

Relevant phases
Cooling water extraction and discharge for the purpose of the PALLAS-reactor will only take place during the transition and operational phases. This sub-aspect has therefore not been assessed for the construction phase. During the transition phase, both the HFR and the PALLAS-reactor extract and discharge water.
The construction height variants have no influence on this sub-aspect. They have therefore not been assessed.

SEA assessment scale
Table 19 shows the translation of the impact into the qualitative assessment scale.
Discharge of cooling water results locally in a cooling water plume, which may have a negative impact on ecology. This report discusses the requirements as described by the Dutch Water Act.
The impact is measured on the basis of the mixing zone scope. A significant impact is expected in the case of a mixing zone larger than 25% of the cross-section of the water system. Mixing zones of 25% and larger are therefore assessed as very negative. Table 20 shows the translation of the impact into the qualitative assessment scale.

8.1.2.4 Soil quality

The soil quality data, available via the soil policy, can be aggregated into the following three-way distinction for impact assessment in this SEA:

1. Autonomous development: As a result of the Covenant on soil development policy, the approach to urgent locations can be regarded to be an autonomous development. 'Pressing' cases are based on a decision within the scope of the former Dutch Soil Protection Act (prior to 1-1-2007), and therefore become equal to urgent locations in the covenant. Regardless of the soil quality, there is by definition autonomous development at ongoing decontamination and after-care locations. Agreements have been signed with subcontractors and finances have been reserved for execution of the decontamination.
2. Positive impact: In cases of extensive soil contamination

Table 19 Scoring of assessment for Cooling water extraction

Score	Meaning	Explanation
++	Extremely positive impact	>50% less cooling water is extracted than the HFR at present
+	Positive impact	>5-50% less cooling water is extracted than the HFR at present
0	No impact	+5% / -5% cooling water is extracted than the HFR at present
-	Negative impact	>5-50% more cooling water is extracted than the HFR at present
- -	Extremely negative impact	>50% more cooling water is extracted than the HFR at present

10 When assessing the chemical and ecological quality of water bodies, a distinction is made in assessment classes. These classes are 'compliant' and 'non-compliant' for priority substances and other pollutants. The classes for general physical-chemical parameters and biological quality elements are 'extremely good', 'good', 'reasonable', 'inadequate' and 'poor'.

Table 20 Scoring of assessment for Cooling water discharge

Score	Meaning	Explanation
++	Extremely positive impact	Not applicable
+	Positive impact	Not applicable
0	No impact	Mixing zone smaller than or equal to 5%
-	Negative impact	Mixing zone between 5% and 25%
- -	Extremely negative impact	Mixing zone is larger than 25% Significant impact of cooling water discharge Further model study is essential

– dating prior to 1 January 1987 and of no urgency – there is no obligation nor direct necessity to undertake decontamination. However, ground work (for example construction, excavation or extraction of groundwater) may only be conducted once the authoritative body has approved a decontamination plan. It is assumed that direct decontamination takes place in the case of developments at or across (sub-)locations with extensive soil contamination. The decontamination of extensive cases of soil contamination therefore has a positive impact on soil quality. For that matter, decontamination does not by definition always require removal of extensively contaminated soil. Prevention of exposure often already suffices as a decontamination measure in the case of immobile soil contamination. In such cases, there will then be 'no impact' on soil quality. However, there is no insight into decontamination measures during the planning phases. Generally speaking, decontamination of extensive cases of soil contamination results in a positive impact on soil quality.

3 No impact: Cases of non-extensive soil contamination, dating prior to 1 January 1987, need not be decontaminated, unless this becomes necessary due to a change in function. In case of function change, there must be an assessment whether the soil quality is adequate for the proposed function. This is in principle always the case for the 'infrastructure' function. This means that non-extensive soil contamination normally does not require decontamination and therefore also has no impact.

Relevant phases
Only the construction phase is relevant for the soil quality sub-aspect. During this phase, known and/or unknown soil contamination will be decontaminated if necessary.

SEA assessment scale
The table hereafter shows the scoring of assessment criteria for Soil quality (Table 21).

Table 21 Scoring of assessment for Soil quality

Score	Meaning	Explanation
++	Extremely positive impact	Decontamination of two or more extensive cases of soil contamination
+	Positive impact	Decontamination of an extensive case of soil contamination
0	No impact	Non-extensive case of soil contamination
-	Negative impact	Not applicable
- -	Extremely negative impact	Not applicable

8.2 Current situation and autonomous development

8.2.1 Current situation
The current situation has been described hereafter, per sub-aspect.

8.2.1.1 Groundwater
Hydrogeological soil composition
The hydrogeological basis (the geological layer which forms the bottom of the groundwater system) comprises the tertiary and pleistocene deposits from the Maassluis Formation at a depth of approximately NAP -230 m to NAP -290 m. These deposits comprise mainly impermeable clay. Above them lies a thick layer of permeable sandy deposits from the Peize and Waalre Formations. From approximately NAP -80 m, these formations transgress into the Urk Formation. There are a number of thin clay layers in the Urk Formation at the proposed location of the PALLAS-reactor. These clay layers end to the east of the proposed location of the PALLAS-reactor.
Above approximately NAP -50 m, there is alternation of permeable sandy layers and impermeable clay layers. These deposits are the Drenthe Formation, the Eem Formation, the Kreftenheye Formation and the Boxtel Formation.
The top of the Boxtel Formation and underside of the holocene

cover layer is a dividing layer which separates the phreatic aquifer on top from the 1st aquifer below. There is relatively little hydraulic resistance in the deep-lying dividing layers (a number of hundred days per dividing layer). The first dividing layer which separates the phreatic aquifer layer from the deeper aquifer is the most relevant dividing layer as far as this project is concerned. This dividing layer, situated at approximately NAP 0 m tot NAP -10 m, comprises sandy clay and clay-type sand with local enclosed layers of peat. The base peat in particular offers great hydraulic resistance. This layer is approximately 40 cm thick at the reactor location. In the surrounding area, its thickness varies between 0 and 80 cm.

Groundwaterflow

The groundwater flow in the aquifers below the phreatic aquifer is oriented from west to east. Drainage in the Wieringermeer polder approximately 20 kilometers east of the location of the PALLAS-reactor causes a hydraulic head gradient of approximately NAP 0 m at the coast to approximately NAP -4.5 m in the polder.

The phreatic aquifer mainly comprises dune sand. Infiltration of rainwater has formed a freshwater lens in these dunes, which displaces the saltwater down to below the first dividing layer. The phreatic freshwater lens is extremely important for the quality of the groundwater in the dune area and for the dune vegetation, particularly the vegetation in the dune valleys, where there is seepage of fresh, carbonated water. When the phreatic water table is high enough, the (fresh) phreatic groundwater reaches the low-lying dune valleys and forms marshy areas and fens there. The water table in the dune area varies greatly depending on rainfall and evaporation.

Figure 6 shows the calculated infiltration for the 1998-2006 period, calculated by means of the Dutch NHI groundwater model (national hydrological instrument). This period is regarded to be a hydrologically representative period and has been applied for description of the average hydrological situation. The average highest (AH) and average lowest (AL) water table levels have been sourced from Gaast et al. (2010) and are shown in Figure 7 and Figure 8.

Distribution of fresh and salt groundwater

In terms of groundwater quality, the saline level is always the most important parameter. The saline level influences the physical behavior of the groundwater (flow density) and is of importance for ecology and agriculture. Freshwater can be found in the 1st aquifer in the agricultural area between the dune area and the Noordhollandsch Kanaal, to the east of the reactor location.

The borderline between fresh/brackish and saline groundwater is much deeper under the dunes, up to a few dozen meters below NAP. The borderline between freshwater (chloride concentration < 150 mg/L) and brackish (chloride concentration between 150 and 1500 mg/L) at the location of the PALLAS-reactor is above NAP -0.65 m. The borderline between brackish and saline (chloride concentration > 1500 mg/L) is expected to be slightly under NAP -32.71 m.

Surface water

Surface water can be divided into naturally occurring surface water and man-made surface water. The natural surface water in the vicinity of the reactor location comprises the North Sea and a number of dune lakes. The location of this surface water is shown in Figure 10.

- **North Sea**: The reactor location is situated approximately 750 m from the coastline. The seabed depth gradually increases to the west, reaching a depth of 25 m at approximately 25 km from the coastline. The closest water level measuring station is at Petten-Zuid at approximately 1 km from the coastline. In 2015, the average water level was

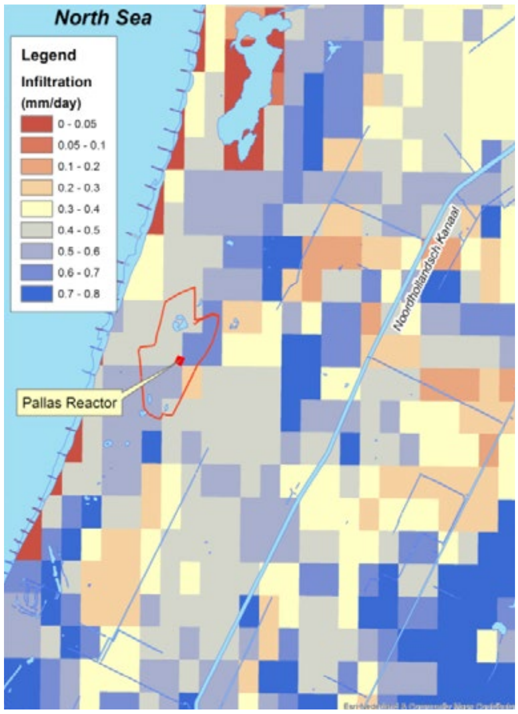

Figure 6 Average infiltration (1998-2006), based on the NHI

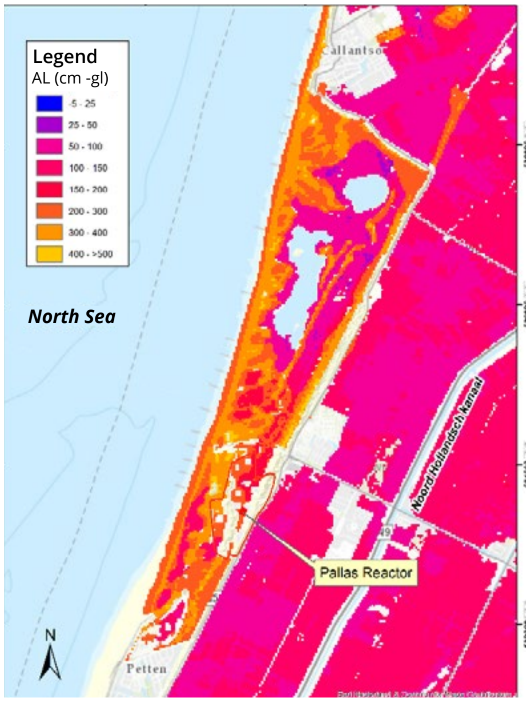

Figure 7 AL (average lowest water table) according to Gaast et al. (2010) in cm below water table (cm-gl)

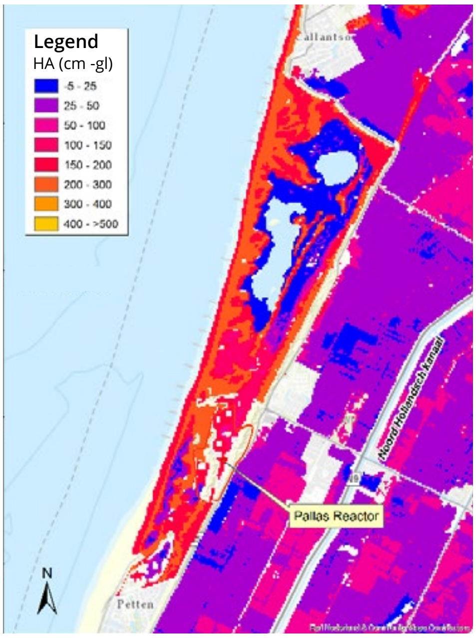

Figure 8 HA (highest average water table) according to Gaast et al. (2010) in cm below water table (cm-gl)

NAP +0.05 m. The 2015 5th and 95th percentiles of the sea water level were NAP -0.91 m and NAP +0.96 m, respectively. The seawater contains mainly dissolved salts. Sodium chloride (NaCl) accounts for nearly 70% of these salts. The remaining 30% mainly comprises chlorides (mostly magnesium and calcium chlorides). The chloride concentration is therefore regarded to be a suitable measure for total salt content of the sea water. The salt concentration in the North Sea varies as a result of the percentage of river water mixing with the sea water. Due to the outflow from rivers depending on the season, the distribution of the salt concentration also depends on the season. The salt concentration close to the coastline is approximately 30 g/L. The remaining part of the dissolved substances mainly comprises the chloride salt cations (Na, Mg and Ca).

- **Dune lakes**: The two largest lakes in the dune area are the Eerste Water and the Tweede Water, both of which are located in the Zwanenwater nature reserve to the north of the PALLAS-reactor location (Figure 10). The water levels in both lakes vary between NAP +2.4 m and NAP +2.8 m. The two lakes are interconnected, whereby water can flow from the Tweede Water to the Eerste Water. According to the HHNK, there has been sheet piling installed in the past, to the east of the Zwanenwater along the Westerduinweg, in order to limit seepage to the agricultural land. The water level of the two lakes is determined by the relationship between rainfall, evaporation and the volume of groundwater flowing to the North Sea and to the polders west of the dune area. At extremely high water levels, nutrient-enriched water can flow from the lakes to the easterly dune valleys. In order to limit this flow, the lakes are drained if the water levels exceed NAP +2.7 m for any length of time. The water is drained to the Uitlandse polder north of the Eerste Water.
- The dune lakes and smaller waters are mainly groundwater, fed by the phreatic groundwater in the surrounding dunes. This is confirmed by the water quality. Chloride concentrations in the Eerste and Tweede Water are between 120 and 160 mg/l. Seepage water rich in carbonates and iron is found in the Zwanenwater nature reserve.
- **Noordhollandsch Kanaal, watercourses and drainage**: The land to the east of the dune area is relatively low-lying (NAP +0.5 m to NAP -0.5 m) which is drained intensively via a system of watercourses and drainage. The agricultural land is assumed to be drained by means of drains at a depth of 1.1 m-gl. This takes place using drainage pipes and tertiary watercourses. The secondary watercourses collect this drainage water and transport it to the primary watercourses, which in turn have a more regional function in water transport. The Noordhollandsch Kanaal is the largest drainage canal in the area, which flows into the IJ river in Amsterdam in the south and into the Wadden Sea at Den Helder in the north. The canal is approximately 35 m wide and the water level is approximately NAP -0.50 to NAP -0.55 m. The water depth is approximately 3.5 to 3.7 m. The average chloride concentration of the canal water at these two measuring points is approximately 240 to 280 mg/l. There are however peaks in excess of 480 mg/l.

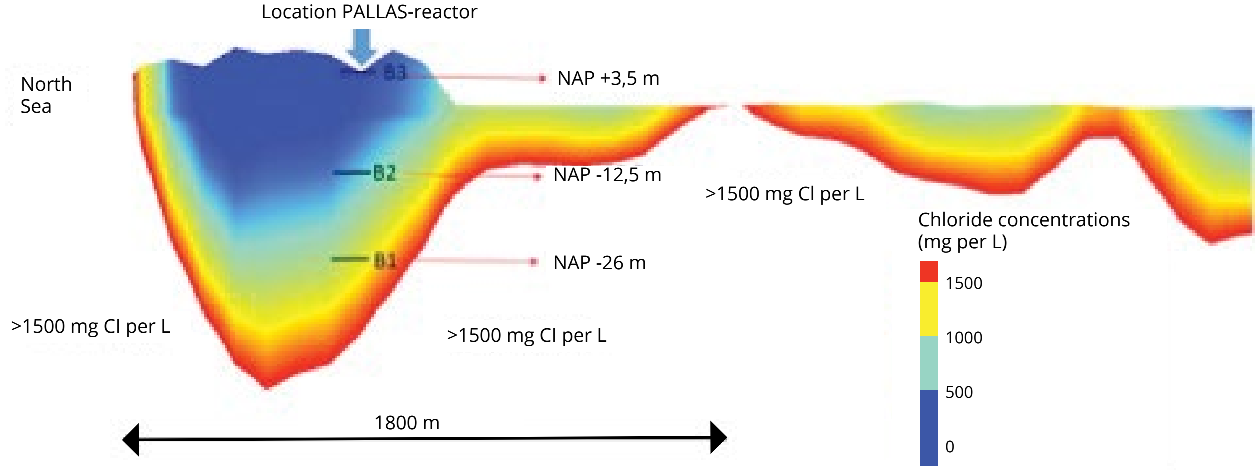

Figure 9 Average fluoride concentrations in groundwater at the nuclear island

Groundwater extractions

In order to keep (cellars and) buildings (buildings 13, 201 and 204) and pipelines dry in case of a high water table, groundwater is pumped up and discharged into the pond on the site. The maximum admissible extraction is 30m^3 per hour. In 2013, 2014 and 2015, the total volumes extracted were 9432, 5709 and 1490 m^3, respectively (ECN, VGM Annual reports 2013, 2014 and 2015). Leakage of water containing tritium into the groundwater was discovered in 2012. In 2013, 1,200 m^3 of groundwater contaminated with tritium was pumped up and disposed of. The Dutch Ministry of Economic Affairs took the intervention decision for final decontamination in 2014. This decontamination process was conducted in two phases: removal of the 'hot spots' by means of extraction of maximum 15 m^3 per day via two wells and a total of 21,900 m^3 in the first phase. From 2014 to 2019, a total volume of 5110 m^3 of groundwater was extracted via a single well during the second phase.

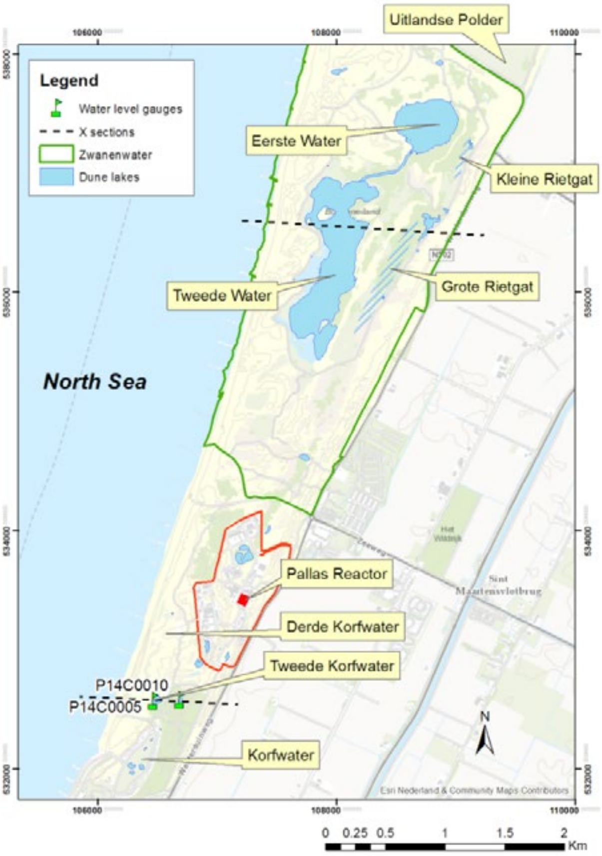

Figure 10 Location of the North Sea and dune lakes in the vicinity of the reactor location

The groundwater pumped up is stored in a buffer tank. The contents of this tank are regularly transported to the DWT in a tanker truck, where it is pumped to the basins of the water processing plant over a liquid-tight floor according to the routine procedure. Decontamination will be complete in 2019. The revised intervention decision by the Dutch Minister for Infrastructure and Environment has since come into force on 4 May 2017. The groundwater extraction process will be terminated due to the revised intervention decision by the Minister.

Excess rainfall

During the calibration period from 1996 through 2005, the excess rainfall based on the nearby meteorological stations in Petten (rainfall), Callantsoog (rainfall) and De Kooy (evaporation) ranged between 0.6 and 0.7 mm per day. In the previous five-year period, the excess rainfall was around 0.8 mm/day. The excess rainfall during the 1991 through 1995 period may have influenced the hydraulic head of the groundwater during the first years of the 1996 through 2005 calibration period. In large sections of the dune area, less evaporation is expected that has been measured at the meteorological stations, due to the water table in the dune area being mainly a number of meters below ground level. In the lower sections of the dune area, where the water table is close to ground level or surface water is fed by the groundwater, extra evaporation may take place. The initial value for calibration has been set at a rainfall excess of 0.8 mm per day for the dry land section of the model area. There is no excess rainfall model for the sea area.

Table 22 Current assessment of water quality in Holland coastline water body (Source: WFD fact sheet Holland coastline in (Department of Public works & Ministry of Infrastructure and Environment, 2015))

Quality element	Target	Assessment 2015	Explanation
Ubiquitous priority substances[11]	Dutch Water Quality and Monitoring Decree 2009 norms	Non-compliant	Norm exceeded for benzo(a)perylene and tributylin
Non-ubiquitous priority substances.	Dutch Water Quality and Monitoring Decree 2009 norms	Compliant	No norms exceeded
Specific pollutants	Regulation of Norms in WFD monitoring	Non-compliant	Norm exceeded for silver
General physical-chemical parameters • Winter DIN • Temperature (max) • Oxygen saturation	 ≤ 0.46 mg N/l ≤ 25°C ≥ 60%	Inadequate	DIN[12] (dissolved inorganic nitrogen inadequate, temperature and oxygen good)
Phytoplankton	EQR ≥ 0,60[13]	Good	
Macrofauna	EQR ≥ 0,60	Reasonable	

11 'Omnipresent' substances: substances no longer discharged, but expected to exceed the norm for a long period of time due to continued supply from the system.
12 DIN: Dissolved Inorganic Nitrogen.
13 Ecological Quality Ratio: measure of biological quality between 1 (maximum) and 0 (minimum).

8.2.1.2 Water quality

The current quality of the Dutch national waters has been recorded in the WFD fact sheets, which are part of the Management and development plan for Dutch national waters 2016 – 2021 (Rijkswaterstaat & Ministerie van Infrastructuur en Milieu, 2015). These are summarized in Table 22.

In the current situation, most of the quality elements do not yet comply with the applicable norms and targets. Exceptions are phytoplankton and the non-ubiquitous priority substances. The concentrations of a number of substances hinder compliance with norms and targets for the other quality elements covered by the (physical-chemical) water quality criterion. Within the group of biological quality elements, macrofauna is the only element to meet the targets. The WFD monitoring system does not include targets for other aquatic flora and fish in coastal waters.

When monitoring discharge of substances via cooling water, the current concentrations of active chlorine and (free available chlorine/ FO) and the most important conversion products (chloroform and bromoform) are relevant. These are shown in Table 23.

Table 23 Background concentrations of active chlorine, chloroform and bromoform

Substance	Background conc. North Sea	Source
Free available chlorine (FO)	0.0 µg/l	Not applicable (the highly reactive FO is converted directly into other compounds)
Trichloromethane (chloroform)	0.011 µg/l	Monitoring data from the Department of Public Works (Rijkswaterstaat)
Tribromomethane (bromoform)	0.011 µg/l	Monitoring data from the Department of Public Works (Rijkswaterstaat)[14]

8.2.1.3 Cooling water extraction and discharge

In the current situation, cooling water is extracted by the HFR from the Noordhollandsch Kanaal and discharged to the North Sea.

With a view to the enormous volume of water in the North Sea, there are no restrictions concerning availability for extraction of cooling water, and this is therefore not further described here. However, the volume and availability of freshwater from the Noordhollandsch Kanaal is relevant in relation to cooling variant K1. The average daily discharge of the Noordhollandsch Kanaal at the search area was 40,743 m^3/hour in 2015. Figure 11 shows the average daily discharge of the Noordhollandsch Kanaal at the search area.

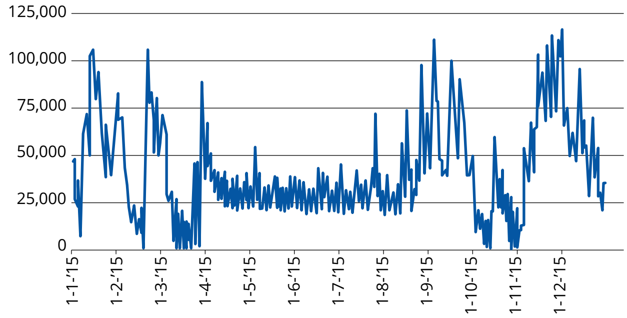

Figure 11 Average daily discharge (in m^3/hour) of the Noordhollandsch Kanaal at the search area

8.2.1.4 Soil quality

The 'ECN Energy Research Center of the Netherlands Site in Petten (planning area) is not governed by any specific regional policy in the *Soil management memorandum for the 'Kop van Noord-Holland*' region. The planning area is therefore not featured on the soil quality map, and the general framework of the Soil quality ruling applies to the location.

On the one hand, this means that the quality of soil or dredged materials to be used must comply with the maximum values of the function designated for the receiving soil, on the soil function classification map. On the other hand, the quality of the receiving soil must be examined to determine whether the quality of the soil or dredged materials to be used is superior or comparable. The final requirement regarding the use of soil will comply with the strictest requirement of this double survey. The planning area is classified as 'Industry', as shown in Figure 12.

Soil contamination

Figure 13 shows the locations for which soil quality data is available via the Noord-Holland Noord Regional Implementation Office.

PALLAS-reactor

Soil location 1 (Westerduinweg 3 in Petten) is relevant for this sub area. There is a great deal of soil information available for this location, due to (compulsory) soil surveys having been conducted for the purpose of: renovation and new construction on the site, applications for (revision) permits within the scope of the Dutch Environmental Act and follow-on studies due to detected contamination. Two cases of extensive soil contamination were detected in 2006, during an exploratory and supplementary soil survey, in combination with an asbestos survey, which have not (yet) been solved:

1. Extensive soil contamination with copper and zinc (42 m^3), around the HFR, probably caused by abrasive blasting of the HFR.
2. Between buildings 102 and 104, both the top surface and the subsurface are contaminated with asbestos. The weighted asbestos concentration far exceeds the intervention value of 100 mg/kg for asbestos.

A conducted risk assessment has shown that the current use of the location does not result in unacceptable risks as a result of the soil contamination. There is therefore no necessity to

14 The background concentration of chloroform and bromoform in the North Sea has been derived from monitoring data provided by the Department of Public works. For chloroform, these have been downloaded from http://live.waterbase.nl. The average of the measured concentrations at the 'Noordwijk 2 km from the coast' monitoring location, has been calculated for both substances. For chloroform, the available measuring values for the 2009 through 2014 period were used. For bromoform, the data provided for the January 2014 through June 2016 period were used. Values below the detection limit have been included as 'half value of the detection limit' (< 0.01 µg/l = 0.005 µg/l).

Figure 12 Soil function classes in planning area and surrounding area (Source: Interactive soil quality map of Kop van Noord-Holland)

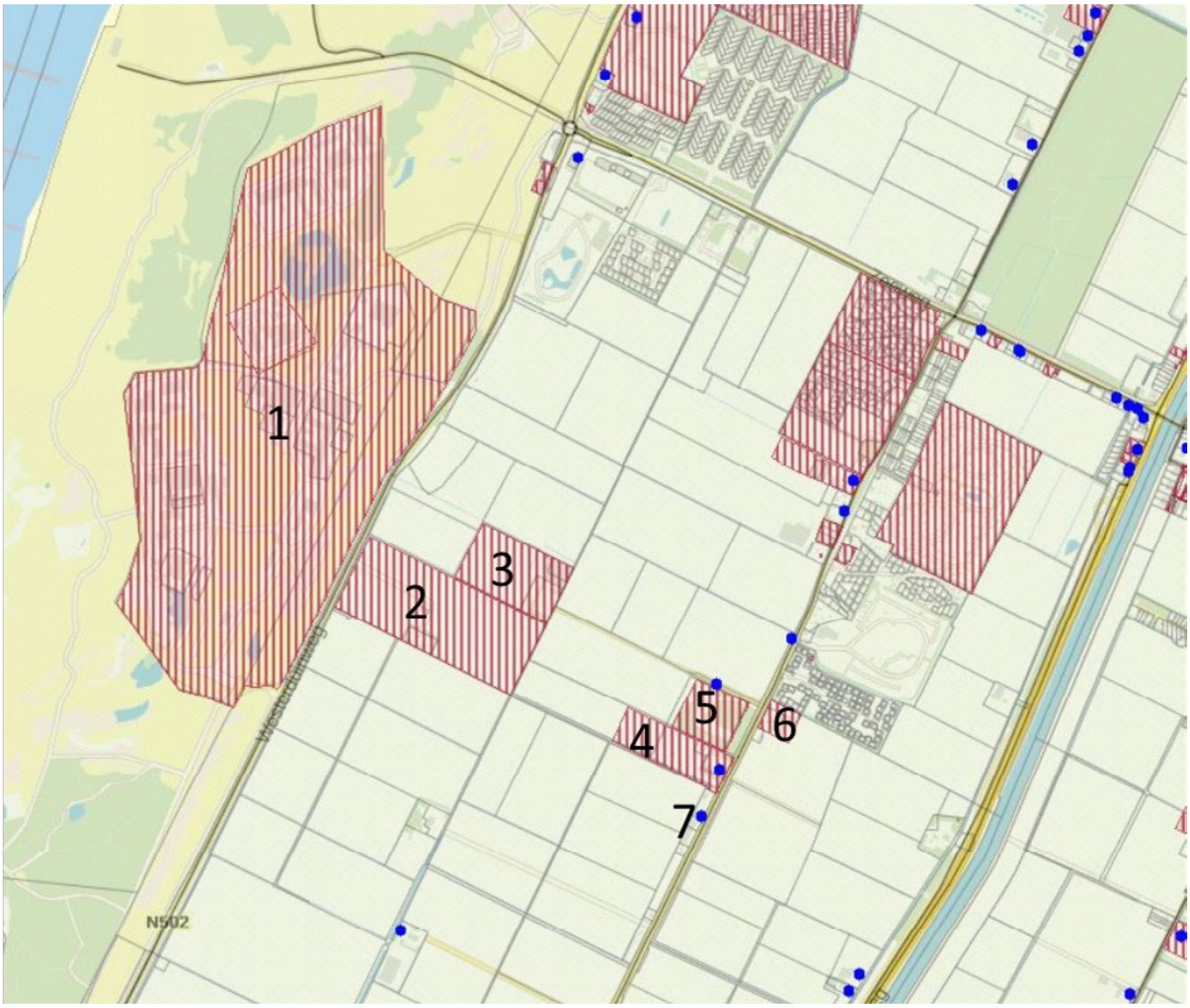

Figure 13 Registered soil locations Noord-Holland Noord Regional Implementation Office.

undertake decontamination. Both cases of soil contamination are situated on the NRG site and are therefore outside the scope of influence of the measures foreseen for realization of the PALLAS-reactor. It concerns immobile soil contaminants. The other soil surveys did not detect any current cases of extensive soil contamination (which have not yet been solved). There is, however, slight to strong contamination locally.
In 2012, strongly increased concentrations of tritium were measured in the groundwater in the soil around the HFR and surrounding area. The tritium contamination of the groundwater was the result of a leak in a transport pipeline, which transported water from the primary system of the HFR to a storage tank. This leak has since been repaired and decontamination of the 'tritium plume' has been underway since February 2013. The decontamination process is monitored by the ANVS Dutch Authority on Nuclear Safety and Radiation Protection. Periodical monitoring takes place to assess the current 'tritium plume'. The monitoring shows the scope of strong contamination to decrease as the result of groundwater decontamination efforts. There is limited spread of the plume (eastward).

Search area LDA
The following soil locations are situated in this sub area:

- Soil location 2 (Westerduinweg 22 in Sint Maartensvlotbrug): An exploratory soil survey was conducted at this location in 1999. The background level was exceeded for the topsoil, while all values remained below the background level for the subsoil and groundwater. As there is no strong contamination or any extensive soil contamination, no further survey is required.
- Soil location 3 (Belkmerweg 67 Sint Maartensvlotbrug): An exploratory soil survey was conducted at this location in 2001. The background level was exceeded for the topsoil, while all values remained below the background level for the subsoil and groundwater. As there is no strong contamination or any extensive soil contamination, no further survey is required.

Search area pipelines
Besides the soil locations in the sub areas of the PALLAS-reactor and LDA, there are 4 other soil locations within this sub area (4 to 7). The survey results do not indicate (potentially) extensive contamination.

8.2.2 Autonomous developments

The following paragraphs describe the autonomous developments relevant to each sub aspect.

8.2.2.1 Groundwater

Climate change
The autonomous developments in terms of groundwater and groundwater quality are mainly driven by climate change and rising sea levels. Changes in rainfall and evaporation influence groundwater supplementation and therefore the water table and groundwater quality. Rising sea levels will increase the intrusion of saline groundwater in the subsoil of the study area. In 2014, the KNMI Royal Netherlands Meteorological Institute sketched 14 climate scenarios for the future. These scenarios indicate that besides a temperature increase, the strong increase in rainfall volume during winter months (measured over the past century) will continue in the future. The risk of extensive summer drought will also increase towards the end of the century. However, all scenario calculations concur that in the event of rainfall, the intensity of summer showers will increase strongly in the future. Hailstorms and thunderstorms will also increase in intensity in all scenarios.
Greater intensity of rainfall will result in enlarged surface flow. In combination with higher temperatures and therefore greater evaporation, this can result in less groundwater supplementation from excess rainfall, which in turn will result in a lower phreatic water table in summer months. Additional rainfall during winter months can result in a higher winter and spring water table. The differences between the summer and winter water table will increase.
According to the climate scenarios, sea level rises will accelerate on the North Sea coast. Any discrepancies between the scenarios will mainly depend on the differences in global warming. Sea level rises will result in greater intrusion of seawater in the subsoil, while less freshwater may become available in the tillage layer[15] of the agricultural areas. The fresh/brackish water buffer in the dunes may also be less readily formed and retained.

Such developments will have limited impact for the timescale of the reference year 2026 and have therefore not been calculated or quantified.

Coastal defense works
Another development which may impact the groundwater regime in the study area, concerns reinforcement of the coastal flood defenses along the Hondbossche & Pettemer coastal defense structure. There is an artificially formed sandbank a few hundred meters wide along the sea side of this dike. This is expected to (temporarily) result in increased salinity of the groundwater and raised water table inside the dike. In summer 2015, the surface water in Petten was found to be more saline than in previous measurements, and HHNK and the municipality of Schagen immediately began flushing the water system. Research has since confirmed that the surface water in Petten has indeed become more saline due to the coastal flood defenses. It also became apparent that the flushing process caused the surface water in the adjacent polder R (to the east of Petten) to become more saline during a number of periods. HHNK has found a solution in consultation with the local farmers.
By March 2016, the water system in Petten will have been adapted so that the water once again has a normal salinity, without any outflow of extra saline water to Polder R. The highly saline water is diverted to the Hazepolder and the area to the south of Petten, where the increased salinity of the surface water due to the coastal defenses is not a problem. These areas (polders) have always been brackish and are a natural environment. The salt is not expected to be flushed out of the

15 The tillage layer is the top layer of soil in which most plant roots are formed.

coastal flood defenses sand for a number of years. Until then, HHNK will monitor the situation closely, to determine whether salt is still being flushed out of the coastal flood defenses. There is special attention for the bulb growing area.
The water table in the Korfwater in Petten has been monitored more closely since the construction of the coastal defenses, due to estimations that the level would rise here. Recent measurements have indeed indicated a locally raised water table. The problem will be solved by means of drainage.

Other developments
Groundwater is currently being extracted at the NRG site, as part of decontamination of a tritium contamination in the groundwater. This extraction process will be terminated, on the basis of the revised intervention decision by the Minister for Infrastructure and Environment, dated 4 May 2017.

8.2.2.2 Water quality
The Management and development plan for national Dutch waters 2016 – 2021 (RWS, 2015) gives a prognosis for the postulated water quality at the end of the 2016-2021 and 2022-2027 planning periods. This is shown in Table 24.
The Dept of Public Works expects (virtually) all quality elements to comply with the applicable norms and targets in 2027, with the exception of the ubiquitous priority substances. The concentration of benzo(ghi)perylene is still not expected to comply with the norm. Such non-compliant ubiquitous substances will be found in the aquatic environment, in concentrations which form a significant risk, for a number of decades to come, even if extensive measures have been taken to limit or terminate emissions. Such substances remain in the environment for a lengthy period due to their persistent character.
There are no known relevant autonomous developments with regard to concentrations of free available chlorine, chloroform and bromoform.

8.2.2.3 Cooling water extraction and discharge
The availability of water from the Noordhollandsch Kanaal can possibly change under the influence of climate change. In turn, this may influence the volume of cooling water available for PALLAS.
The decision lies with the HHMK regarding the volume of water which can be made available for PALLAS, given the development in the availability of water and developments in the use of water. The freshwater supply of the HFR currently has priority, after the drinking water supply and polder water level maintenance (to avoid subsidence and salinization). Nevertheless, should less cooling water prove to be available, this will have no impact on the safety aspect. The production capacity would however be reduced to a capacity which is workable for the available water. This is however an undesirable scenario, when considering the almost indispensable production of isotopes by the Netherlands. The situation regarding the planned exit point in the North Sea is considered to be stable for now, and no developments are foreseen.

8.2.2.4 Soil quality
As there is no need for decontamination within the sub areas, with the exception of the tritium plume, no changes are expected to occur in the autonomous development for the soil quality aspect.
There is an active decontamination obligation for the tritium plume, which must result in the following standards of decontamination by 2019[16]:

- maximum 100 Bq/l from the Research Location Petten site border outward.
- Maximum 100 Bq/l at the Research Location Petten site border outward.
- Maximum 400 Bq/l at the HFR and NRG site border, declining to 100 Bq/l at the Research Location Petten site border.
- 7400 Bq/l on the HFR site, declining to 400 Bq/l at the HFR site border.

Table 24 Prognosis for water quality in Holland coastline water bodies in 2021 and 2027 (Source: WFD fact sheet Holland coastline in RWS, 2015)

Quality element	Target	Prognosis 2021	Prognosis 2027
Ubiquitous priority substances	Dutch Water Quality and Monitoring Decree 2009 norms	Non-compliant	Non-compliant
Non-ubiquitous priority substances.	Dutch Water Quality and Monitoring Decree 2009 norms	Compliant	Compliant
Specific pollutants	Regulation of Norms in WFD monitoring	Non-compliant	Compliant
General physical-chemical parameters • Winter DIN • Temperature (max) • Oxygen saturation	 ≤ 0.46 mg N/l ≤ 25°C ≥ 60%	Inadequate	Good
Phytoplankton	EQR ≥ 0,60	Good	Good
Macrofauna	EQR ≥ 0,60	Reasonable	Good

16 Intervention decision based on art. 119 Dutch Radiation Protection Decree, 3 March 2014.

8.3 Environmental impact

8.3.1 Impact description

8.3.1.1 Groundwater

Construction phase

The principle is that the PALLAS-reactor will be constructed by means of the caisson method (variant B1) or in a pit with underwater concrete under the base of the pit (variant B2) to provide a dry work environment. No drainage is required in this situation (besides possibly a small open drainage system for discharge of rainfall and limited volumes of leakage water), there will be no reduction in the hydraulic head and a negligible change in the chloride concentration[17]. Brackish water will be removed according to statutory legislation, and will therefore not infiltrate the soil if it is overly saline. Working on this principle, there are no effective differences in the impact of the various variants. Model calculations have been conducted to determine the impacts, and this paragraph contains a brief description of the conclusions per assessment criterion.

The PALLAS-reactor construction pit will be built within sheet piling or slurry walling. These walls are virtually watertight and will become fully watertight upon completion of the PALLAS-reactor. Vertical flow is not expected over these walls. The situation for piles may be different, depending on the type of pile used. This may result in desalination in the aquifer under the Holocene deposits.

As far as the risk of leakage is concerned, the following applies:

- Construction height variant B1 is excavated in a wet work environment, with caissons being sunk. The hydraulic pressure is balanced inside and outside the sheet piling, and leakage can therefore by definition not occur.
- Construction height variant B2 is also excavated in a wet work environment. Upon reaching the required depth and following drilling of the foundation piles, underwater concrete is poured and the construction pit pumped dry. This can result in leakage, either through the slurry walls themselves or via the connection to the underwater concrete. Grout anchors may also be used, requiring drilling through the walls. The use of valves should prevent any leakage, but the water pressure always involves a risk.
- Construction variant B3 will be built on ground level, with foundation piles being sunk to approximately NAP -30 m. Theoretically, leakage current (short-circuit current) could occur along the piles between aquifers.

The construction of the cooling water pipeline depends on the choice of variant for cooling water supply and discharge. If cooling water is extracted from the Noordhollandsch Kanaal, a trench must be dug or drilling must occur between the Noordhollandsch Kanaal and the nuclear island. When extracting cooling water from the North Sea and discharging to the North Sea, excavation or drilling is also an option. Temporary drainage will be required in order to excavate the trenches. The drainage system between the PALLAS-reactor and the Noordhollandsch Kanaal will have a limited and temporary impact on the water table in the surrounding area, and will not result in salinization. There may, however, be damage to crops, depending on the season. Drainage of an open trench between the PALLAS-reactor and the North Sea will have great impact on the water table (lowering it 5 cm or more, up to hundreds of meters). This will then impact the vegetation and may result in displacement of the tritium contamination.

The following conclusions have been drawn per assessment criterion:

- Vegetation: As long as there is no drainage, the scenario calculations show that there will be no impact on dune valleys, low-lying wet locations or the seepage zone to the east of the dune area. Trench drainage for construction of the cooling water pipeline may have a temporary, great impact on the phreatic water table and thereby the vegetation.
- Buildings: The PALLAS-reactor location is surrounded by a number of other buildings. This concerns building 204 at approximately 50 m distance. Other buildings are further away. No impact is expected at the location of these buildings, as long as there is no drainage of the reactor location. Trench drainage for construction of the cooling water pipeline may have a temporary impact on the water table. The consequences for subsidence at the location of existing buildings can only be calculated once the exact location and construction method of the pipeline are known.
- Dunes as part of the primary flood defenses: As long as the PALLAS-reactor is constructed without drainage, there will be no subsidence impact on the primary flood defenses. Trench drainage for construction of the cooling water pipeline may have a temporary impact on the water table. The consequences for subsidence at the location of the primary flood defenses can only be calculated once the exact location and construction method of the pipeline are known.
- Agriculture: As long as the nuclear island is constructed without drainage, there will be no impact on the agricultural area. Trench drainage for construction of the cooling water pipeline may result in crop damage, depending on the season.
- Groundwater extraction or infiltration systems:
  - The closest groundwater system concerns the management system for the tritium plume at least 100 m to the north of the nuclear island. This system is expected to be discontinued, as a result of the revised intervention decision of May 2017.
  - The vertical heat exchanger is located approximately 500 m north of the nuclear island. This extraction would only be influenced if the reactor location is constructed making use of large-scale drainage. This is not expected to be the case, and there is therefore no expected impact on the vertical heat exchanger.
  - There is a third groundwater system at the location of buildings 13 and 204. Building 204 is located approximately 50 m away from the reactor location. In order to keep (cellars) of buildings (13, 201 and 204) and pipelines dry in case of a high water table, groundwater

17 In order to gain insight into the impact in the case of excavation of the construction pit taking place within sheet piling, whereby the pit is kept dry by means of pumped drainage, the drainage scenarios are discussed in appendix 2 " Impact of construction drainage on groundwater".

is pumped up and discharged into the pond on the site. As long as the nuclear island is constructed without drainage, no impact is expected on this system. Trench drainage for construction of the cooling water pipeline may have a temporary impact on the water table. The consequences for existing water table systems can only be calculated once the exact location and construction method of the pipeline are known.

- Mobile contaminants: The closest mobile contamination concerns the tritium plume at least 100 m to the north of the reactor location. The assumption is made that there will be very limited or no drainage at all during the construction phase, and therefore no influence on the plume or the management system. Trench drainage for construction of the cooling water pipeline may have a temporary impact on the water table. This may result in displacement of the tritium contamination. Depending on the spread of the tritium plume at the time of drainage, drainage of a pipeline trench between the pump building and the Noordhollandsch Kanaal may influence the spread of the plume.

Transition phase and operating phase

Chloride concentrations

The impacts will be assessed per construction height variant. The impacts as a result of upward pressure and lowering of the hydraulic head and water table on the chloride concentrations, have been calculated for the operational phase. The design includes the possibility for an extraction drain on the upstream side of the nuclear island and an infiltration drain on the downstream side. The impacts of these provisions are shown hereafter.

Water table and hydraulic head levels

■ Groundwater flow blockage

The partially sunken construction of the nuclear island forms a blockage for the more or less eastward flow of groundwater. This will raise the water table and hydraulic head to the west of the building and cause the water table and hydraulic head to fall to the east of the building. In order to reduce this impact where possible, a drain has been foreseen at approximately the height of the highest naturally occurring water table (approx. NAP +1.6 m) on the upstream side of the building, in construction height variants B1 and B2. This drain will prevent upward pressure on the phreatic groundwater. On the downstream side of the building, the water will be infiltrated via another drain. This will result in very slight lowering of the phreatic water table on the southern and eastern sides of the building. The impact on the visualized hydraulic head is negligible, at only a few millimeters. Construction height variant B3 will not result in blockage of the groundwater flow.

Cooling variant K1b assumes a gravity flow water supply from the Noordhollandsch Kanaal. The drilled pipelines will run to a pumping station constructed to a depth of NAP -11.5 m at the Research Location Petten for that purpose. The pumping station will be constructed within sheet piling to a depth of NAP -18 m. This cooling variant will therefore result in an extra blockage of the groundwater flow. Cooling variants K2 and K3 have no impact on the groundwater flow.

■ Hydraulic head

The pumping station has a very limited impact on the phreatic water table in the deepest lying variant K1b. A larger fall in the phreatic water table, of up to 13 cm, will occur to the east of the pumping station. This (extra) fall will only occur within the developed area of the Research Location Petten. At NAP -12.5 m, the pumping station has hardly any extra influence on the hydraulic head. The upward pressure and lowering of the hydraulic head around the nuclear island is the same as without the pumping station, though the lowering impact reaches slightly further south.

The foundation piles will possibly intersect the poorly permeable layers at depths between NAP -15 and NAP -28 m (the Kreftenheye, Boxtel and Eem Formations). In this variant however, the foundation piles will be constructed within a diaphragm wall sunk to approximately NAP -60 m. The calculations show that any groundwater flow within these diaphragm walls will be so limited that any leakage along the foundation piles will not affect the water table, hydraulic head levels or chloride concentrations.

The foundation piles sunk to NAP -30 m will possibly intersect the poorly permeable Holocene layers at depths between NAP -2 and NAP -10 m and NAP -15 to NAP -28 m (the Kreftenheye, Boxtel and Eem Formations).[18] This could theoretically result in short-circuit flows between the phreatic and the groundwater in the deeper aquifers.

The phreatic water table is higher than the hydraulic head in the underlying aquifers. The hydraulic head above the poorly permeable layers of the Boxtel, Kreftenheye and Eem Formations is also slightly higher than the hydraulic head beneath these layers. Any short-circuit currents would therefore cause a vertical flux. A flow from the phreatic aquifer layer to the underlying aquifer will result in slight desalination of the aquifer around the locations of the short-circuit currents. However, this desalination is less than 1 mg/l and therefore insignificant. The reduction in the phreatic water table due to the vertical flux is also insignificant (a number of millimeters at most).

The same applies to the fluxes between the aquifers under the phreatic aquifer. The hydraulic heads would be in significantly influenced (a number of millimeters at most) and the impact on the chloride concentrations is less than 1 mg/l.

Other impacts:

- Vegetation (dehydration, salinization): the phreatic water table in the dunes to the east of the nuclear island will fall by 1 to 5 cm. This will not have a negative impact on the ecological values there (see Nature, section 13).
- Buildings (risk of subsidence damage): the impact on the water table and hydraulic head is so limited that no risk of

18 The foundation plan is not yet known, but vibro-piles are assumed to be used, whereby a steel casing is first driven into the ground, or inserted into a pre-drilled hole. This casing is then filled with reinforcement steel and concrete, after which the casing is retracted. Retraction of the casing can theoretically result in slight leakage in the poorly permeable clay layers, due to sand flowing into the gaps between foundation piles and the clay.

subsidence is expected.
- Dunes as a component of the coastal defense structure (risk of subsidence): the impact on the water table and hydraulic head is so limited that no risk of subsidence is expected.
- Agriculture (dehydration damage, salinization damage): there will be no change in the level of the water table in the agricultural area to the east of the PALLAS-reactor.
- Groundwater extraction or infiltration systems: the water table will rise at buildings 201 and 204. Additional water will be extracted as a result of the water management measures at this location. The extra volume to be extracted is extremely limited, resulting in a limited negative impact.
- Mobile contamination (influence on control measures): the tritium contamination is outside the scope of influence (the 5 cm contour) of raised or lowered levels of the water table.

8.3.1.2 Water quality

The water quality will only be influenced during the transition and operational phases. This sub-aspect has therefore not been assessed for the construction phase.

Transition phase and operating phase

(Physical) chemical water quality

The only negative impact to be expected on the (physical) chemical water quality due to discharge of cooling water, is as a result of chlorination. The assessment is based on discharge of free available chlorine and the conversion products bromoform and chloroform.

The emission-immission test was used for this purpose. This instrument is used to assess the impact of a specific residual discharge (following application of the best available techniques) on water quality and the admissibility of the discharge, according to the system of the Dutch Immission Test Guide (Dutch Min. of Infrastructure and the Environment, 2016)

K1 and K2 do not comply with the emission-immission test for free available chlorine (FO). However, it should be noted that these results were calculated using a conservative discharge concentration of 0.2 mg/l (daily average). This is the admissible concentration upon monitoring directly behind the condenser / heat exchanger. In practice, free available chlorine in the cooling water system will almost immediately react with other compounds with which it has contact. The actual average discharge concentration is therefore expected to be lower than the (currently admissible) value deployed. Furthermore, the residual free available chlorine will disperse extremely quickly upon discharge in the sea and will no longer be traceable. The test module does not take account of this, but rather assumes conservative (non-reactive) substances.

All cooling variants comply with the effluent test for bromoform and chloroform. In other words, the concentration of the substance in the cooling water to be discharged is lower than the water quality norm. Further testing is no longer necessary in that case. The norms applied for both free available chlorine (FO) and bromoform have no statutory status and are therefore purely indicative.

Biological water quality

The assessment of impact on the biological water quality follows the system of the 'Testing framework for water quality' (appendix 5 of the Management and development plan for Dutch national waters 2016-2021). This is the framework deployed by the Department of Public Works for assessment of the ecological impact of physical interventions in the water system. The testing framework has a general section and a section for specific types of water. Depending on the results of the general section, the section for a specific water type must also be conducted. The assessment concerns the impact of installation of the discharge construction (pipeline and discharge point) on the state of phytoplankton and macrofauna. Other potential ecological impacts are assessed within the 'nature' aspect.

Although the details of the discharge construction and method of insulation are not yet known, the general section of the testing framework can be conducted. This results in the following findings:

a There is indeed an intervention within the delineation of the water body.

b The intervention is not designated a permit-free activity of insignificant ecological importance for the North Sea.

c The intervention has not only a positive impact on the ecological water quality (there can potentially be a negative impact locally/temporarily).

d The intervention has no negative impact on the scope of a planned or already conducted Water Framework Directive measure.

Following the general section of the testing framework, the specific section for a type of water must also be conducted. This results in the following findings:
- 2-I: A negative impact on macrofauna and phytoplankton cannot be excluded beforehand.
- 2-I: There is no ecologically relevant area for macrofauna in the vicinity of the planning area[19]. The intervention is therefore not assessed as relevant for macrofauna.

No ecologically relevant area has been defined for phytoplankton, primary production (growth of phytoplankton) can take place throughout the water column, as long as there is sufficient availability of light and nutrients. Physical interventions can mainly be relevant if they may result in strong turbidity and therefore reduced light penetration. Any impact on the visibility in the Holland Coastline water body caused by installation of the discharge pipeline and discharge construction, will only be local and temporary during the installation process.

Any impact on the primary production of phytoplankton is therefore expected to be negligible. There is therefore also no reason to expect a negative impact on the phytoplankton.

8.3.1.3 Cooling water extraction and discharge

Transition phase and operating phase

Cooling water extraction

Cooling variant K1 will result in additional extraction of maximum 3150 m^3 water per hour from the Noordhollandsch Kanaal during the transition phase. During the operational

19 Based on the digital area map of the Department of Public Works (map layer 'water service potential area - Area Mafauna' at http://www.rijkswaterstaat.nl/apps/geoservices/mapviewer2i/).

phase, the cooling water consumption will increase by 25 m water per hour, due to the PALLAS-reactor requiring slightly more cooling water than the HFR (3125 m^3/hour).
Seawater extracted for cooling in cooling variant K2, is subsequently discharged back into the sea. During the operational phase, less water will be extracted from the Noordhollandsch Kanaal versus the situation in which the HFR is in operation.
Cooling variant K3 does not extract any water from either the Noordhollandsch Kanaal or the North Sea. During the operational phase, less water will be extracted from the Noordhollandsch Kanaal versus the situation in which the HFR is in operation.

Cooling water discharge
In order to check whether the cooling water discharge has a significant impact, the following formula has been applied, which is used as a simple test of cooling water discharges:
Formula 1:
Mixingzone (T >25°C) =

$$Q_{cooling\ water}/Q_{outfall} \cdot (1+ T_{discharge}-SR)/(SR- T_{intake})$$

Whereby:
- SR = 25 °C (Serious Risk level for saline water).
- T = Temperature in Celsius.
- Q = Flow in m^3/s

The mixing zone concerns that part of the cooling water plume with a temperature of 25 degrees or more. The mixing zone stops at the point where the cooling water plume has been cooled to less than 25 degrees (the SR level).
The formula does not represent what actually occurs in the surface water. It is an overestimation of the scope of the mixing zone, in order to render the formula effective as a quick test. If the scope of a mixing zone calculated by means of the formula complies with the set maximum of 25% (0.25 in the formula), this means that the heat discharge complies with the requirements for the mixing zone.
No further numerical model research is then required for the permit procedure within the scope of the Dutch Water Act. For that matter, numerical model research may be required after all, if the ecological impact assessment shows additional quantitative information to be required on the cooling water plume. However this does not appear to be the case (see paragraph 13.4.1).
As the width of the water system cannot be as clearly defined in the open sea as in a river, canal, harbor or estuary, an assumption has been made for this purpose. The initial assumption is 10 m (equal to twice the water depth), so that the discharge flow (speed x width x depth) equals 79 m^3/s. Insertion into the mixing zone formula results in values ranging from 0.0222 to 0.142, which are well under the critical 0.25 level. The critical 0.25 level is not exceeded until a fictional value of less than 6 m is assumed for the width. The same applies if the seawater temperature were to exceed 24°C. In combination with a conservative assumption for the discharge temperature of 47.5°C, there is leeway in the assessment to absorb these risks.
The second aspect which plays a role in assessing a cooling water discharge is the principle that the mixing zone of the cooling water plume must not reach the seabed. This must be a principal in the design and optimization of the cooling water outfall system (height above the seabed, size of outflow opening, angle of outflow, possible use of diffusers).

8.3.1.4 Soil quality

Construction phase
Cases of serious soil contamination, in relation to planned spatial interventions, must be decontaminated in accordance with a formal notification according to the Dutch Soil Protection Act (articles 28 and 39 (regular decontamination plan) or article 39b of the Dutch Uniform Remediation Decree. New cases of soil contamination are covered by the duty of care principle, resulting in compulsory decontamination measures being required in order to remove the contamination as completely as (reasonably) possible. The Dutch Soil quality ruling, as detailed in the Soil management memorandum for the 'Kop van Noord Holland' ensures that the quality of soil or dredged materials to be used must comply with the maximum values given in the soil function classification map. The quality of the receiving soil must also be examined to determine whether the quality of the soil or dredged materials to be used is superior or comparable. The final requirement regarding the use of soil will comply with the strictest requirement of this double survey.[20]

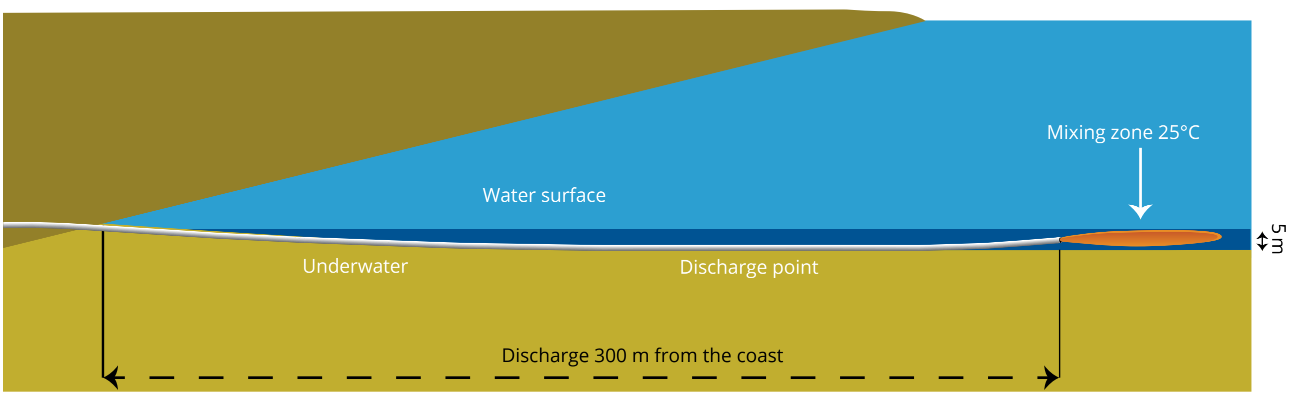

Figure 14 Schematic representation (bird's eye view) of cooling water discharge in the sea

20 A particularized testing framework can possibly be used in the case of large-scale soil applications, as detailed in the Soil management memorandum for the 'Kop van Noord Holland', Paragraph 4.2 and appendix 2.

Based on these statutory and policy frameworks, it can be concluded that the proposed developments have no negative impact on the soil quality. On the contrary: at locations of (possible) decontamination, there is by definition an improvement in the soil quality.

8.3.2 Impact assessment

The impact assessment is given per sub aspect in the following paragraphs.

8.3.2.1 Groundwater

Construction phase

During the construction phase, it is apparent that only cooling variants K1 and K2 will have an (extremely) negative impact on vegetation, agriculture and mobile contaminants (see explanation in paragraph 8.3.1.1). The construction height variants do not result in any negative impact and are therefore assessed as neutral (0). (Table 25)

Transition phase and operating phase

During the operational phase, only the construction height variants B1 and B2 will have a negative impact on the vegetation and groundwater extraction or infiltration systems (see paragraph 8.3.1.1). The other height variant does not result in any negative impact and is therefore assessed as neutral (0). (Table 26)

8.3.2.2 Water quality

Construction phase

There will be no cooling water discharge during the construction phase, and therefore no impact on the water quality due to cooling water discharge.

Transition phase and operating phase

The impact of the transition phase and the operational phase on the chemical and biological water quality is assessed hereafter (see paragraph 8.3.1.2).

Physical-chemical water quality

The assessment per construction height and cooling variant is shown in Table 27 The discharge of substances via the cooling water is assessed as neutral (0) for cooling variants K1 and K2. The assessment using the emission-immission test shows the discharge of bromoform and chloroform to comply in all variants, due to the discharge concentrations being lower than the norm. This does not apply in the case of discharge of free available chlorine, but this discharge is not assessed as negative due to the reasons given in paragraph 8.3.2.1.

Biological water quality

The assessment according to the Testing framework for water quality shows no negative impact to be expected on the macrofauna and phytoplankton quality elements, as a result of the installation of the pipeline and discharge construction

Table 25 Impact assessment on Groundwater, construction phase[21]

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Vegetation	0	0	0	- -	- -	0
Buildings	0	0	0	0	0	0
Dunes as part of the coastal defense	0	0	0	0	0	0
Agriculture	0	0	0	-	-	0
Groundwater extraction or infiltration systems	0	0	0	0	0	0
Mobile contaminants	0	0	0	- -	- -	0

Table 26 mpact assessment on Groundwater, transition phase and operational phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Transition phase and operating phase						
Vegetation	0	0	0	0	0	0
Buildings	0	0	0	0	0	0
Dunes as part of the coastal defense	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0
Groundwater extraction or infiltration systems	-	-	0	0	0	0
Mobile contaminants	0	0	0	0	0	0

21 The principle is that no drainage takes place. If drainage does take place, B1 and B2 both score negatively for all user functions. The score is even extremely negative for Vegetation, Groundwater extraction systems and Mobile contamination. See also appendix 2.

Table 27 Impact assessment on Water quality

Assessment criterion	B1	B2	B3	K1	K2	K3
Transition phase						
Physical-chemical water quality	n/a	n/a	n/a	0	0	n/a
Biological water quality	n/a	n/a	n/a	0	0	n/a
Operational phase						
Physical-chemical water quality	n/a	n/a	n/a	0	0	n/a
Biological water quality	n/a	n/a	n/a	0	0	n/a

(during the operational phase) (0). There is no differentiating impact for the various cooling variants defined in assessment criterion 1 (Table 27).

8.3.2.3 Cooling water extraction and discharge

Only the transition and operational phases are relevant with regard to cooling water, as the PALLAS-reactor does not require cooling water during the construction phase.

Transition phase and operating phase

Cooling water extraction

In cooling variant K1, cooling water will be extracted from the Noordhollandsch Kanaal by both the HFR and the PALLAS-reactor, during the transition phase. There will therefore be an increase in the volume of cooling water extracted in the transition phase, for variant K1. This will require a doubling of the cooling water extraction from the Noordhollandsch Kanaal, which is assessed as extremely negative (- -).

In the operational phase, there is a potential increase of cooling water extraction in variant K1. The maximum cooling water extraction for the PALLAS-reactor is 3150 m^3 per hour versus a maximum of 3125 m^3 per hour for the HFR. This potential increase in water extracted from the Noordhollandsch Kanaal is less than 5% and is therefore assessed as neutral (0).

Cooling variant K2 is assessed as neutral (0) during the transition phase and very positive (+ +) during the operational phase. By moving the cooling water extraction from the Noordhollandsch Kanaal to the North Sea, cooling water extraction is reduced by more than 50% (namely by 100%).

Cooling variant K3 is assessed as neutral (0) during the transition phase and extremely positive (+ +) during the operational phase. The air cooling variant will not require water to be extracted from the sea or from the Noordhollands Kanaal.

During the operational phase, it will have a positive impact due to water not being extracted from the Noordhollandsch Kanaal, which means that cooling water extraction is reduced by more than 50% (namely by 100%).

This assessment is summarized in the table below.

Cooling water discharge

In all cooling variants, the mixing zone remains limited to less than 5%. Their impact is therefore assessed to be neutral (0). The impact assessment is shown in the table below.

8.3.2.4 Soil quality

As stated earlier, only the construction phase is relevant in terms of the soil quality sub aspect.

Construction phase

The impact assessment is shown in table 29.

The following conclusions can be drawn from the overview of the sub areas and the soil locations in those sub areas.

- In the sub areas: 'PALLAS-reactor' and 'LDA', there are no known cases of serious soil contamination. Based on this information, no decontamination measures will be required for future developments, so that there is no impact on the (future) soil quality (score: 0).
- In the sub area: 'Pipeline search area', two cases of serious soil contamination are known to exist on the NRG site. As it is not yet known whether these cases of serious soil contamination will be 'affected' by a proposed new pipeline, the assumption is made for the time being that no decontamination measures will be required as a result of the proposed developments within the 'Pipeline search area'. There is therefore also no impact on the (future) soil quality in this sub area (score: 0).

Table 28 Impact assessment on Cooling water extraction and discharge

Assessment criterion	B1	B2	B3	K1	K2	K3
Transition phase						
Cooling water extraction	n/a	n/a	n/a	- -	0	0
Cooling water discharge	n/a	n/a	n/a	0	0	0
Operational phase						
Cooling water extraction	n/a	n/a	n/a	0	++	++
Cooling water discharge	n/a	n/a	n/a	0	0	0

Table 29 Impact assessment on Soil quality

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Soil quality	0	0	0	0	0	0

8.4 Mitigating measures

The following paragraphs describe whether mitigating measures are required, per sub aspect, and which measures may need to be considered.

Groundwater

The (limited) impact caused by upward pressure and lowering of the phreatic water table can be mitigated by installing a drain to the west of the nuclear island and re-infiltrating the water on the eastern side via an infiltration drain.
The trench drainage for the inlet and outlet to the North Sea will have great impact on the phreatic water table in the dune area. The exact impact will need to be determined once the drainage advice and plan have been formulated and the route, depth, duration and installation technique is known (permit phase). The impact on the phreatic water table can probably be largely or entirely prevented by excavating the trench within sheet piling. The sheet piling will need to be sunk down to the poorly permeating Holocene deposits under the dune sand. The impact of drainage of a trench for a cooling water pipeline between the Noordhollandsch Kanaal and the pumping station cannot be precisely determined until a decision has been taken on the pipeline route and the execution period is known. The impact will be described in the drainage advice and plan in the event of such drainage.

Water quality

Cooling of the PALLAS-reactor using canal water or seawater is not expected to have a negative impact on water quality. No mitigating measures are required therefore.

Cooling water extraction and discharge

During the transition phase, cooling variant K1 may require additional extraction of water from the Noordhollandsch Kanaal, of maximum 3150 m^3/hour. The additional extraction may prove to be lower in practice, due to the maximum extraction not always taking place. The possibilities for limitation of the absolute extraction by the HFR and the PALLAS-reactor can be considered in more detail in the EIA.
The HFR has priority status. In the hierarchy, the PALLAS-reactor has priority directly after the drinking water supply and polder water level maintenance (to avoid subsidence and salinization) (Dutch Water distribution and Drought Manual 2016). During the transition phase, there will be greater demand for cooling water than the current reservation[22] as there will be times at which PALLAS and the HFR have simultaneous cooling requirements.
In case of drought, both the PALLAS-reactor and the HFR can be switched off. Within a few seconds, the cooling capacity can be reduced to 10% of the maximum, after which the cooling capacity can be gradually further downscaled if necessary. By switching off PALLAS and the HFR, there will always be adequate cooling water from the Noordhollandsch Kanaal during the transition phase, even in the event of drought. However, switching off the reactors has consequences for the isotopes production and a negative financial impact.
Mitigating measures are not applicable, seeing as the discharge of cooling water is not expected to have any negative effect. There are various ways of ensuring the mixing zone does not reach the seabed, during design of the cooling water outlet system. By, for example:

- Locating discharge points higher above the seabed.
- Varying the size of the outflow openings.
- Varying the angle of outflow.
- Using diffusers.

Soil quality

Mitigating measures are not applicable, seeing as no negative effects can be expected. Any extensive cases of soil contamination must be decontaminated which contributes in a positive manner to soil quality. Decontamination measures cannot yet be excluded, seeing as the cooling water route has not yet been determined and there is no comprehensive picture of the soil quality in the search area.

8.5 Gaps in knowledge

Groundwater

No impact is expected at the location of the buildings at the Research Location Petten, as long as there is no drainage of the reactor location. For control purposes however, we recommend the installation of a monitoring well, along with height benchmarks in order to observe any effects.
The saline content is the most important parameter for the quality of groundwater. The saline level influences the physical behavior of the groundwater (flow density) and is of importance for ecology and agriculture. However, there is limited availability of direct monitoring data for the current saline distribution, so that this is a gap in the knowledge.
Further research is not considered necessary to address this lack of knowledge. All available data have been used for groundwater modeling. The installation of deep monitoring wells in the dune area in order to gather more direct mon-

22 The reservation for the HFR is 0.9 m^3 / second (3240 m^3 / hour).

itoring data, may possibly damage the dunes. This must be weighed up against the added value of monitoring.
The impact of a possible pipeline trench through the dunes and through the agricultural area between the Noordhollandsch Kanaal and the pumping station can only be precisely determined when any pipeline routes, construction depths and execution period are known. For the purpose of the drainage advice and plan, the freshwater-saline ratio of the groundwater will need to be determined in the route to be drained, as well as the saline content of nearby surface waters such as ditches in the agricultural area.

Water quality
The design for the new discharge point to be constructed for the PALLAS-reactor has not yet been worked out in detail. Part of the data required to assess the impact of the discharge has therefore been estimated, based in most cases on the HFR. The final situation may therefore deviate slightly from the assessed situations. Due to the assessment working on the basis of a worst-case approach, this will not result in differing test results (with a negative assessment).

Cooling water extraction and discharge
The additional extraction of water from the Noordhollandsch Kanaal by cooling variant K1 during the transition phase, translates as 15% of the average daily discharge[23] into the Noordhollandsch Kanaal at the location of the future reactor. The additional extraction is temporary and only applies during the transition phase. During the operational phase, there is actually potentially less extraction of water.
The Water Authority for Northern Holland (HHNK), the Authority on Nuclear Safety and Radiation Protection (ANVS) and the Noord-Holland Noord Safety Region (NHN) have requested attention for climate change, which will affect the freshwater supply in the future. The freshwater supply of the HFR is currently priority number 3, following the drinking water supply and polder water level maintenance. The scenario of a possible decrease in the freshwater buffer in relation to the PALLAS extraction in the future has not been explicitly considered in this SEA, but does deserve attention in the EIA. There should also be consultation with the Water Authority for this purpose, before making any further choices regarding the form of cooling.
The calculated mixing zone of the cooling water discharge remains under the critical level, and therefore does not require a model study within the scope of the Dutch Water Act. The mixing zone must not come in contact with the seabed, due to possible impact on seabed life. This exit point has not yet been detailed in the design. The discharge point will require further detailing in due time, for the purpose of the EIA and the permits.

Soil quality
The soil quality of the sub areas has been assessed from previous soil surveys. These surveys were not prompted by the planned developments, so that there is no comprehensive insight into the soil quality. The number of locations containing soil contamination may therefore possibly be underestimated. The 'Pipeline search area' does not yet concretely cover the proposed pipeline routes. It is therefore unclear whether the two extensive cases of soil contamination will be 'affected' by the future developments.
As the (decontamination of) soil contamination is assessed as 'positive', a possible underestimation of the number of cases of soil contamination results in a worst-case impact assessment. The gap in knowledge therefore has no unfavorable consequences regarding the impact score and thus is not relevant for the decision-making process.

23 Based on daily averages in 2015.

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9 Water safety

The following description of the Water safety aspect is based on the Water safety background report (see Appendix F4).

9.1 Assessment framework

9.1.1 Policy framework

Table 30 summarizes the relevant policy and relevant legislation and regulations for the Water safety aspect, along with an indication of their relevance for the project. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Water safety.

Table 30 Policy, legislation and regulations on Water safety

Policy plan, law, regulation	Description/ Relevance for PALLAS
Statutory Assessment Tools, Dutch government	This concerns a sandy coastal defense. The test method of the TRDA (Technical Report on Dune Erosion) dating from 2006, will be used, the TRDA2006 [10]. The hydraulic load to be applied (sea levels and wave pounding) is given in the HP2006 [11]. This concerns the calculation of values which result in a degree of dune erosion for which there is a 1/100,000 risk of it being exceeded annually, at a calculated level of NAP+5.1 m. The planned location of the PALLAS-reactor is landward, more than 500 m from the dune base. In that case, the intervention will by definition not take place in the applicable swash zone (according to the HP2006 conditions). It will therefore have no direct impact on the current dune safety. There may however be an impact in the longer term. Specific attention must therefore be paid to the longer term situation (200 years) and the more taxing circumstances which may then apply.
Hydraulic Preconditions (HP) 2006, Dutch Ministry for Infrastructure and Environment, 2006.	The HP2006 are applied in determining the location of the rear of the Waterworks structure. This zone is significant during the construction phase, as the applicable testing circumstances are important here. The protection zone lies landward from the Waterworks structure, and comprises two parts: • Part A of this zone refers to the extra width of the coastal defense structure required in order to guarantee sufficiently safe coastal defense structures, also in the longer term. The 200-year circumstances must be deployed for this purpose. • Part B must be reserved to provide leeway for landward displacement of the erosion point, within the physical coastal defense structure. HHMK applies a fixed dimension of 100 m for the width of part B. This section is necessary in order to avoid part A no longer functioning stably enough, for example due to restrictions imposed regarding admissibility of major excavation work in part B. Work taking place in the protection zone B without excavation or seismic testing, explosive materials or a pressure exceeding 10 bar, is not regarded to be hazardous. This work can be conducted without a permit or notification being required, and is exempt from the permit obligation, unlike work conducted in protection zone A [12]. The protection zone is significant during the construction phase,
Register and Regulation, the Water Authority for Northern Holland (HHNK)	The Register for the Petten coastline has yet to be determined, though HHNK has already made the necessary calculations. The basic zoning plan has therefore been formulated for the coastline, taking into account the PALLAS-reactor. As the authoritative body, the HHNK is responsible for good condition of the coastal defense structure, so that people can live safely in the lower-lying areas inland (HHNK, 2012). In order to maintain that safety, requirements have been formulated regarding the use of the coastal defenses and the surrounding area. These requirements are recorded in the Regulation. The Register records the dimensions of the coastal defense structure, from a legal and technical point of view. The delineation of zones present within the Regulation area are schematically represented in Figure 1. The protection zone lies landward from the waterworks structure (Figure 1). Part A of this zone refers to the extra width of the coastal defense structure required in order to guarantee sufficiently safe coastal defense structures, also in the longer term. This zone is significant during the operational phase,

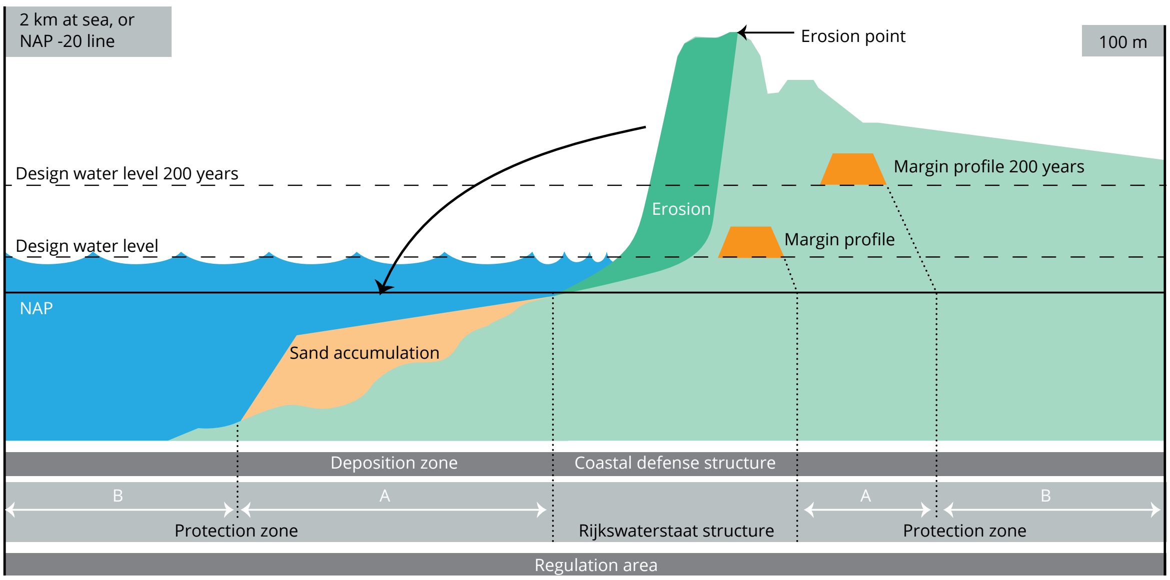

Figure 15 Schematic representation of Regulation area with Waterworks structure and the various protective zones, including the Inner protection zone on the landward side of the coastal defense structure, divided into parts A and B.

9.1.2 Assessment framework and methodology

Table 31 gives the assessment framework for the Water safety aspect. The following constructions are assessed with regard to water safety: building work, pipeline intersections and access road.

Study area

The study area stretches to the coastal defense structures, the seaward and landward protection zones and the coastal defense structure of the Noordhollandsch Kanaal, see Figure 16.

Assessment framework

The definition of the Register delineations is the starting point for further assessment of the interventions. The nature of the intervention and the technical flood defense requirements depending on the location, automatically results in an assessment of the impact of the intervention on the safety of the water defense structure.

Relevant phases

The impact on the Water safety aspect is described for the construction phase and operational phase. The transition phase has not been separately assessed, as the activities during this phase, in which both the HFR and PALLAS-reactor will be operational, will have no other impact than during the operational phase.

SEA assessment scale

The translation of the results of the safety assessment into the SEA is based on the explanation given in Table 32.
The degree of occurrence of a certain impact depends greatly on the degree to which the intervention occurs in the active part of the coastal flood defenses. The definition of the position of the various zones (Figure 15) and the time horizon to be considered, is therefore even more important. The time horizon to be applied is directly linked to the relevant phases (construction phase or operational phase).

Figure 16 Study area for Water safety

Table 31 Assessment framework for Water safety

Assessment criteria	Description
Building work	The intervention for construction of the building work is assessed with regard to increased and decreased water safety.
Pipeline intersections	Pipeline intersections with both the primary flood defenses and the regional flood defenses are assessed, during both the construction phase and the operational phase.
Access road	The Access road intervention concerns the construction of a temporary access road through the inner (secondary) dune ridge.

Table 32 Scoring of assessment for technical impact on the coastal defense structure

Score	Meaning	Explanation
++	Extremely positive impact	The safety of the coastal defenses will be significantly improved following construction (i.e. the risk of failure of the coastal defenses will decrease considerably). In terms of safety, at least a factor of 10 for both aspects.
+	Positive impact	The safety of the coastal defenses will (theoretically) be slightly improved due to extra sand being effectively added in the relevant part of the cross-sectional area.
0	No impact	The construction clearly takes place landward of the swash zone and therefore has no physical effect on the safety of the coastal defenses.
-	Negative impact	The intervention has a negative impact on the coastal defense structure, but there is sufficient residual safety for this to not pose a real problem. The actual safety is still factor 10 larger than the statutory norm.
- -	Extremely negative impact	The intervention has an extremely negative impact on safety of the coastal defenses, which cannot be otherwise mitigated. The safety of the cross-sectional area does not meet the statutory norm.

9.2 Current situation and autonomous development

9.2.1 Current situation

The dune ridges seaward of the Research Location Petten are relatively weak in places. The dune ridges have therefore been reinforced on the inside, here and there, at the end of last century. The amendment in the hydraulic conditions to be applied for assessment of the safety aspect (which resulted in more stringent conditions) resulted in a number of these transects once again being designated as (too) weak. As a much larger section of the coast was regarded to be a weak link at that point, maximum efforts were made to reinforce the Noord Holland coastline on a large scale.
Particularly significant in the section of coastline under consideration is the completed sandy reinforcement of the Hondsbossche & Pettemer coastal defense structure in 2015. This expansion will also gradually lead to an increased volume of sand in the dunes situated in front of the Research Location Petten. This will by definition be beneficial for the safety of the coastal defense structure in this section of coastline, therefore removing the need for local reinforcement of narrow dune ridges in this area.
Figure 17 shows the situation before and after the sandy reinforcement referred to. As can be seen, the waterline has been moved considerably seaward at Petten. Expectations are that this expansion will gradually lose some degree of sand, which will benefit the section of coastline directly north of it.

Figure 17 Overview of Dune section showing PALLAS site (in the yellow circle) in the situation before (left) and after the completed coastal reinforcement (right) in 2015

9.2.2 Autonomous developments

Coastline shifting further seaward

These considerations are based on the present-day situation, with a pessimistic perspective of the circumstances for the coming 200 years. The starting point is an estimation of the minimum required coastline location in this process. The coastline may be expected to have shifted further seaward by the reference year 2026 deployed in the PALLAS definitions. Upon repetition of the 200-year definitions, this will automatically result in a more seaward location of the positions determined within the scope of the Register (see delineations in Figure 15).

Revision of Basic Coastline (BC)

Seeing as revision of the current Basic Coastline (BC) is not yet foreseen, calculations cannot yet be made for this purpose. The dune erosion calculations based on the current coastline location will therefore serve as the basis for the assessment. It will be clear that the definitions for the 2026 situation will always be more favorable. This means that a negative impact may be less negative in reality, or that a positive impact may be assessed even more positively.

9.3 Environmental impact

9.3.1 Impact description

Besides the proposed location for the new reactor, the red lines in the overview above show the positions of the various AnnCoa transects[24] Km transect 1880 (located at 18.8 km from the zero point at Den Helder) relates to the cross-sectional area which more or less intersects the location of the planned reactor. This figure also shows the location of the BP line[25] (straight coastal line along the beach). This is the zero point for each AnnCoa transect (JarKus, in Dutch).

The locations indicated in Figure 18 relate to the erosion points after 200 years. The points on these transects refer to the position of the erosion point. The green points mark the calculated erosion point based on the cross-section measured in 2015. The yellow points mark the erosion point according to the reference profile deployed for the Register. The most recent erosion points (2015) are located seaward from this reference erosion point. The various Regulation zones are also recognizable in the figure:

- The Rijkswaterstaat structure located in km transect 1880 up to the Research Location Petten delineation approximately 450 m from the BP line.
- The inner protection zone A which borders the Rijkswaterstaat structure, on the seaward side, and is located at the rear of the dunes on the Research Location Petten, on the landward side.
- The inner protection zone B which borders the inner protection zone A, on the seaward side, and intersects the proposed location of the PALLAS-reactor, on the landward side.

Table 33 shows the derived delineations for the reference profile. In assessing the impact on water safety, the rear side of the Rijkswaterstaat structure is significant during the construction phase. The protection zone is significant during the operational phase.

9.3.2 Impact assessment

Based on the impact description in the previous paragraph, a picture can be sketched of the impact of the intervention on the safety of the flood defenses. The assessment of the three points of attention relevant to the flood defenses is based on the results described in Figure 18A.

Table 34 presents the impact scores determined per intervention. The impact score per intervention is then described.

Construction phase

During the construction phase, the intervention is at a great distance from the Rijkswaterstaat structure, so that there are no technical implications for the flood defenses.

Table 33 Overview of detailed results Register zoning km transect 18.80 and relevance [14]

Situation under consideration	Position	Relevance
Rijkswaterstaat structure, landward side (= protection zone A, seaward side)	BP -433 m (at NAP level)	Current conditions; Construction phase
Protection zone A, landward side (= protection zone B, seaward side)	BP -679 m (at NAP level)	Register conditions; Transition and operational phases
Protection zone B, landward side	BP -779 m (at NAP level)	Register conditions; Transition and operational phases

24 AnnCoa stands for Annual Coastal monitor (Jaarlijkse Kustmeting).
25 The main transect (also known as the Beach Post line, or BP line) for annual coastal monitoring is an articulated straight line set out seaward of the flood defenses, analogous to the shape of the coastline.

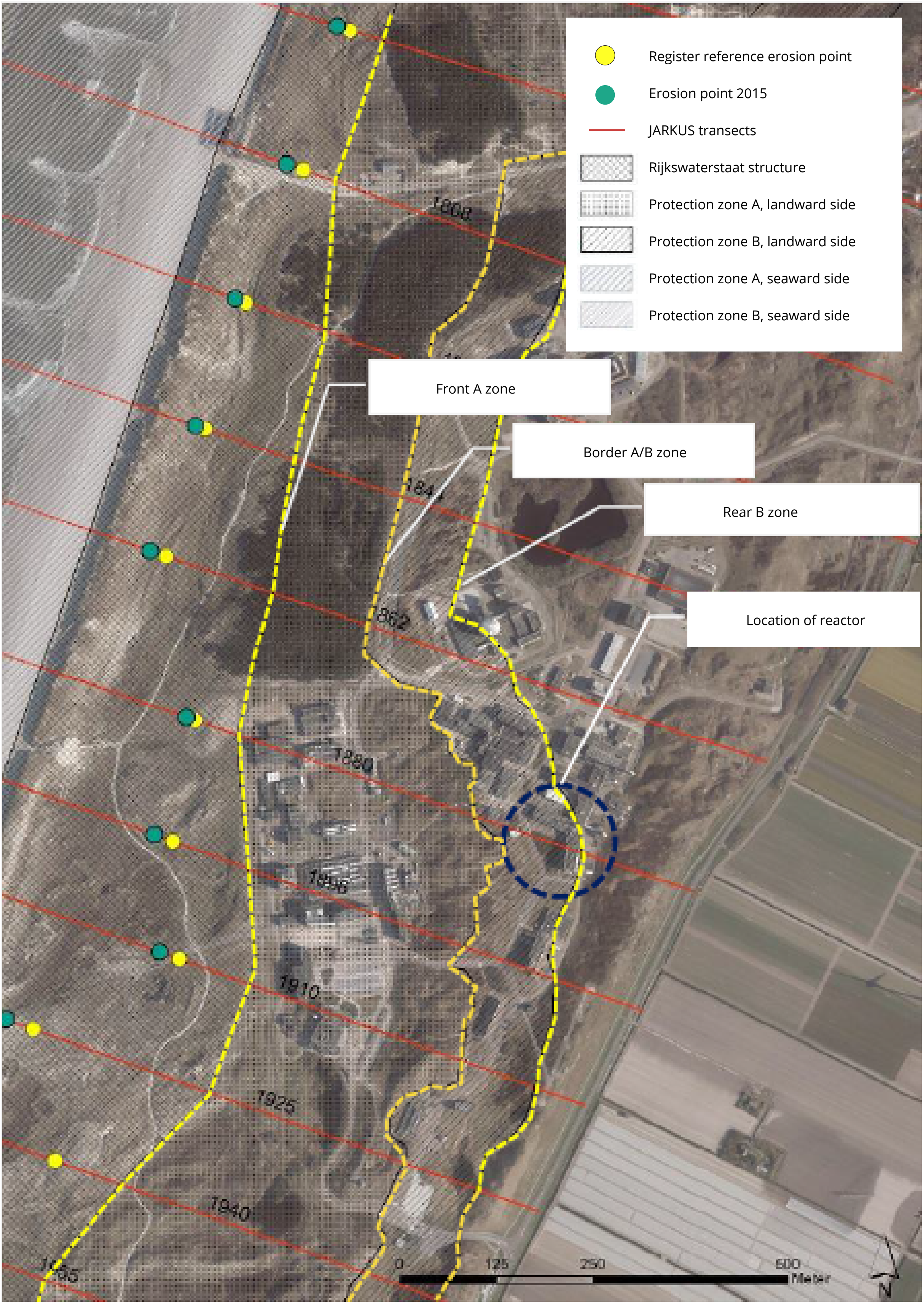

Figure 18A Total overview of Research Location Petten location in primary flood defenses (dune area) including planned reactor location and position of the Rijkswaterstaat structure according to the draft Register (version 16 June 2016) [15]

Table 34 Overview of interventions in terms of water safety and the impact score

Intervention	Effectscore	Opmerkingen
a) Building work	0	By definition, the outline design for the construction height variants B2 and B3 results in a slight increase in the sand volume in the inner protection zone, leading to some degree of extra water safety. The volume of sand will remain more or less equal in construction height variant B1, thus a neutral impact. These considerations become significant in the operational phase. During the construction phase, the intervention is at a great distance from the Rijkswaterstaat structure, and the impact is by definition neutral for all construction height variants.
b) Pipeline intersections	0	As long as they are installed according to the NEN3651 guidelines[26] , there is no (negative) impact on water safety. There is neither improvement nor deterioration of water safety. This applies to the intersections with both primary flood defenses and regional flood defenses.
c) Access road	0	The intervention is located outside the Register zone of the primary flood defenses and is also temporary.

Table 35 Impact assessment on Water safety, construction phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
a) Building work	0	0	0	n/a	n/a	0
Pipeline intersections	n/a	n/a	n/a	0	0	n/a
Access road	0	0	0	n/a	n/a	n/a
Total Water safety	0	0	0	0	0	n/a

Table 36 Impact assessment on Water safety, transition phase and operational phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Transition phase and operating phase						
a) Building work	0	+	+	n/a	n/a	0
Pipeline intersections	n/a	n/a	n/a	0	0	n/a
Access road	n/a	n/a	n/a	n/a	n/a	n/a
Total Water safety	0	+	+	0	0	0

The results from Table 34 have been combined in a total score for Water safety during the construction phase, in Table 35. The conclusion can be drawn that construction and installation of the cooling water pipelines during the construction phase will have a neutral impact on water safety.

Transition phase and operating phase

Table 36 gives the impact assessment for the transition phase and operational phase. There may be a positive impact during the operational phase, due to a positive sand balance for the construction height variants B2 and B3.

Impact of building work and excavation work

Figure 18B shows the detailed position of the PALLAS-reactor in relation to the determined location of the Regulation zones. The figure also explicitly visualizes the position of the border between protection zones A and B in the relevant area.
The proposed location of the PALLAS-reactor is in the inner protection zone B. This is zone for which the least stringent guidelines apply. The purpose of the underlying guidelines is to prevent deterioration of the A zone. The border of the A zone coincides with the inner edge of the dunes on Research Location Petten, which reach well above the NAP +10 m level locally. This can be seen clearly in Figure 19.
The proposed intervention in this zone comprises a combination of a partially sunken construction of the nuclear island (in two of the three construction height variants under consideration) in combination with elevation of the surrounding site. The earlier definitions have shown a net addition of material for the construction height variants B2 and B3, in accordance with the design framework. In principle, this is beneficial for the safety of the coastal defense structure. The net excavation for construction height variant B1 is 4,936 m³. As it is located in the most landward protection zone B, it will have no (negative) impact on the water safety. After all, the local excavation is located at the rear of the site in an area which is to be elevated, and thus has no negative impact on the landward border of protection zone A and therefore also not on the water safety of the primary flood defense.
The impact of the intervention can therefore be assessed as positive for construction variants B2 and B3. This is in line with the scores presented in Table 32 and results in a neutral

26 Supplementary requirements for pipelines in or near important Rijkswaterstaat structures.

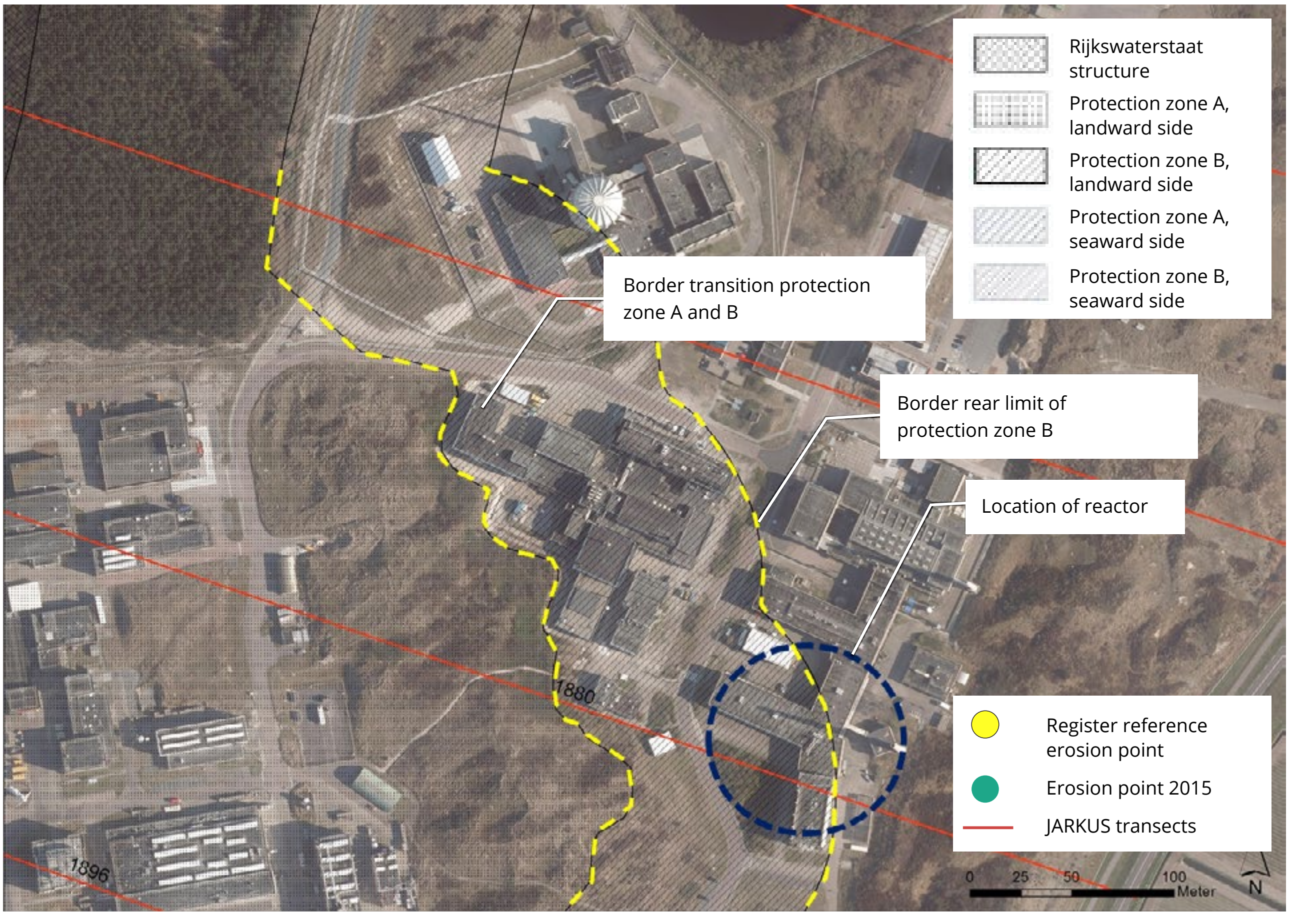

Figure 18B Detailed position of the PALLAS-reactor in relation to the Register zoning, showing how the construction is located in the inner protection zone B (landward) at a great distance from the Rijkswaterstaat construction

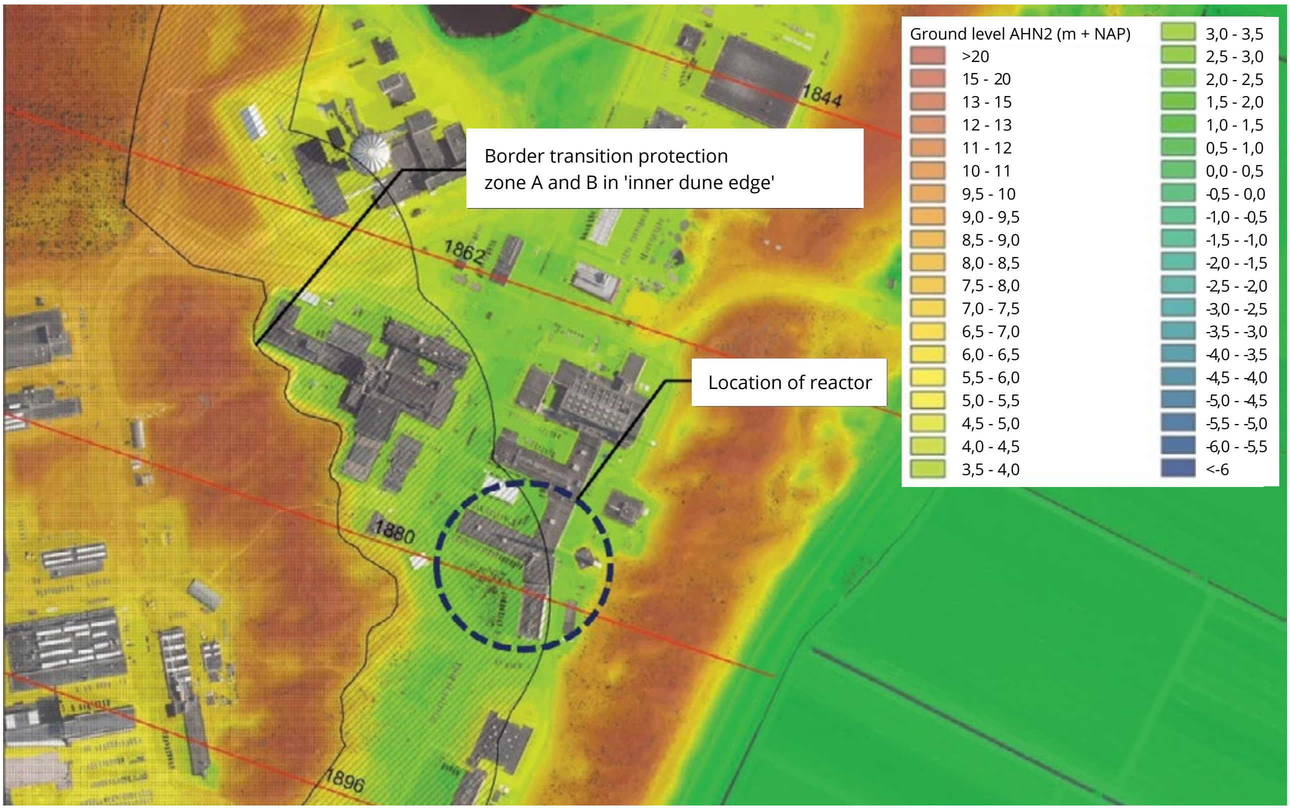

Figure 19 Detailed position of PALLAS-reactor in combination with Regulation delineations and AHN data (General Elevation model of the Netherlands)

(score: 0) to positive impact (score: +) (see also the summary in Table 34). Even if a lower volume of elevation is chosen, this will have no impact on safety. In that case, the assessment score will be neutral (see Table 34). This impact will almost certainly become even more favorable in the near future, due to the ongoing influence of the coastal reinforcement conducted for the Hondsbossche & Pettemer coastal defenses, as the positions of the borders of the protection zone can in principle be moved seaward.

Pipeline intersection with primary flood defenses
Figure 20 shows the detailed location of the planned intersection of the cooling water pipeline with the foredunes. This intersection is clearly within the Rijkswaterstaat structure. The intersected dunes are highest on the beach side, reaching NAP +12 m, as can be seen on the elevation map (Figure 21).
The guidelines of the NEN3650 series (the NEN3651) apply for assessment of pipeline systems [15]. According to this norm, intersection of the foredunes is not a problem as long as the pipeline is not dug in deeply and therefore follows the dune profile. The maximum level at which the outer dune ridge is passed, is therefore well above the maximum expected water levels also in the longer term).
The level at the intersection of the dune area can be clearly seen in Figure 21 in which it is shown in an AHN2 elevation map. The two AnnCoa profiles are also presented, in Figure 22. As can be seen, the front dune ridge reaches approximately NAP +13 m here. This is well above the level of the maximum storm surge level, also in the longer term (design water level in operational phase NAP +7.2 m). Although the crest level is slightly lower at the location of the current intersection (see elevation map), there is still sufficient margin.
The new pipeline can in fact be installed using the same approach applied in construction of the cooling water pipeline already in place. The current pipeline is also not dug deeply into the dune profile.
As long as these conditions are met, the intersection by one or more cooling water pipelines will have no net impact on water safety. The impact is therefore assessed as neutral (score: 0).

Pipeline intersection with regional flood defenses
A regional flood defense is a non-primary flood defense defined on the basis of a provincial order and/or included in the Register/Regulation of the regional water board. This includes not only the 'wet' defense structures (walls along drainage waterways, for example), but also 'dry' defense structures. Such non-primary flood defenses are subject to safety norms defined by the Province of Noord-Holland.

Depending on the option chosen for the cooling water pipeline, there are two intersections with such regional flood defenses:

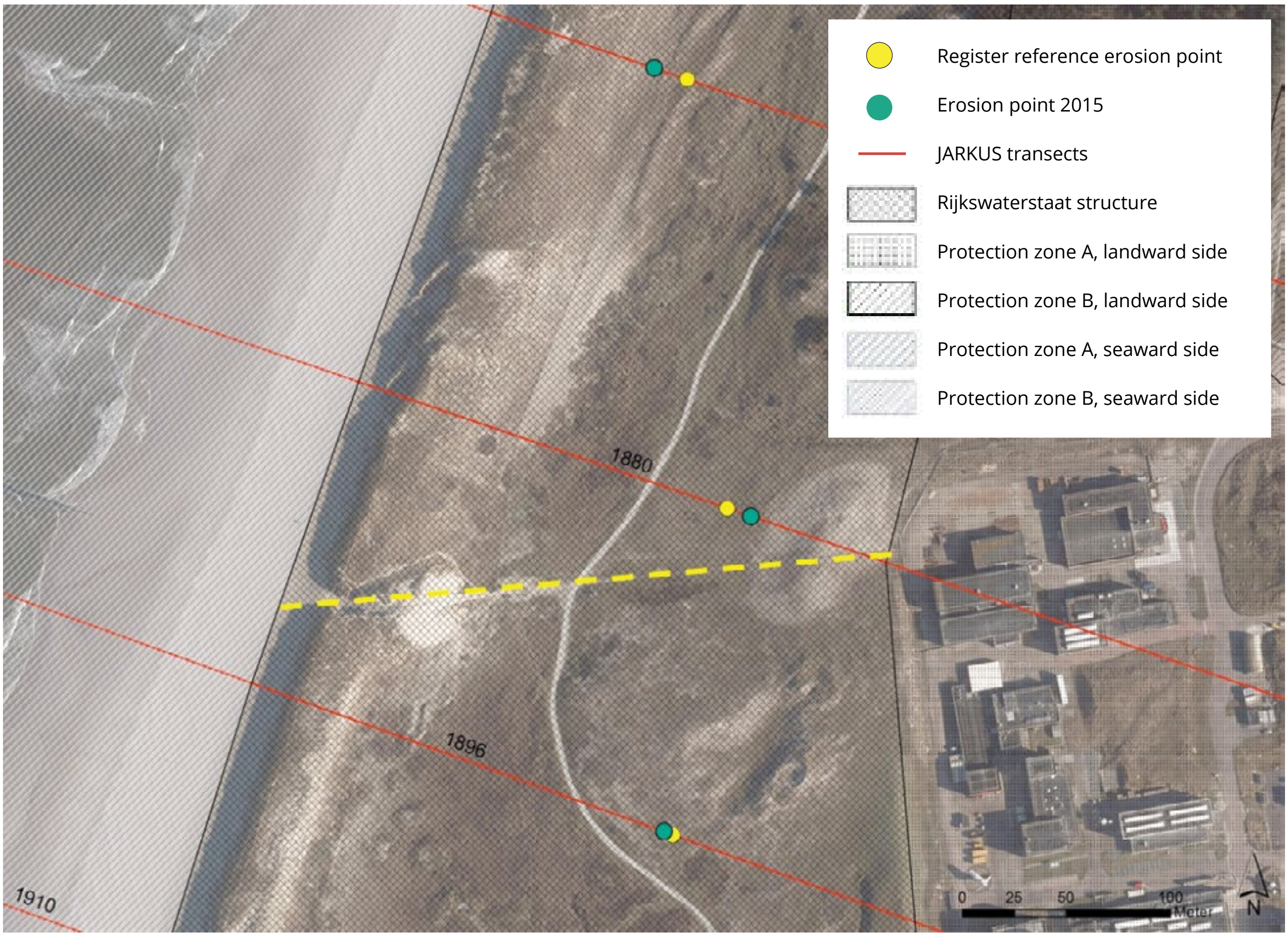

Figure 20 Details of coastal defense structures at the planned intersection with the foredunes. Including route of current cooling water pipeline (yellow line)

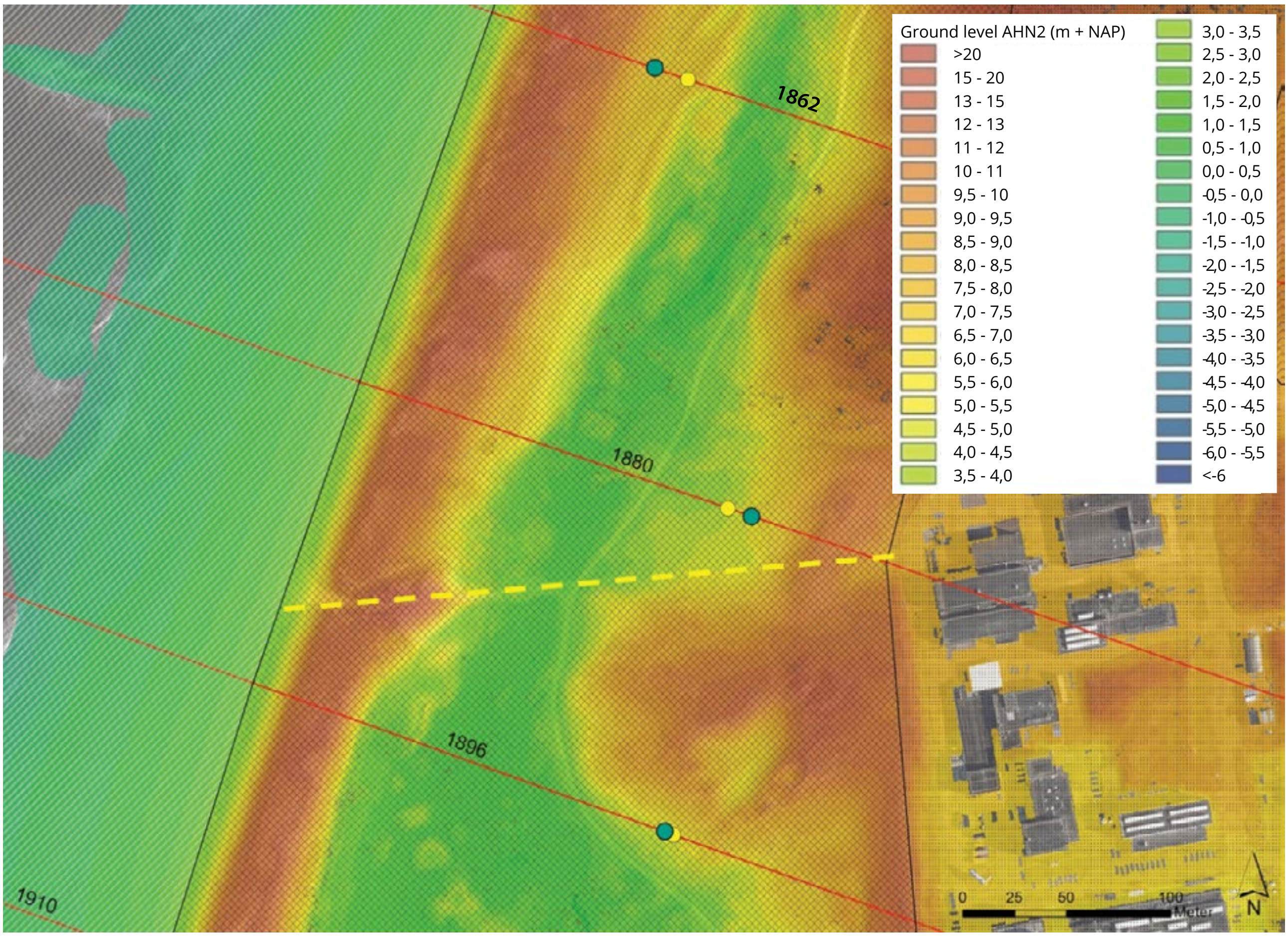

Figure 21 Details of coastal defense structures at the location of the planned intersection with the dune ridge, showing AHN elevation information, including the route of the current cooling water pipeline (yellow line)

- The dune ridge along the N502, as the secondary coastal defense structure.
- The drainage waterway defense structure along the Noord-hollandsch Kanaal.

A safety test must be conducted prior to construction of large diameter pipelines (D ≥ 0.30 m) and high-pressure pipelines (p ≥ 10 bar) [16] This test is comparable with that for primary flood defenses, as described in the VTV Safety Test Conditions 2006, and via these conditions according to the NEN 3650 and NEN 3651 (2003) norms. The chosen solution must be defined in detail in order to comply with these conditions. Upon compliance, there will be no further safety issues.

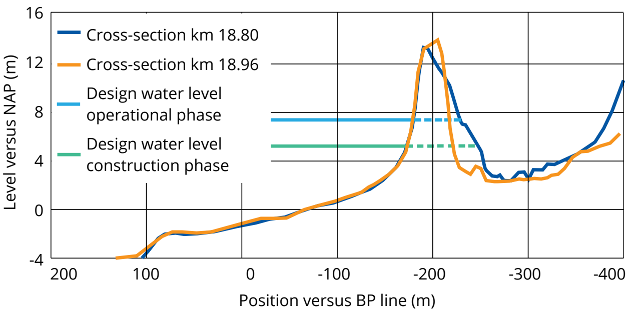

Figure 22 Cross-section of the pipeline intersection at the km transects 18.00 and 18.96 including the design water level applied for the construction and operational phases

Realization of temporary connecting route

Figure 23 shows details of the most landward dune ridge which will be intersected for admission of the necessary construction traffic for construction of the PALLAS-reactor. A possible logical location for this intersection is at building 107. There is already a road here in the current situation, which will only need to be extended to a limited extent. The secondary dune ridge reaches NAP +12 m locally, resulting in a more southerly intersection being illogical but not impossible. Another option is to expand the southern access route to the Research Location Petten location.

The dune ridge located along with the provincial road is not within the Register delineation for the primary flood defenses, so that there are no technical flood defense requirements along this road.

It is after all a non-primary, second (regional) coastal defense structure intended as a secondary defense in the unlikely event of failure of the primary coastal defense. In principle, this coastal defense structure must remain in place at all times.

However, a temporary local excavation of this structure is admissible if the excavated material is stored in the direct vicinity (preferably adjacent to the excavation). This then makes it possible to relatively quickly close the temporary gap in this coastal defense structure. It is of course also important that this concerns a temporary situation during the construction phase. The connecting road is no longer necessary upon com-

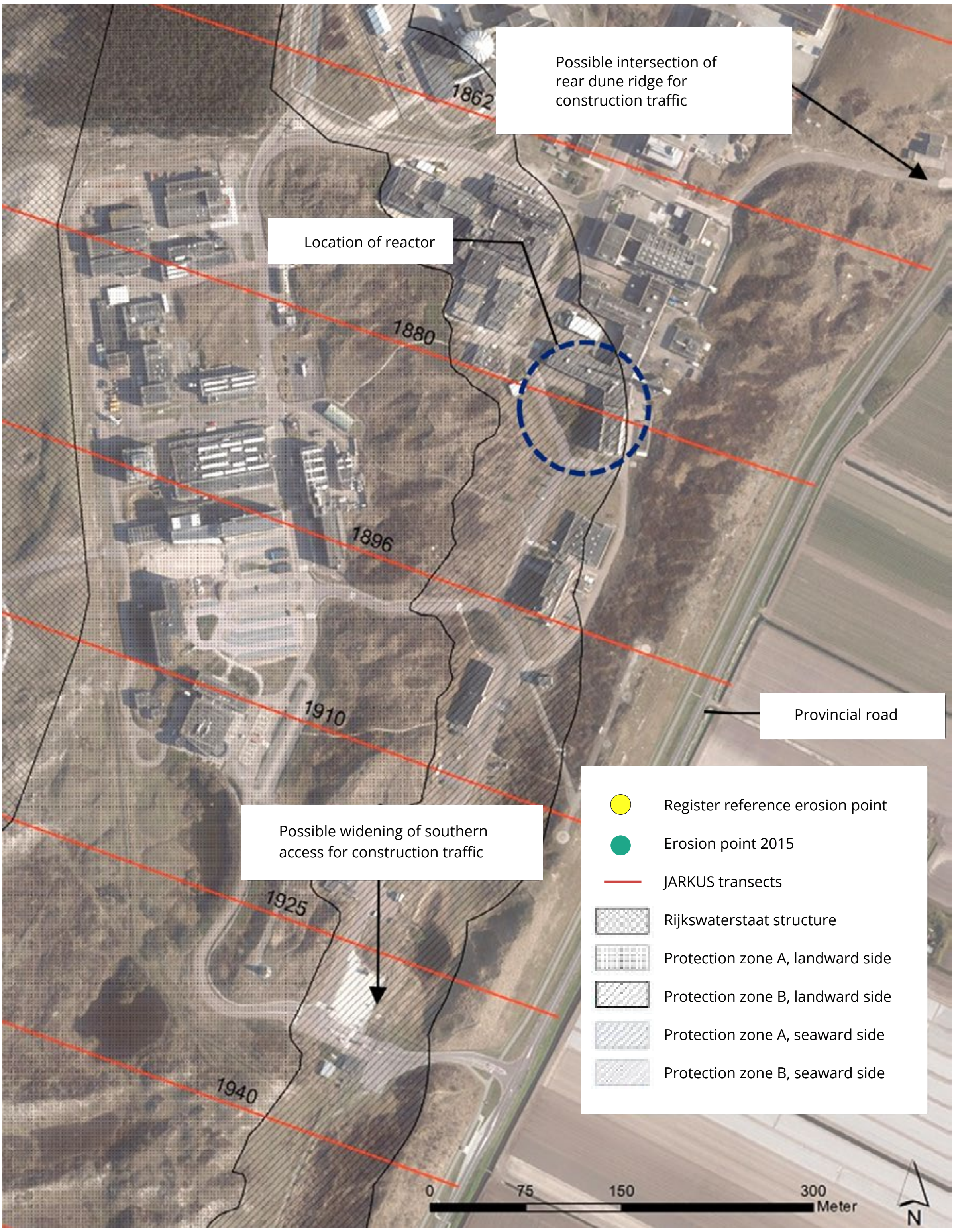

Figure 23 Details of position of the PALLAS-reactor in relation to the Rijkswaterstaat structure, including logical positions for possible intersection with the dune ridge along the provincial road, for construction traffic.

pletion of the construction phase, and the secondary coastal defense must be restored to its former level.

9.3.3 WBI2017, Statutory Assessment Tools influence on impact assessment

Since 2017, a new norm and new set of procedures are applied, in accordance with the Delta program (DP 2015). This paragraph discusses the influence of this switch to the impact assessment given in the previous paragraph.
An important area of attention when switching from the current to the new safety methodology is that it considers two different types of norms. These different types of norms also have differing normative levels (data). In addition to this change, the WBI2017 takes account of uncertainty in the reference water levels. This was not yet the case in the previous Hydraulic Preconditions 2006, and will result in a slight

increase in the test water level for dunes, versus the current situation.

Current norm and reference design water level

The current norm is based on a probability of the water level being exceeded, which the primary flood defenses must be able to withstand. In Noord-Holland (dike ring 13), the current normative level is 1/10,000 per annum, when applying the 2016 TRDA Technical Report on Dune Erosion test method. When assessing the safety of dune flood defenses, this results in a maximum probability of failure of the dune flood defenses, at the cross-section level, of 1/100,000 per annum [10]. The cross-section failure (combined with exceeding the critical erosion position) will then implicitly also result in flooding of the area behind the flood defenses.

On applying the TRDA Dune Erosion test method, the design water level (the reference water level applied in the dune erosion calculation) plays an important role. In this test method, the calculated level is determined by adding 2/3 of the factor 10 risk reduction height to the norm height relevant to that water level (therefore at a 1/10,000 exceeding probability per annum). This results in a design water level in keeping with a probability of the water level being exceeded, of 0.215 times 1/10,000, which gives 1/46,500.

If the calculation was based on the probability of failure of the cross-section (therefore at a 1/100,000 exceeding probability per annum), 1/3 of the factor 10 risk reduction height would need to be subtracted[27]. This results in a design water level in keeping with a probability of the water level being exceeded, of 2.15x1/100,000, which once again gives 1/46,500. The latter probability deviates in the new approach.

Norm adjustment

However, the future norm is based on a flood probability of (part of) a dike ring. In the location under consideration (norm section 13-3), the normative level is 1/3000 per annum (Delta program 2015). This norm is expressed as the maximum admissible probability of flooding. The OI2014 Design Tool guideline indicates how this probability of flooding (applicable to the dike ring section) must be translated into a failure probability requirement per cross-section, for testing and design purposes. Two aspects must be taken into account: the failure probability margin and the length effect. This method was recently also adopted in a legislative amendment [17].

Failure probability margin

Generally speaking, multiple mechanisms can result in failure of a coastal defense structure. The failure probability estimation determines a failure probability margin for each failure mechanism. This depends on the type of coastal defense structure.

When making this failure probability estimation (for the failure probability margin), a distinction is made between dune sections and dike/other sections. Depending on the type of section, a certain percentage of the total 'margin' is reserved for 'other mechanisms' for which testing and design rules are not (yet) available, and the other 'margin' is subdivided among the various failure mechanisms.

The location under consideration can be defined as a dune section. In such a section, a failure probability margin of 70% is foreseen for the dune erosion failure mechanism, which means that the probability of flooding in this section, related to dune erosion, is equal to 0.7 times 1/3000, which can be rounded off to 1/4285 per annum. Recently published WBI Statutory Assessment Tool documents also applied this failure probability margin for this part of the coast.

Length effect

The translation of a probability per section into a probability per cross-section must take account of the length effect. The principle of the length effect is that there is a greater probability of failure somewhere within the dike ring, than the probability that it occurs at a precise location. The length effect is expressed in terms of the N-value. A standard value of 2 is applied in the case of dune coastal defenses. According to the new approach, which assumes a flood probability of 1/4285 per annum as the result of dune erosion, this then results in a failure probability requirement per cross-section, of 1/4285 divided by 2, i.e. 1/8570 per annum.

In order to make an initial comparison with the prevailing approach, the derived value (1/8570 per annum) is compared with the (now still prevailing) 1/100,000 per annum exceeding probability of the critical erosion point. The norm is therefore much lower, i.e. a factor 11.

The same ratio is identified for the exceeding probability of the water level in the design water level. In the new situation, 1/3 of the factor 10 risk reduction height must be deducted from the water level for which an exceeding probability of 1/8570 per annum applies. This results in a design water level in keeping with a probability of the water level being exceeded, of 2.15 times 1/8,570, which once again gives 1/3,985 per annum. The now prevailing value is an exceeding probability of 1/46,500 per annum.

Influence of including uncertainties in the water levels

When accounting for uncertainty in the water levels, the water level increases slightly when compared with the HP2006 values. Via an integrated work line, this results in increases of 6.3 and 5.3 cm, respectively, for the IJmuiden and Den Helder monitoring stations, for a repetition period of 10,000 years. [18]. Rounded off, this can be translated into a design water level increase of approximately 0.1 m. As this conservative estimation is much smaller than the locally occurring factor 10 risk reduction height of approximately 0.6 m (a factor 10 in the exceeding probability of the water level), its impact will not result in full use of the factor 11 previously derived. What remains is a decrease in the reference load.

Conclusion

It can be concluded that the assessment norm (including the impact of uncertainties in the water level) will be reduced.

27 By definition, a factor 10 risk reduction height decrease in the water level will result in a factor 10 increase in the exceeding frequency. A decrease of 1/3 of the factor 10 risk reduction height then corresponds with an increase in the exceeding frequency by a factor equal to the cube root of 10, which is equal to 2.15

This means that future assessments may assume lower sea levels and less extreme wave pounding, which will lead to a reduction in the degree of dune erosion. The position of the reference erosion point will shift seaward. Interventions will be assessed versus a norm on which they will have even less impact.

The 2017 switch to the new norm therefore does not result in more critical assessment with regard to the impact assessment described in the previous paragraph. The impact assessment can at most be considered to be somewhat conservative. The impact assessment as given in paragraph 9.3.2 remains in force.

9.4 Mitigating measures

Mitigating measures must be implemented, in the event of a negative impact on the safety of the coastal defense structure. Think in terms of the addition of extra sand in the profiles (assessed as too weak). In that case, none of the assessed interventions have a negative impact. The comments per intervention can therefore mainly be regarded to be areas of attention.
Depending on the ground flows, there will (or may be) a temporarily significant negative balance of sand mass during the construction phase. However, that is not problematic in this phase due to the intervention taking place at a great distance landward from the then reference Rijkswaterstaat structure. The excavated sand may then even be disposed of outside the site.
There will be a limited negative to significant positive balance of sand mass during the operational phase, depending on the construction height variants. As this concerns an excavation located at the rear of a site to be elevated, it has no negative impact on the rear border of the so-called A- section of the protection zone and therefore also not on the safety of the primary flood defense.

Pipeline intersection with primary flood defenses
An area of attention concerns the excavation of a temporary gully in the foredunes, for construction of the new cooling water pipeline(s). It is important that this excavation work takes place outside the storm season (if possible). Moreover, the excavated material must be reused in order to restore the original ground level.
The storm season is considered to be the closed period within which building and excavation work is generally prohibited in or close to the Rijkswaterstaat structure of the primary flood defenses (from 15 October to 15 April). The full robustness of the flood defenses must be available for defense purposes during the storm season and may not be weakened due to work being conducted. Work is only permitted if it has no negative impact at all on safety, or if it even boosts safety [13].

Realization of temporary connecting route
With regard to the temporary connecting route, we recommend that the sand volume excavated from the secondary flood defense be stored in the direct vicinity (adjacent to) the excavation work and that care is taken to retain the original volume (at the scale level of this secondary flood defense).
Upon completion of the construction work, the original ground level must be restored at the excavation site in order to render the secondary flood defense functional again.

9.5 Gaps in knowledge

No knowledge gaps have been detected for assessment of the implication of the planned interventions in the primary flood defenses, on the water safety of the flood defenses. There is however an area of attention, regarding insight into the Basic Coastline values to be adjusted in the future. For that matter, the expected impact will represent a further increase in the safety of the flood defenses.

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10 Air quality

The following description of the Air quality aspect is based on the Air quality background report (see Appendix F5).

10.1 Assessment framework

10.1.1 Policy framework

Table 37 summarizes the relevant policy and relevant legislation and regulations for the Air quality aspect, along with an indication of their relevance for the project. A number of policy plans are discussed in more detail following the table. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Air quality.

Table 37 Policy, legislation and regulations on Air quality

Policy plan, law, regulation	Description/ Relevance for PALLAS
Dutch Environmental Act title 5.2	This title of the Dutch Environmental Act comprises the air quality requirements to be assessed (article 5.16, first paragraph). This also includes the applicability principle (article 5.19, paragraph 2) which prescribes those locations where no assessment is required. The Dutch Environmental Act offers a number of principles with which to prove that a plan complies with the legislation and regulations on air quality: • The project does not result in target values being exceeded. • There is only limited deterioration of the air quality, but: - there is an improvement in the concentration of the substance in question or the concentration remains equal, on balance. - there is an improvement in the concentration of the substance in question or the concentration remains equal, on balance. • The plan does not significantly contribute to deterioration of the air quality. • The project is named or described in, or is in keeping with, or any case not in conflict with the Dutch National Cooperation program for Air quality (NSL). If a plan complies with one or more of these principles, air quality does not form a limitation for realization of the plan.
Dutch air quality assessment regulation, 2007 (RBL2007) including all subsequent amendments.	The RBL2007 describes how the air quality must be completed and assessed. It also includes the exposure criterion, which concerns the period for which people may be exposed to concentrations. The calculations within the scope of the SEA and the zoning plan must be conducted according to the RBL2007.
Decree and regulation on 'no significant contribution' (air quality), 2007	A project makes no significant contribution to the concentration of particulate matter (PM_{10}) or nitrogen dioxide (NO_2) in the exterior air, as long as the 3% limit is not exceeded. This refers to 3% of the target value (40 µg/m³) for the average annual concentration of particulate matter or nitrogen dioxide. In practice, this means that an increase of 1,2 µg/m³ is considered admissible.

Dutch Environmental Act title 5.2

Immissions of nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$) must be tested in relation to the target values given in appendix 2 of the Dutch Environmental Act.

Testing framework for nitrogen dioxide

As of 1 January 2015, the target value is 40 µg/m³ for the average annual concentration, with an average hourly concentration of 200 µg/m³ which may be exceeded a maximum of 18 times per annum.

Table 38 gives an overview of the target values for nitrogen dioxide.

Testing framework for particulate matter

As of 11 June 2011, the target value for the average annual concentration of particulate matter is 40 µg/m³ with an 24-hour concentration of 50 µg/m³ which may be exceeded on a maximum of 35 days per annum. Table 39 gives an overview of the target values for particulate matter (PM_{10}).

As of 1 January 2015, the target value for the average annual concentration of particulate matter ($PM_{2.5}$) is 25 µg/m³. Table 4 gives an overview of the target values for particulate matter ($PM_{2.5}$).

Table 38 Overview of target values for nitrogen dioxide

Test unit	Maximum concentration	Test unit
Average annual concentration		
Target value	40 µg/m³	
Average hourly concentration:		
Target value	200 µg/m³	May be exceeded maximum 18 times per calendar year

Table 39 Overview of target values for particulate matter (PM_{10})

Test unit	Maximum concentration	Test unit
Average annual concentration		
Target value	40 µg/m³	
Average hourly concentration:		
Target value	50 µg/m³	May be exceeded on maximum 35 days per calendar year

Table 40 Overview of target values for particulate matter ($PM_{2.5}$)

Test unit	Maximum concentration	Test unit
Average annual concentration		
Target value	25 µg/m³	

Applicability principle
The Dutch Environmental Act states that air quality no longer needs to be tested at locations which are out of reach for people. The most important consequences of article 5.19 are:
- No assessment of the air quality at locations to which the general public have no access and where there is no permanent residence.
- No assessment of the air quality on industrial estates or sites housing industrial installations (these are covered by Occupational Health regulations). This also includes (private) company residences. An exception is made for publicly accessible locations such as garden centers; assessment is required here (the so-called exposure criterion plays a role).
- When assessing an installation within the scope of the Environmental Act, testing takes place from the border of the installation or industrial estate.

There is no assessment of the air quality on road lanes or on the central reservation of roads, unless pedestrians normally have access to the central reservation.

Air quality assessment regulation 2007 (RBL2007)
According to article 5.19, first paragraph of the Dutch Environmental Act, the airborne particles caused by natural phenomena, are individually determined and included when establishing the PM_{10} quality level. According to paragraph 4 of this article, the concentrate contributions made by natural sources are always deducted in case of target values being exceeded. Appendix 5 of the 'Air quality assessment regulation 2007' includes a deduction for concentrations of particulate matter found naturally in the air. This concerns sea salt. Depending on the region in the Netherlands, a deduction of 1 to 5 µg/m³ is made from the calculated average annual concentration of particulate matter, for sea salt. The calculation results presented in this section do not include a correction for sea salt, as the target values are not exceeded at any point.

Exposure criterion
The air quality must only be determined (measured or calculated) at locations where there is significant exposure. It is therefore important to determine the significant exposure locations when assessing the impact of a project in terms of the air quality requirements. This first requires a definition of what is significant and what not.
Article 22 of the Air quality assessment regulation 2007 states that the air quality is determined at locations where the general public 'can be exposed during a period which is significant versus the averaging period of the relevant air quality requirement'. This means that the average duration of the period in which a person (a single individual) is exposed, determines whether or not the air quality must be assessed. No further distinction is made regarding the sensitivity of groups or the nature of the exposure. The target values have been set for the purpose of general public health.
In other words, when determining whether an exposure period is significant, the exposure period must be compared versus a year, day or hour, depending on whether you are dealing with a yearly average, daily average or hourly average target value for substance.

10.1.2 Assessment framework and methodology

Table 41 gives the assessment framework for the Air quality aspect. An explanation of the assessment criteria is given below the table.

Study area
The study area for the Air quality aspect delineates the area within which an increase or decrease of NO_2, PM_{10} and $PM_{2.5}$ is assessed for housing and sensitive structures. This concerns 1000 meters on each side of the roads and locations under consideration, where equipment may possibly be deployed during the construction phase. As these are low-level sources, the concentrations will be lower outside at this kilometer than within this distance. Consideration of a larger area will therefore not influence the assessment.

Table 41 Assessment framework for Air quality

Assessment criterion	Description
Impact on NO_2	Impact of the realization of the PALLAS-reactor on nitrogen dioxide concentrations in the air.
Impact on PM_{10} en $PM_{2.5}$	Impact of the realization of the PALLAS-reactor on particulate matter concentrations in the air.

Assessment framework
Realization of the PALLAS-reactor may have an impact on air quality emissions and immissions in the planning area and surrounding area. This impact has been calculated and quantitatively assessed for the Air quality aspect. In doing so, the impact of each construction height and cooling variant has been offset against the background concentrations in the autonomous future situation.
In the Netherlands, the reference air pollution substances are nitrogen dioxide NO_2) and particulate matter (PM_{10} and $PM_{2.5}$) This is due to the background concentrations of these substances already approaching the target values at many locations. The impact assessment of this SEA is therefore based on these reference substances. For NO_2 the assessment determines how many houses (residential units) will be subject to an increase of 1.2 µg/m³ due to the proposed activity. This is 3% of the target value, also known as the insignificant contribution limit[28]. A lower contribution is applied for PM_{10} and $PM_{2.5}$ due to this contribution generally already being a factor

28 The 'insignificant contribution' tool is a calculating tool used to ascertain the impact of land-use plans on air quality. Its main purpose is to determine whether a plan makes a significant/insignificant contribution. The tool was developed in 2008 by the Dutch Ministry for Infrastructure and Environment, in collaboration with the InfoMil knowledge center, and is updated annually by InfoMil.

10 lower than for NO_2 For further information, the assessment scale is given in Table 42.
Besides impacting air quality, NO_x emissions can also influence nature areas (nitrogen deposition). The impact on nature areas as a result of nitrogen deposition is assessed in the background report on Nature (and in section 13 of part B).

Relevant phases
There is limited effect in the operational phase, as there are very low concentration contributions versus the background concentrations. The greatest impact will be during the construction phase. The construction phase therefore provides the reference level for the air quality aspect. For this reason, the impact assessment is based on the impact during the operational phase and construction phase.
There is no differentiating impact between the construction height and cooling variants, and they are therefore not separately considered.

SEA assessment scale
Table 42 gives the assessment scale for the Air quality aspect.

Table 42 Scoring of assessment for Air quality

Score	Meaning	Explanation	
		Impact on NO_2	Impact on PM_{10} en $PM_{2.5}$
++	Extremely positive impact	Improvement of more than 1.2 μg/m³ in 10 – 20% of number of houses and sensitive structures	Improvement of more than 0.4 μg/m³ in 10 – 20% of number of houses and sensitive structures
+	Positive impact	Improvement of more than 1.2 μg/m³ in 5 – 10% of number of houses and sensitive structures	Improvement of more than 0.4 μg/m³ in 5 – 10% of number of houses and sensitive structures
0	No impact	Improvement of more than 1.2 μg/m³ in less than 5% of number of houses and sensitive structures	Improvement of more than 0.4 μg/m³ in less than 5% of number of houses and sensitive structures
-	Negative impact	Deterioration of more than 1.2 μg/m³ in 5 – 10% of number of houses and sensitive structures	Deterioration of more than 0.4 μg/m³ in 5 – 10% of number of houses and sensitive structures
- -	Extremely negative impact	Deterioration of more than 1.2 μg/m³ in 10 – 20% of number of houses and sensitive structures	Deterioration of more than 0.4 μg/m³ in 10 – 20% of number of houses and sensitive structures

10.2 Current situation and autonomous development

10.2.1 Current situation

The immission concentration of nitrogen dioxide (NO_2) and particulate matter PM_{10} and $PM_{2.5}$) in the current situation in the planning area is determined by industry, road traffic, shipping, agriculture and foreign emissions.
In the current situation, the air quality in the study area is determined by the large-scale background concentration. The following illustrations show the background concentrations for nitrogen dioxide (NO_2) and for particulate matter (PM_{10} and $PM_{2.5}$) for 2017. They make use of the large-scale background concentration definition as published by the Ministry for Infrastructure and Environment on 15 March 2017.

Figure 24 Background concentration of NO_2 in the current situation 2017

In the current situation, the background concentrations for NO_2 in the vicinity of the planning area range between 8.5 and 11.0 µg/m³. The maximum concentration is found approximately 1.5 kilometers east of the planning area, along the N9 road. This is well within the target value of 40 µg/m³ for the average annual concentration.

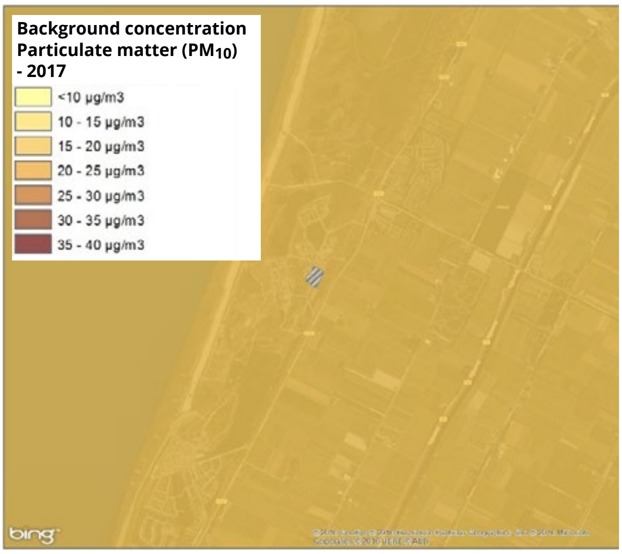

Figure 25 Background concentration of PM_{10} in the current situation 2017

The background concentrations of PM_{10} are also well within the target value of 40 µg/m³ for the average annual concentration, in the current situation. The maximum concentration of PM_{10} is no more than 17.9 µg/m³ in the vicinity of the planning area. This concentration is found to the east of the planning area.

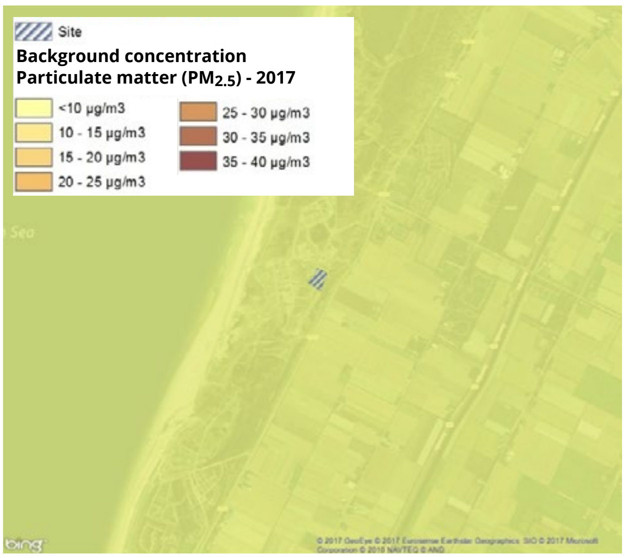

Figure 26 Background concentration of $PM_{2.5}$ in the current situation 2017

As for NO_2 and PM_{10} , the background concentrations of $PM_{2.5}$ are well within the target value of 25 µg/m³ for the average annual concentration, in the current situation. The concentration of $PM_{2.5}$ ranges from 7.8 to 9.1 µg/m³ in the vicinity of the planning area. The maximum concentration is found to the east of the planning area.

10.2.2 Autonomous developments

In the autonomous situation for 2026, the air quality in the study area is determined by the large-scale background concentration. The following illustrations show the background concentrations for nitrogen dioxide (NO_2) and for particulate matter (PM_{10} and $PM_{2.5}$) for 2026. They make use of the large-scale ground concentration definition as published by the Ministry for Infrastructure and Environment on 15 March 2017.

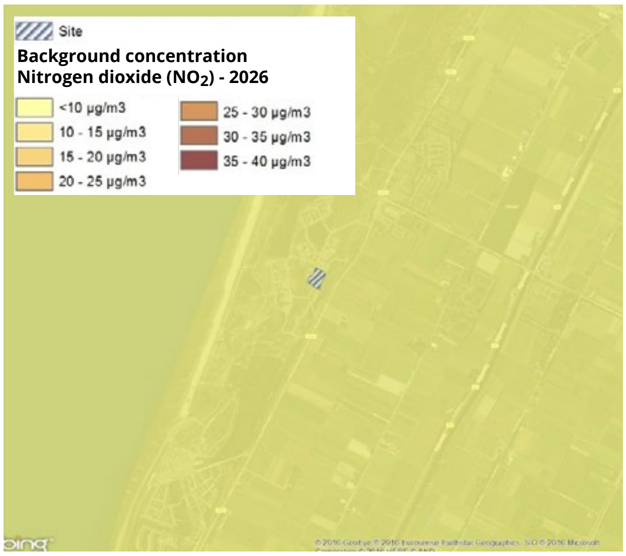

Figure 27 Background concentration of NO_2 in the autonomous situation 2026

In the autonomous situation for 2026, the average annual concentrations of NO_2 in the vicinity of the planning area are lower than in the current situation due to stricter emission requirements and increasingly cleaner motor vehicles. In 2026, the background concentrations in the vicinity of the planning area range from 6.5 to 8.2 µg/m³. This is well within the target value of 40 µg/m³ for the average annual concentration.

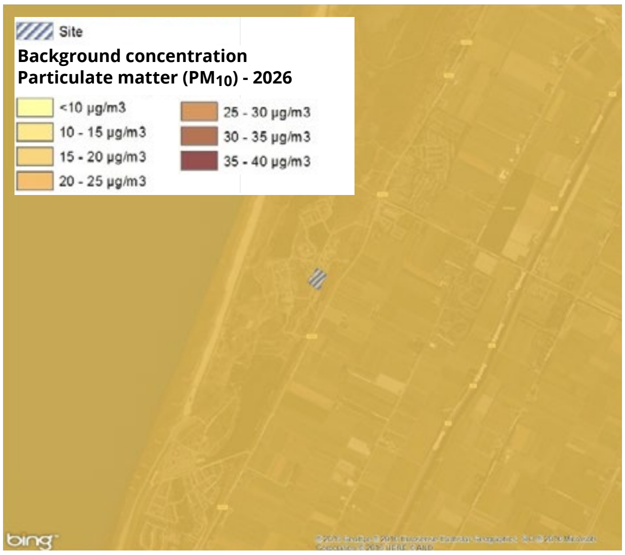

Figure 28 Background concentration of PM_{10} in the autonomous situation for 2026

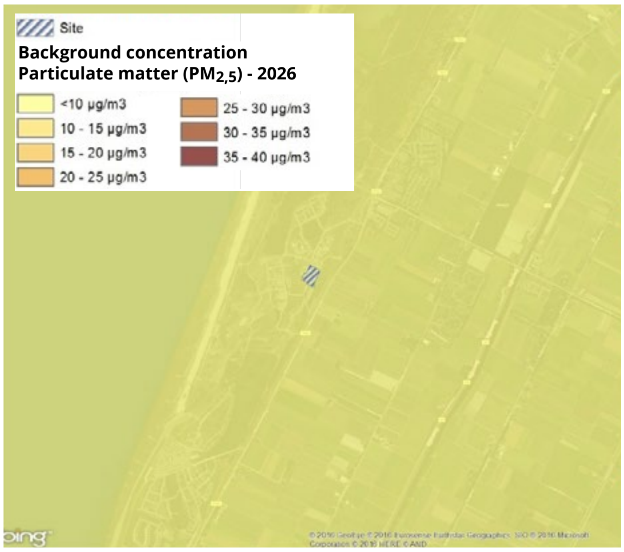

Figure 29 Background concentration of $PM_{2.5}$ in the autonomous situation for 2026

The background concentration for particulate matter PM_{10} is also lower than in the current situation. The background concentration of PM_{10} in the planning area ranges from 15.6 to 16.4 µg/m³. This is also well within the target value in the autonomous situation.

The background concentration of $PM_{2.5}$ ranges from 6.8 to 7.7 µg/m³ in the vicinity of the planning area in the autonomous situation for 2026. The concentrations of $PM_{2.5}$ are therefore also well within the target value in the autonomous situation.

10.3 Environmental impact

10.3.1 Impact description

Construction phase

The impact for nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$) is described hereafter for the construction phase.

Nitrogen dioxide (NO_2)

Figure 30 shows the concentration contribution to the average annual concentration of NO_2 during the construction phase.

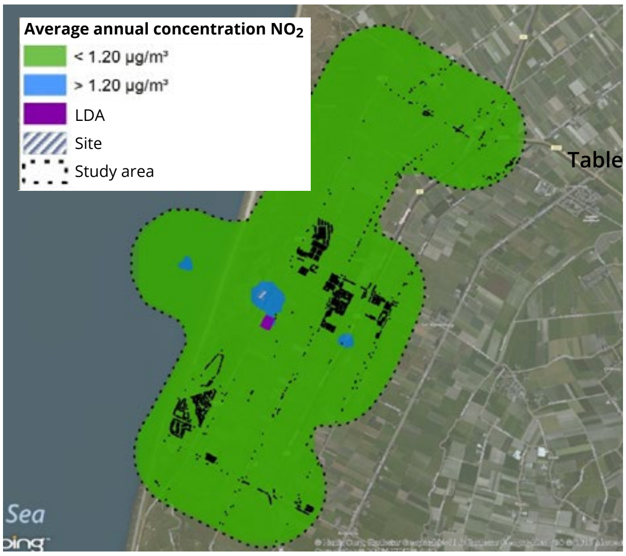

Figure 30 Average annual concentration contribution to NO_2 in the study area during the construction phase.

Figure 30 'Average annual concentration contribution to NO_2 in the study area during the construction phase' shows that only those average annual concentrations close to the site, LDA2 and a possible location for a pumping station, exceed the 'Insignificant Contribution' limit of 1.2 µg/m³. This distance concerns maximum approximately 400 m around the site and LDA2. At the possible location for the pumping station, the distance to the insignificant contribution limit is approximately 150 meters. A single house is located within the contour. The count is given in the table hereafter.

Table 43 Count of houses and addresses with increased or decreased average annual concentrations of NO_2

Improvement or deterioration: change in concentration of NO_2	Number of houses or sensitive structures
-1.2 µg/m³ - 0 µg/m³	0
0 µg/m³ - 1.2 µg/m³	2792
> 1.2 µg/m³	2

Table 43 shows that virtually all houses and sensitive structures within the planning area are subjected to an increase of less than 1.2 µg/m³ in the average annual concentrations of NO_2. Two houses are subjected to an increase greater than 1.2 µg/m³. The total average annual concentrations (background concentration + contribution) is no higher than 10.9 µg/m³ at any locations of houses or sensitive structures, during the construction phase. The average hourly norm for NO_2 is not exceeded anywhere.

Particulate matter (PM_{10} and $PM_{2.5}$)

Figure 31 shows the concentration contribution to the average annual concentration of PM_{10} during the construction phase.

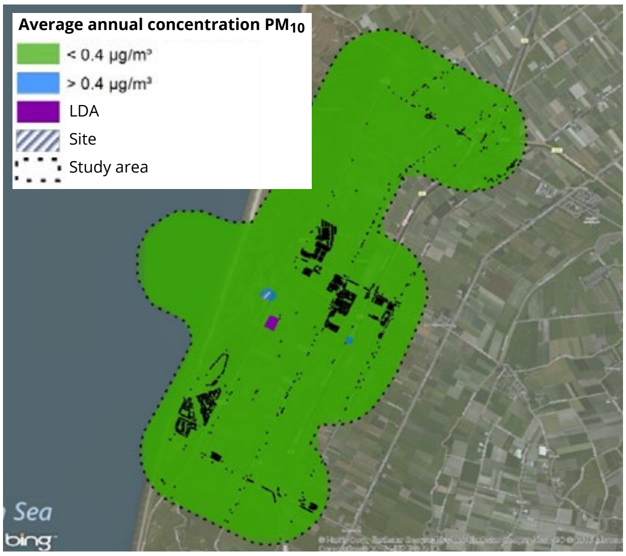

Figure 31 Shows the concentration contribution to the average annual concentration of PM_{10} during the construction phase.

Figure 31 'Average annual concentration contribution to PM_{10} in the study area during the construction phase' shows that the average annual concentrations of PM_{10} only exceed 0.4 µg/m³ close to the site, LDA, and at a possible location for a pumping station. This distance concerns maximum approximately 200 m from the site and 90 m from the pumping station. There are two houses located within contours greater than 0.4 µg PM_{10}/m³. The count is given in the table hereafter.

Table 44 Count of houses and addresses with increased or decreased average annual concentrations of PM_{10}

Improvement or deterioration: change in concentration of PM_{10}	Number of houses or sensitive structures
-0.4 µg/m³ - 0 µg/m³	0
0 µg/m³ - 0.4 µg/m³	2792
> 0.4 µg/m³	2

The table above shows that two houses and sensitive structures within the planning area are subjected to an increase of more than 0.4 µg/m³ in the average annual concentrations of PM_{10}.
The total average annual concentrations (background concentration + contribution) of PM_{10} is no higher than 17.3/m³ at any locations of houses or sensitive structures, during the construction phase. The 24-hour average normal for PM_{10} is exceeded on maximum 6 days. Figure 32 shows the concentration contribution to the average annual concentration of $PM_{2.5}$ during the construction phase.

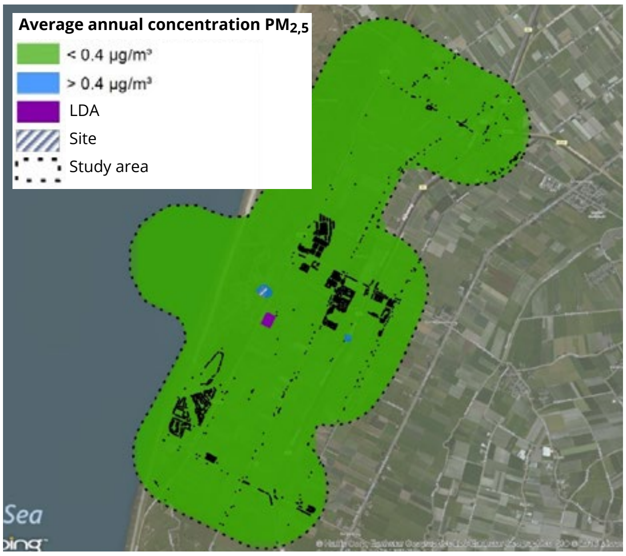

Figure 32 Average annual concentration contribution to $PM_{2.5}$ in the study area during the construction phase

The figure above shows that the average annual concentrations of $PM_{2.5}$ only exceed 0.4 µg/m³ close to the site, LDA and at a possible location for a pumping station. This distance concerns maximum approximately 110 m from the site and LDA[29]. The distance from the pumping station is approximately 83m. There are no houses or sensitive structures located within these contours. The count is given in the table hereafter.

Table 45 Count of houses and addresses with increased or decreased average annual concentrations of $PM_{2.5}$

Improvement or deterioration: change in concentration of $PM_{2.5}$	Number of houses or sensitive structures
-0.4 µg/m³ - 0 µg/m³	0
0 µg/m³ - 0.4 µg/m³	2792
> 0.4 µg/m³	2

Table 45 shows that two houses or sensitive structures within the planning area are subjected to an increase of more than 0.4 µg/m³ in the average annual concentrations of $PM_{2.5}$.
The total concentrations (background concentration + contribution) of $PM_{2.5}$ are no higher than 10.5 µg/m³ at any locations of houses or sensitive structures, during the construction phase.

Operational phase

The impact for nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$) is described hereafter for the operational phase. With a view to the extremely low concentration contributions, no concentration plots have been included, as they offer no added value versus the background concentration plots.

Nitrogen dioxide (NO_2)

The maximum calculated concentration contribution of NO_2 at the location of houses or sensitive structures is approximately

29 The exact location of the LDA is not yet known. A search area is deployed for this purpose. In order to be able to estimate emissions in the calculations, a worst case location is assumed within this search area. This concerns a location close to the housing, with an unfavorable position in relation to the prevailing wind direction and a location which results in increased concentrations in cumulation with the site.

0.05 µg/m³ as the average annual concentration in both 2017 and 2026. This maximum contribution is found just to the north east of the location at which the LDA has been projected for the air quality assessment (see Figure 30). In combination with the current background concentrations, the total average annual concentrations do not exceed 11 µg/m³ either in 2017 or 2026.

Particulate matter (PM_{10} and $PM_{2.5}$)
There are no significant concentration contributions to either PM_{10} or $PM_{2.5}$ in 2017 and 2026. All calculated increases remain below 0.01 µg/m³ as an average annual concentration. It can be ascertained that the concentrations of particulate matter will be fully accounted for by the background concentrations in 2017 and 2026.

10.3.2 Impact assessment

Construction phase
As described in paragraph 10.1.2 , the construction phase is the reference phase, and the impact in the construction phase will therefore be considered. The table hereafter shows the impact assessment (based on the reference construction phase). There is no differentiating impact between the construction height and cooling variants, and they are therefore not separately considered.

Effect on NO_2
Based on a count of addresses (see Table 8) within the planning area, it becomes apparent that a single house or sensitive construction is subject to an increase of more than 1.2 µg/m³. Due to this number of houses or sensitive structures being less than 5%, the allocated score according to Table 6 is 0 (no impact).

Impact on PM_{10} and $PM_{2.5}$
Based on a count of addresses (Table 9 and Table 10) within the planning area, it becomes apparent that no houses or sensitive structures are subject to an increase of more than 0.4 µg/m³ for either PM_{10} or $PM_{2.5}$. These increases are less than 5% of the houses or sensitive structures, hence the allocated score of 0 (no impact), according to Table 42.

Statutory monitoring
The reference situation is determined by the construction phase. Concentrations and contributions are lower in the operational phase than in the construction phase, and the required norms for air quality are therefore met, as long as they are met in the construction phase. A description of the construction phase assessment is given hereafter.
The calculations show that a contribution of more than 1.2 µg/m³ occurs at the location to be assessed. The project therefore 'Significantly contributes' to the concentrations of air pollution substances and must therefore be assessed according to the target values of the Dutch Environmental Act. During the construction phase, a maximum concentration of 10.9 µg/m³ is calculated for NO_2. This value exceeds the target value for the average annual concentration of 40 µg/m³. The average hourly norm for NO_2 is not exceeded anywhere.
The maximum calculated concentration for PM_{10}, is 17.3 µg/m³ during the construction phase, at a location/locations subject to assessment. This value exceeds the target value for the average annual concentration of 40 µg/m³. The 24-hour average norm for PM_{10} is exceeded maximum 6 times and is accounted for mainly by the background concentrations. This is lower than the admissible number of 35 exceeding days.
The maximum calculated value for $PM_{2.5}$ is 10.5 µg/m³ in the construction phase, at the location to be assessed. This concentration does not exceed the target value of 25 µg/m³ which applies for the average annual concentration of $PM_{2.5}$.
There is no exceeding of the target values for the Air quality aspect at any location. The Air quality aspect is therefore not a restrictive factor for plan formation.

Table 46 Impact assessment for Air quality, construction phase (reference phase)

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Impact on NO_2	0	0	0	0	0	0
Impact on PM_{10} en $PM_{2.5}$	0	0	0	0	0	0

10.4 Mitigating measures

Due to the reasonably low background concentrations in the planning area and the limited contribution by the project during the construction and operational phases, no target values are exceeded. No mitigating measures are required for the Air quality aspect therefore.
In terms of granting the permit, one area of attention must be named. There is a great difference in the emission requirements for diesel-powered equipment, between phases III and IV. The working locations are close to vulnerable types of habitat. This is the reason why PALLAS is opting to apply the principle of diesel with phase IV emission requirements (cleanest possible diesel equipment). This is therefore not a mitigating measure, but rather a pre-emptive principle to be applied.

10.5 Gaps in knowledge

Gaps in knowledge and information can partly arise due to a lack of knowledge and information at the present time, but also as a result of uncertainty regarding future developments. The following gaps have been detected for the Air quality aspect:

1. Uncertainty regarding background concentrations and emission factors.
2. Uncertainty regarding the number of operating hours of emission sources and the volume of diesel-powered equipment and motorized vehicle movements.

Sub1) Uncertainty regarding background concentrations and emission factors.

Emission factors and background concentrations are determined annually according to the latest insights. The trend in terms of air quality is that both the emission factors and background concentrations decline. When emission factors and background concentrations are adjusted, this often concerns minor changes. New insights are not expected to have any great impact on the results of the study.

Sub2) Uncertainty regarding the number of operating hours, volume of diesel-powered equipment and motorized vehicle movements

The overview of emission sources is based on the Design framework [19] and estimation of the volumes of soil, concrete and other materials to be applied. When determining the air emissions as the result of construction of PALLAS, conservative construction methods have continually been sought from the air quality perspective. Moreover, the upper limit has been applied in terms of capacity of the equipment to be deployed, when determining the emissions. Once again, new insights are not expected to have any great impact on the results of the study.

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11 Noise

The following description of the Noise aspect is based on the Noise background report (see Appendix F6).

11.1 Assessment framework

11.1.1 Policyframework

Table 47 summarizes the relevant policy and relevant legislation and regulations for the Noise aspect, along with an indication of their relevance for the project. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Noise.

11.1.2 Assessment framework and methodology

The Noise aspect is assessed according to the assessment framework given in Table 48.

Study area

The study area stretches to the area containing noise-sensitive sources which may be influenced, see Figure 33.

Table 47 Policy, legislation and regulations on Noise

Policy plan, law, regulation	Description/ Relevance for PALLAS
Dutch Building Decree, Ministry of Infrastructure and the Environment, 2012	The 2012 Dutch Building Decree is the assessment framework for most construction/building work, and includes requirements with regard to noise nuisance. The construction work for PALLAS must be conducted according to the set requirements for working hours and for duration and degree of exposure.
Notice on Construction noise, Ministry of Infrastructure and the Environment, 2010	According to the Notice on Construction noise 2010, work may only be conducted on Saturdays when an exemption has been obtained. In the case of noise sources which are continually operational, such as groundwater pumps, the Notice on Construction noise advises that the noise level according to the exemption may not exceed a long-time average assessment level of 45 dB(A) and 40 dB(A) at the closest noise-sensitive structures, during the evening and nighttime periods respectively. This is comparable with a target value of 50 dB(A) 24-hour value.
Guide to Industrial noise and Permits, former Dutch Ministry of VROM, 1998	This ministerial guide is mainly aimed at non-zoned industrial estates and solitary companies. If a municipality develops its own policy on industrial noise, by formulating a so-called Memorandum on Industrial noise, this forms the assessment framework for the environmental permit requirements. The HFR site and the proposed PALLAS site are both non-noise-zoned sites. With a view to the LAmax maximum noise levels, the aim is that levels are no higher more than 10 dB(A) than the long-time average assessment levels at the housing location. The target values for the maximum noise level are: • 70 dB(A) in the daytime period. • 65 dB(A) in the evening period. • 60 dB(A) in the nighttime period.
Dutch Environmental Act, former Ministry of Housing, Spatial Planning and the Environment (VROM), 1996	In the case of installations subject to a permit, traffic to and from the installations is assessed on the basis of the Notice on 'Noise nuisance caused by road traffic to and from the installation'. This notice advises a preferred target value of 50 dB(A) 24-hour value and a maximum target value of 65 dB(A) 24-hour value.

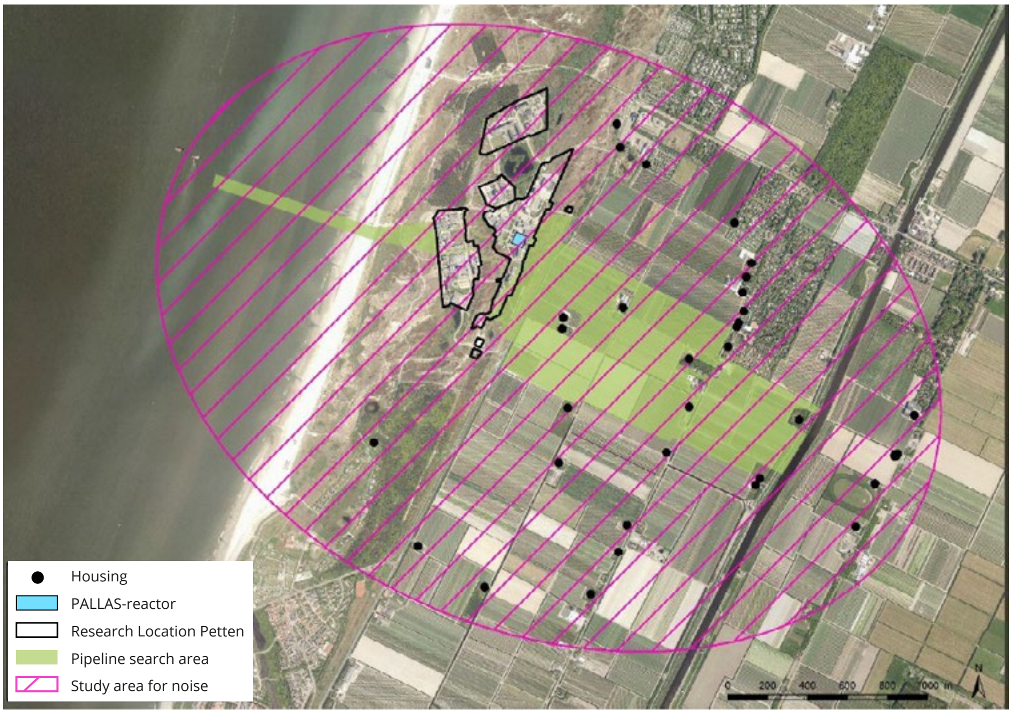

Figure 33 Study area for Noise

Assessment framework

This section is aimed at describing the impact on the residential environment and therefore only discusses the first assessment criterion. The impact on sensitive areas, the second criterion, is described in section 13 , as well as in the background report on Nature (Appendix F8).

Table 48 Assessment framework for Noise

Assessment criteria	Description
Noise hinder for housing	Noise hinder for housing, other noise-sensitive buildings and noise-sensitive sites
Noise hinder for sensitive areas	Noise hinder for designated quiet areas, nature areas, etc.

Noise hinder for housing

Noise hinder for housing, other noise-sensitive buildings and noise-sensitive sites is assessed on the basis of the *Guide to Industrial noise and permits* and the *Environmental Act*.

Guide to Industrial noise and permits

The municipality of Schagen has not yet determined its own policy for industrial noise, in a so-called Memorandum for Industrial noise. This means that noise regulations must be formulated in accordance with the system of design values and target values given in section 4 of the Guide to Industrial noise and permits.

For residential zones, the guide recommends the design values given in Table 49. The permits procedure for the Noise aspect is as follows:

For new installations:

- The values given in Table 49 are applied during the initial assessment.
- It may be possible to exceed these design values, following weighing of interests at the administrative level.
- The existing reference level of ambient noise then plays an important role.
- The maximum level is the "24-hour value[30]" of 50 dB(A) on the facade of the nearest housing or the reference level of the ambient noise.

For existing installations:

- When reviewing permits, the design values according to Table 49 are always reassessed.
- It may be possible to exceed the design values, up to the reference level of the ambient noise.
- Exceeding the reference level of the ambient noise up to a maximum "24-hour value" of 55 dB(A) may be considered admissible in some cases, following weighing of interests at the administrative level, in which the costs of combating noise must play an important role.

When the existing level (for which a permit was granted) caused by the installation exceeds the "24-hour value" of 55 dB(A), the latter value or the reference level of the ambient noise must be applied as a maximum when formulating permit conditions.

In such cases, the design values may only be exceeded following application of the Best Available Techniques (BAT) in order to limit noise emissions wherever possible.

The area around PALLAS can best be characterized as a rural environment. At the location of housing, the design value for the long-time average assessment level is 40 dB(A) during daytime, 35 dB(A) in the evening and 30 dB(A) at night time (see Table 49).

Indirect noise due to traffic to and from the installation

On the basis of the Notice on 'noise nuisance caused by road traffic to and from the installation'; the impact assessment for the purpose of the permit procedure, based on the Environmental Act, assumes:

- A design value of 50 dB(A) 24-hour value at housing locations and other noise-sensitive structures.
- A maximum target value of 65 dB(A) 24-hour value at housing locations and other noise-sensitive structures.

Relevant phases

The impact on the Noise aspect is described for the construction phase and operational phase. The transition phase has not been separately assessed, as the activities during this phase, in which both the HFR and PALLAS-reactor will be operational, will have no other impact than during the operational phase.

SEA assessment scale

The assessment scale for the Noise aspect is shown in Table 50 for the construction phase and in Table 51 for the transition and operational phases.

Table 49 Design values for residential areas

Type of residential area	Recommended design values in the residential area in dB(A)		
	Daytime	Evening	Nighttime
Rural environment	40	35	30
Quiet street, little traffic	45	40	35
City street	50	45	40

30 The 24-hour value is the highest value of:
- The long-time average assessment level LAr, LT in the daytime period (07:00-19:00 hours).
- The long-time average assessment level LAr, LT in the evening period (19:00-23:00 hours) + 5 dB(A).
- The long-time average assessment level LAr, LT in the nighttime period (23:00-07:00 hours) + 10 dB(A).

Table 50 Scoring of assessment for Noise, construction phase

Score	Meaning	Explanation
++	Extremely positive impact	Not applicable
+	Positive impact	Not applicable
0	No impact	The noise level complies with a daytime value of 60 dB(A) and a long-time average assessment level of 45 dB(A) in the evening and 40 dB(A) in the nighttime period.
-	Negative impact	The noise level exceeds a daytime value of 60 dB(A), but the duration of exposure complies with the requirements of the Dutch 2012 Building Decree, or the noise level exceeds a long-time average assessment level of 45 dB(A) in the evening and 40 dB(A) in the nighttime period, by no more than 5 dB(A).
- -	Extremely negative impact	The noise level exceeds the regular noise level requirements of the Dutch 2012 Building Decree, or the noise level exceeds a long-time average assessment level of 45 dB(A) in the evening and 40 dB(A) in the nighttime period, by more than 5 dB(A).

Table 51 Scoring of assessment on Noise, transition and operational phases

Score	Meaning	Explanation
++	Extremely positive impact	Not applicable
+	Positive impact	The noise level is reduced
0	No impact	The noise level complies with the target value of 40 dB(A) for a rural environment.
-	Negative impact	The noise level exceeds the target value of 40 dB(A) 24-hour value for a rural environment, but complies with the target level of 50 dB(A) 24-hour value.
- -	Extremely negative impact	The noise level exceeds the target value of 50 dB(A) 24-hour value.

Construction phase

There can be no positive impact on the noise nuisance aspect during the construction phase. When assessing the construction phase, the daytime value of 60 dB(A) is the initial reference value, with unlimited duration of exposure. When exceeding this daytime value, it must be determined whether there is compliance with the maximum admissible duration of exposure or whether an exemption must be requested. Activities conducted in the evening and nighttime periods are assessed according to a long-time average assessment level of 45 dB(A) in the evening period and 40 dB(A) in the nighttime period.

Transition phase and operating phase

When assessing the transition and operational phases, the 24-hour value of 40 dB(A) is the initial design value, for a rural environment. Any noise nuisance will then be minimal. When exceeding the design value, the target value of 50 dB(A) 24-hour value is the assessment reference for a new installation. When it barely complies with the target value, noise nuisance may be expected, but the degree of nuisance is still considered to be acceptable.

Indirect nuisance

Indirect nuisance is defined as noise nuisance caused by traffic to and from Research Location Petten. The noise hinder caused solely by traffic to and from Research Location Petten has been calculated. There is indirect nuisance in all three phases and it is assessed as being equal in all three. Table 52 gives the scoring for assessment of indirect nuisance during the construction, transition and operational phases.

Table 52 Scoring of assessment on Noise, indirect nuisance during the construction, transition and operational phases

Score	Meaning	Explanation
++	Extremely positive impact	Not applicable
+	Positive impact	Not applicable
0	No impact	The noise level complies with the design value of 50 dB(A) 24-hour value.
-	Negative impact	The noise level exceeds the design value of 50 dB(A) 24-hour value, but complies with the maximum target level of 65 dB(A) 24-hour value.
- -	Extremely negative impact	The noise level exceeds the maximum target value of 65 dB(A) 24-hour value.

11.2 Current situation and autonomous development

11.2.1 Current situation

In the reference situation (HFR in use according to the current situation), the noise hinder in the study area is mainly caused by the HFR and the provincial N502 road. The noise emission from the installation is mainly caused by noise radiating from the primary and secondary pumping stations, the air conditioning building, the auxiliary reactor buildings, fans, central heating outlets, the emergency generator, a forklift truck and traffic movements.

The nearest noise-sensitive structures concern a number of scattered houses along the provincial N502 road (Westerduinweg). These houses are located a few hundred meters from Research Location Petten. There is a row of dunes which are at least 5 m higher than the average ground level of Research Location Petten, between the houses and Research Location Petten.

The long-time average assessment level (LAr,LT) at the location of the nearest housing is at most approximately 25 dB(A) in daytime, 22 dB(A) in the evening and 19 dB(A) at nighttime. This is comparable with a 29 dB(A) 24-hour value.

As indicated earlier, the noise hinder in the study area is partly caused by the provincial N502 road (Westerduinweg). The noise hinder due to this road has been calculated for 2016. The assessment level has been shown to be 61 dB(A) during daytime, 62 dB(A) in the evening and 51 dB(A) at nighttime, at the location of the nearest housing. The noise contours for the nighttime period (the normative period) are shown in Figure 34.

A study was conducted into the current reference level of the ambient noise in 2011[31]. This is defined as the highest value of:

- The measured L_{95} level[32] of the ambient noise.
- The occurring equivalent noise level LAeq in dB(A), caused by roads subject to zoning, minus 10 dB(A).

Noise measurements were conducted in the vicinity of the Westerduinweg and Belkmerweg in order to determine the L_{95} level of the ambient noise, in September and October 2011. The noise measurements showed the following:

- The measured L_{95} level was 41 to 44 dB(A) in the daytime period.
- The measured L_{95} level was 39 to 41 dB(A) in the nighttime period.

It should be noted that the nighttime level was measured between 00.10 and 01.26 hours. The reference level would be even lower in the middle of the night.

The calculations for the reference year 2016 show that the calculated L_{Aeq} minus 10 dB(A), at the nearest housing along the Westerduinweg, equals:

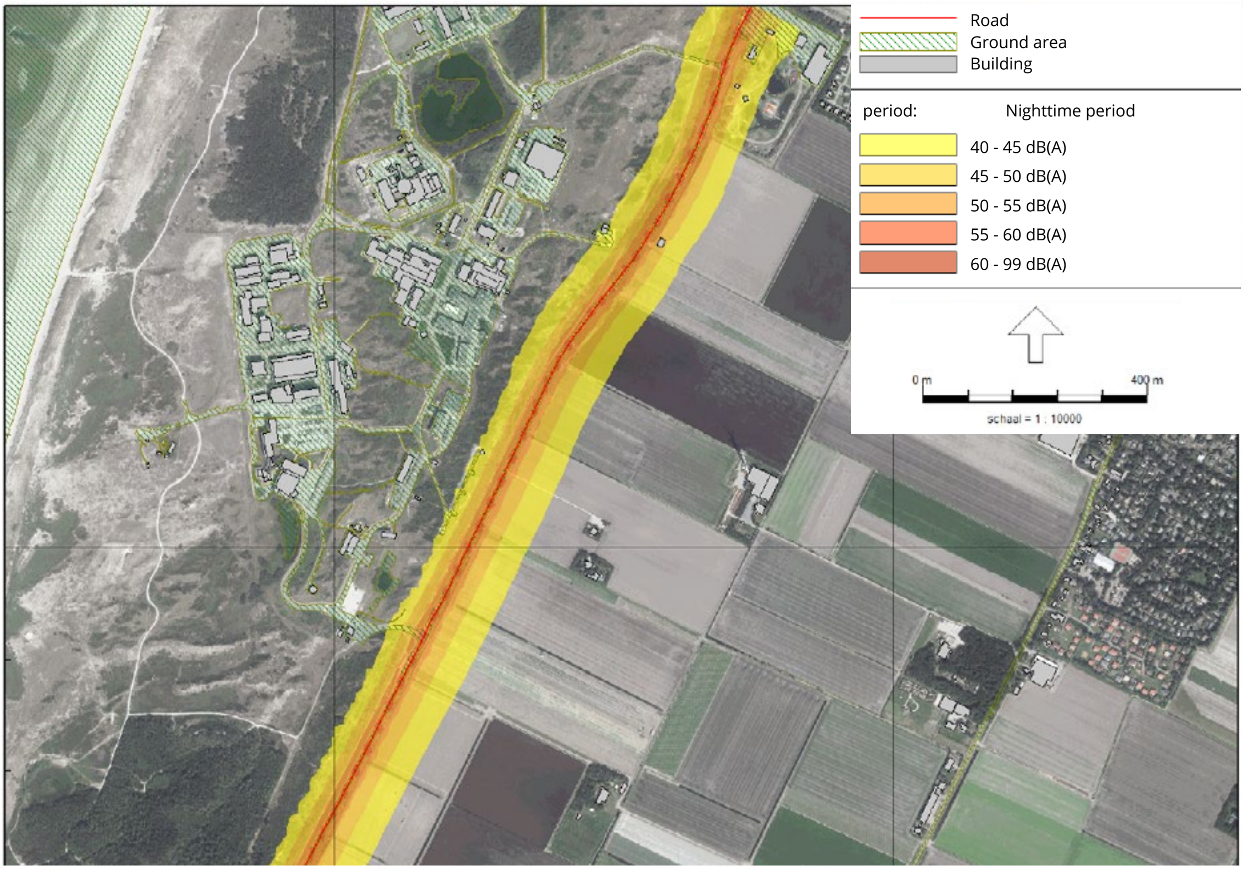

Figure 34 Noise contours for the normative night-time period (reference year 2016)

31 Acoustic norms for study of PALLAS-reactor NRG Petten, Report 2011-12-02 version 2.0 by Witteman Geluidbeheersing.
32 The L_{95}-level is the level of noise exceeding 95%, or the basic level present 95% of the time

- 29 to 51 dB(A) in the daytime period.
- 30 to 52 dB(A) in the evening period.
- 28 to 41 dB(A) in the nighttime period.

11.2.2 Autonomous developments

In the reference situation, the noise hinder in the reference year 2026 will be comparable with the current situation. Only the traffic-based noise hinder may increase, due to autonomous growth of the traffic volume. However, the autonomous growth of road traffic is estimated to be extremely limited, as there are no significant spatial developments planned in the area.

11.3 Environmental impact

11.3.1 Impact description

11.3.1.1 Construction phase

The construction phase will take a number of years, during which a variety of construction activities will be conducted. Many of these activities will not take place simultaneously, but will be conducted successively. A distinction has therefore been made in terms of periods of construction activities during the construction phase:

- Period 1: Establishment of an LDA.
- Period 2: Drilling of piles for the nuclear reactor and excavation work for installation of the pipeline to the sea and to the canal (in the case of cooling variants K1 and K2).
- Period 3: Excavation and construction of the nuclear reactor, with the concrete plant in operation.
- Period 4: Construction of pumping station, drilling of piles for the buildings at the location of the Off Plot Scope (OPS) and the cooling units in the case of cooling variant K3, with the concrete plant in operation.

A distinction is made between regular construction activities and the pile driving activities.

Construction activities

During daytime, the noise hinder has been calculated to be highest at all houses in construction period 4. During the evening and nighttime periods, the noise level is highest in building period 3. The degree of noise hinder has been determined on the basis of the normative period and the normative construction activities at the location of the calculation points, per period. It therefore takes account of the construction of various cooling variants in a single calculation model. This is a worst case approach.

The long-term average assessment level is maximum approximately 53 dB(A) during the daytime, evening and nighttime periods, for regular construction activities. This therefore complies with the requirements of the 2012 Dutch Building Decree for the daytime period. During the evening and nighttime periods, the noise level exceeds the design values of 45 dB(A) for the evening period and 40 dB(A) for the nighttime period, as given in the Notice on Construction noise 2010. These design levels are exceeded at approximately four houses, due to deployment of the concrete plant during the evening and nighttime periods. The concrete plant is located on the LDA. The search area for the LDA is situated to the south of Research Location Petten at approximately 180 m distance from the nearest house. If the LDA were to be realized at this location, mitigating measures must be taken for the concrete plant. The LDA can also be moved elsewhere (within the search area) to a more favorable position in relation to the local housing.

A noise contour has therefore been calculated and a contour distance determined for the 24-hour value of 45 dB(A) and 40 dB(A), which indicates the preconditions for avoidance of excess noise at houses as a result of the concrete plant.

These contour distances are:

- 45 dB(A) 24-hour value: 325 m.
- 40 dB(A) 24-hour value: 500 m.

Noise levels are no longer exceeded at houses at a distance of 500 m or more from the LDA. When houses are located at a distance between 325 m and 500 m, noise levels are no longer exceeded during the nighttime period. This can be solved by means of mitigating measures (see paragraph 11.4). When houses are located within 325 m of the LDA, noise levels are exceeded in both the evening and nighttime periods. This means that mitigating measures are essential at the concrete plant (see paragraph 11.4). It should be noted that the concrete plant is generally only operational in daytime, and that the situation requiring continuous pouring of concrete will only be for a limited period. However, it is more than an incidental occurrence and is therefore regarded to be a normative representation of the acoustic operating situation for the purpose of this study.

Pile driving work

Pile driving work is conducted at the location of the LDA and at the pumping station close to the canal (cooling variant K1). As the precise location is not yet known for either the LDA or the pumping station close to the canal, the exact noise hinder for the surrounding houses cannot be determined. A noise contour has therefore been calculated and a contour distance determined for a number of daytime values based on the 2012 Dutch Building Decree. These distances are shown in the table hereafter (see Table 53). It is possible to determine the maximum admissible period for pile driving work, based on the distance to the nearest house. When pile driving work takes place within this distance to the nearest house or if the pile driving work takes a longer period of time, mitigating

Table 53 Contour distances for pile driving work

Noise hinder (dB(A))	Distance (m)
60	520
65	360
70	250
75	160
80	100

measures must be considered (see paragraph 11.4). This may serve to reduce the impact distance.
The calculated contour distances show that the pumping station is situated at a distance of at least 160 m from housing, and that the requirements of the 2012 Dutch Building Decree are expected to be met (maximum duration of exposure of 15 days). For the time being, this is not expected to be problematic. Should the pumping station be situated closer to the housing after all, then mitigating measures will be required.

Installation of cooling water pipeline
The precise location of the cooling water pipeline from the canal to Research Location Petten is not yet known. The work required for installation of the cooling water pipeline will result in noise. The 60 dB(A) contour is at 45 m distance and the 65 dB(A) contour is at 25 m distance. If the cooling water pipeline is installed at less than 45 m from a house, there will be restrictions for the construction period in accordance with the 2012 Dutch Building Decree or mitigating measures will be required. For the time being, this is not expected to be problematic.

Indirect nuisance
The indirect nuisance has been assessed as a result of construction traffic traveling to and from Research Location Petten over the N502 Westerduinweg. The noise hinder was assessed for construction traffic alone. The preferred target value of 50 dB(A) 24-hour value was exceeded at three houses, where the noise hinder was maximum 59 dB(A). In order to assess the contribution of the construction traffic to the noise hinder caused by the N502 Westerduinweg, the noise hinder was also calculated for current traffic. At those houses with a noise hinder above the preferred target value of 50 dB(A), the construction traffic was shown to give an increase of 2 dB(A).

11.3.1.2 Transition phase and operating phase

Construction height variants
The construction height variants have no differentiating impact for the Noise aspect, due to the noise emission not changing. A slightly different level might only occur locally due to shielding or reflection, but this impact is negligible for the houses at a relatively large distance. The description of the impact of these variants is based on cooling variant K1. The cooling variant determines the impact during the operational phase.

Cooling variants
The long-time average assessment level for cooling variant K1 has been shown to be maximum 28 dB(A) in the daytime period, 25 dB(A) in the evening period and 25 dB(A) in the nighttime period, at the location of the nearest housing. The highest 24-hour value was hereby 35 dB(A). There are therefore no houses subjected to noise hinder in excess of 40 dB(A) 24-hour value. This complies with the design value.
The impact of cooling variant K2 is comparable with that of cooling variant K1, as both variants are sufficiently far away from housing. There are therefore no houses subjected to noise hinder in excess of 40 dB(A) 24-hour value for these variants.
The calculations show that cooling variant K3 exceeds the design value at 2 houses during the daytime period, at 5 houses during the evening period and at 20 houses during the nighttime period. There are two houses subjected to noise hinder in excess of 50 dB(A) 24-hour value. The house subjected to the most noise has a long-time average assessment level of approximately 47 dB(A) during the daytime, evening and nighttime periods. This translates into an approximate 57 dB(A) 24-hour value.
The deployment of quieter cooling units, a different type of cooling system with a lower noise emission, the installation of dampers and/or realization of a protective screen will need to reduce the noise caused by variant K3, by at least 7 dB(A) in order to comply with the target value of 50 dB(A) 24-hour value at the nearest housing. This means that the total (immission-relevant) source capacity of the group of cooling units to be deployed may not exceed 105 dB(A), see paragraph 11.4.

Indirect nuisance
The preferred target value of 50 dB(A) 24-hour value is not exceeded at any housing. The noise hinder is maximum 47 dB(A).
In order to assess the contribution by the traffic to and from the installation, to the noise hinder caused by other traffic on the N502 Westerduinweg, the noise hinder was also calculated for current traffic. The contribution by the traffic to and from the installation is maximum 0.1 dB(A).

11.3.2 Impact assessment
The impact assessment is summarized in Table 54.

The construction height variants have no differentiating impact for the Noise aspect. The description of the impact of these variants is based on cooling variant K1. The impact is merely determined by the cooling variant during the transition and operational phases.

Construction phase
The design values and target values for the evening and nighttime periods are exceeded during the construction phase. The maximum duration of exposure may possibly also be exceeded in the daytime period, due to pile driving work for the benefit of the pumping station at the canal (K1). Due to the target values being exceeded as a result of the construction activities, all construction height variants are scored extremely negatively (- -) during the construction phase of the PALLAS-reactor.
The construction activities for the cooling variants K2 and K3 are insignificant in relation to the other construction activities, as the former activities will only take place in daytime, without pile driving work. The impact of these cooling variants is therefore scored as neutral (0). Pile driving work will be conducted for construction of the cooling variant K1. The daytime value of 60 dB(A) will therefore possibly be exceeded, though the required activities will probably comply with the maximum duration of exposure. For this reason, cooling variant K1 is scored as negative (-).
It should be noted that, with a view to the search area for the

Table 54 Impact assessment on Noise

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Noise hindrance for local residents due to installation	0	0	0	n/a	n/a	n/a
Noise hindrance for local residents due to construction activities	- -	- -	- -	-	0	0
Indirect noise hindrance for local residents	-	-	-	n/a	n/a	n/a
Transition phase and operating phase						
Noise hindrance for local residents due to installation	0	0	0	0	0	- -
Noise hindrance for local residents due to industrial activities	0	0	0	0	0	- -
Indirect noise hindrance for local residents	0	0	0	n/a	n/a	n/a

cooling water pipelines, the exact location and work required for installation of the cooling water pipeline will only become clear following further detailing and choices regarding the cooling variant to be applied, in the following phase (for the permit). As a result of the further detailing and permit application procedure, this score must be adjusted if the noise level is shown to exceed the daytime value of 60 dB(A). However, this is not considered likely. It applies solely to the pipelines search area between the canal and Research Location Petten. There is no housing in the area between the sea and Research Location Petten.
The indirect nuisance has been assessed as a result of construction traffic traveling to and from Research Location Petten over the Westerduinweg. The preferred target value is exceeded at three houses.
The maximum value is not exceeded. For this reason, the indirect nuisance is scored as negative (-). There is no differentiating impact between the various construction height variants.

Transition phase and operating phase
During the transition and operating phases, the impact of cooling variants K1 and K2 hardly differs at all from the reference situation. Thus both variants can be scored as neutral (0). Cooling variant K3 exceeds the target value of 50 dB(A) 24-hour value. This cooling variant is therefore scored as very negative (--). The indirect nuisance caused by the traffic to and from Research Location Petten over the Westerduinweg has also been assessed for the transition and operational phases. The calculations show no exceeding of the preferred target value, due to the limited number of vehicle movements. For this reason, indirect nuisance is scored as negative (-). None of the cooling variants have a direct impact on the indirect nuisance. Vehicles will drive to and from the pumping station near the canal in the case of cooling variant K1, but the number of vehicles is so limited that the impact is negligible. It is therefore scored as neutral (0). Conservative principles were applied in calculations for this study.

11.4 Mitigating measures

The study shows the following noise sources to have (extremely) negative effects:

- Concrete plant (during the evening and nighttime periods).
- Pile driving work.
- Cooling variant K3.

For the time being, worst case principles are applied for these noise sources in this noise study. The precise location has yet to be determined for the concrete plant, the pumping stations and the pile driving work required for the reactor and buildings.

Upon detailing the design, attention must be paid to the mitigation of the aforementioned (extremely) negative effects. The following mitigating measures are possible for the various noise sources:

- Concrete plant: The concrete plant can be screened off from the nearest housing, while the location of the concrete plant can also be taken into account. Fewer mitigating measures may be necessary if the concrete plant is located sufficiently far away from the nearest housing.
- Pile driving work. Measures can be taken during pile driving work, such as the use of a pile driving shield, or alternative techniques such as the drilling of piles, in order to comply with the duration of exposure criterion given in the 2012 Dutch Building Decree.
- Furthermore, the negative impact can be limited by projecting the concrete plant and pumping stations relatively far away from housing. This will probably allow compliance with the maximum duration of exposure criterion of the 2012 Dutch Building Decree.
- Cooling variant K3: The deployment of quieter cooling units, a different type of cooling with a lower noise emission, the installation of dampers and/or realization of a protective screen between the cooling units and the

nearest housing. Deployment of these measures will need to reduce the noise in cooling variant K3 by at least 7 dB(A) for the nearest housing. This means that the total source capacity of the cooling units to be deployed may not exceed 105 dB(A). However, a screening wall will probably not be a realistic option when deploying cooling units with a larger source height, as currently envisaged for cooling variant K3.

By applying these measures, the impact of the construction phase and cooling variant K3 can be limited to 'negative'

11.5 Gaps in knowledge

At the time of the study, there is still limited insight into the noise sources and their strength and intensity. Any deviations from the principles applied may result in a relevantly different impact. Given that conservative principles have been applied, the impact is not expected to become any more negative.

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12 Light

The following description of the Light aspect is based on the Light background report (see Appendix F7).

12.1 Assessment framework

12.1.1 Policy framework

There is not yet national legislation for light nuisance in the Netherlands. There are no strict norms for artificial lighting in the form of distance limits.
Table 55 briefly gives the relevant policy for the Light aspect, along with an indication of their relevance for the project. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Light.

NSVV guidelines
The Dutch Foundation for Illumination (NSVV) has published guidelines with regard to prevention of light nuisance [20]. These guidelines describe a number of visual effects which can result in light nuisance. One such effect is the direct incidence of light. The parameter used to determine this effect is the vertical illuminance in a point in a relevant surface (Exposure value - Ev in lux). In the case of housing, this usually concerns the vertical (facade) surfaces, particularly the windows. The NSVV guidelines include norms which depend on particular areas and periods of time. A distinction is made between four types of area classifications/zones, each with their own norm (see Table 56):

- E1: areas with extremely low ambient brightness, generally nature areas and rural areas far away from residential communities.
- E2: areas with low ambient brightness, generally non-urban and rural (residential) areas.
- E3: areas with average ambient brightness, generally urban (residential) areas.
- E4: areas with high ambient brightness, generally city centers with night-time activities such as entertainment centers, and industrial areas.

In order to give an impression of illuminance, the following Table 57 gives a number of situations and the applicable illuminance.

Table 57 Illuminance in a number of situations [21]

Situation	Illuminance (lux)
Daylight in full sun at the height of summer	50,000 - 100,000
Daylight on a cloudy day	1,000 - 10,000
Average daylight	5,000
Dusk	10
Full moon in a clear sky	0.25
New moon in a clear sky	0.002
Completely moonless, very cloudy night	0.001
Desk lamp	200 - 800
Reading lamp (working surface)	400
Normal room lighting in the evening	25 -50
Human limit for reading (newspaper is readable)	0.3
Human limit for discerning colors	0.1
Human limit for vision once adjusted to darkness	0.0001

12.1.2 Assessment framework and methodology

Table 58 gives the assessment framework for the Light aspect. The impact of the Light aspect is assessed for the housing and living environment. The impact of Light on nature is assessed in section 13 Nature.

Table 55 Policy, legislation and regulations on Light

Policy plan, law, regulation	Description/ Relevance for PALLAS
Dutch Environmental Act, Ministry of Infrastructure and the Environment, 2015	The Environmental Act governs the relationship between installations and their environment. At companies with an environmental permit (art. 2.1 paragraph 1 of the Dutch General Environmental Provisions Act, light nuisance may be arranged via the conditions of the permit. Lighting of an outdoor work site is covered by the NEN-EN 12464-2:2014 (specifications according to Occupational Health legislation).
Provincial Environmental policy plan 2015-2018, Province of Noord-Holland, 2015.	• The Provincial Environmental policy plan 2015 – 2018 gives the policy for light and darkness. The aim is to protect the primal quality of darkness in non-urban areas and to reduce lighting in relatively light urban areas. The Province of Noord-Holland thereby wishes to safeguard the following: • Darkness is one of the aspects taken into consideration in spatial developments, also within the zoning plans of municipal authorities. If this occurs inadequately, the province will engage the party in question in a dialog. • Based on the Environmental Act, the "effective use of energy" is considered when granting and monitoring permits; as a derivative, darkness can benefit from this.

Table 56 Guidelines for illuminance (Exposure value Ev) for prevention of light nuisance [21] [20]

Period	E1: nature area	E2: rural area	E3: urban area	E4: city center/ industrial area
7:00 AM – 9:00 PM	2 lux	5 lux	10 lux	25 lux
9:00 PM – 7:00 AM	1 lux	1 lux	2 lux	4 lux

Study area
The study area for the light assessment is derived from the planning area for the PALLAS-reactor, the search area for the LDA and the cooling water pipelines. This is where the (temporary) light sources for the project can be found. The impact in terms of the Light aspect is considered from a minimum illuminance of 0.1 lux (with relation to nature). In the study, this means that the study area reaches maximum 50 m outside the search zones and the planning area.

Table 58 Assessment framework for Light

Assessment criteria	Explanation
Direct incidence of light in housing	Direct incidence of light in the houses in the direct vicinity of Research Location Petten, along the pipeline route and the LDA.

Assessment framework
Assessment of the impact on the above criterion is based on the principle of a worst case scenario. In this case, it concerns the LDA being as close as possible to the housing, within the search area.
Within the scope of this SEA, the assessment criterion for direct incidence of light is based on the NSVV 'Guidelines on Light nuisance' of November 2014 [20]:

- The areas directly north, west and south of the PALLAS-reactor can be characterized as E1 zones (nature area), see policy framework in paragraph 12.1.1. The design value on the house facades in the E1 zone is 1 lux in the nighttime period, which is the reference period for assessment of light nuisance.
- The houses in the countryside to the east of the planning area, can be characterized as an E2 zone (rural area), see policy framework in paragraph 12.1.1. The design value on the house facades in the E2 zone is 1 lux in the nighttime period.

Relevant phases
The impact on the Light aspect is described for the construction phase and operational phase. The transition phase has not been separately assessed, as the activities during this phase, in which both the HFR and PALLAS-reactor will be operational, will have no other impact than during the operational phase. The construction phase is the reference for the Light aspect. The operational phase will require much less lighting than the construction phase. Furthermore, the reactor location is further away from the built-up area than in the construction phase (lighting at the LDA and installation of the cooling pipelines). If the illuminance complies with the norm during the construction phase, it will easily comply with the norm during the transition and operational phases.

SEA assessment scale
Table 59 gives the assessment scale for the Light aspect. There can be no positive impact on the light nuisance aspect.

Table 59 Assessment framework for Light

Score	Meaning	Explanation
++	Extremely positive impact	Not applicable
+	Positive impact	Not applicable
0	No impact	No change, 0-1 lux increase in lighting brightness for local residents
-	Negative impact	Slight negative effect, 1-2 lux increase in lighting brightness for local residents
- -	Extremely negative impact	Great negative effect, >2 lux increase in lighting brightness for local residents

12.2 Current situation and autonomous development

12.2.1 Current situation
The website of the province of Noord-Holland gives the following description under the heading of 'theme/environment/light and darkness':
"The Netherlands is one of the most illuminated countries in the world, and Noord-Holland one of the most illuminated provinces. Factors which contribute to the increasing occurrence and spread of illumination in our province include traffic safety and the 24-hour economy. The greenhouse horticulture sector in Noord-Holland also radiates large volumes of light. The greenhouses, road lighting, industrial estates, sports fields and advertising objects have increasingly resulted in darkness giving way to light, particularly in the metropolitan region of Amsterdam and the greenhouse area.

The night sky brightness map of the province of Noord-Holland shows that there is relatively little light radiation in the planning area. There is relatively little lighting in the direct vicinity of the PALLAS-reactor. The lighting in the direct vicinity of the planning area is mainly the result of the industry and road lighting present there.

12.2.2 Autonomous developments
In the autonomous situation, more and more low/energy lighting is expected to be deployed along the roads, while (industrial) sites will be illuminated using LED lighting. Such lamps are so small that the light is generally radiated downward, thus radiating relatively little light to the surrounding area.

Night sky brightness with greenhouses illuminated

The night sky brightness map indicates the brightness of the sky straight above us. Most of the light in the night sky does not come from stars but from the sky itself. The brighter the sky and therefore the degree of darkness, is determined by light radiated upward, both directly and reflected from the ground, from an area with a radius of approximately 20 kilometers. The higher the number (expressed in mcd/m²), the greater the amount of light from the sky and the brighter it is. The brightness also determines how many stars are visible.

Brightness (mcd/m²)	Number of stars
<0.3	>1910
0.3 - 0.4	1910 - 1630
0.4 - 0.5	1630 - 1430
0.5 - 0.75	1430 - 1100
0.75 - 1.0	1100 - 890
1.0 - 1.4	890 - 690
1.4 - 2.0	690 - 510
2.0 - 3.0	510 - 360
3.0 - 4.0	360 - 270
4.0 - 6.0	270 - 180
6.0 - 8.5	180 - 130
8.5 - 11.5	130 - 90
Greenhouses	

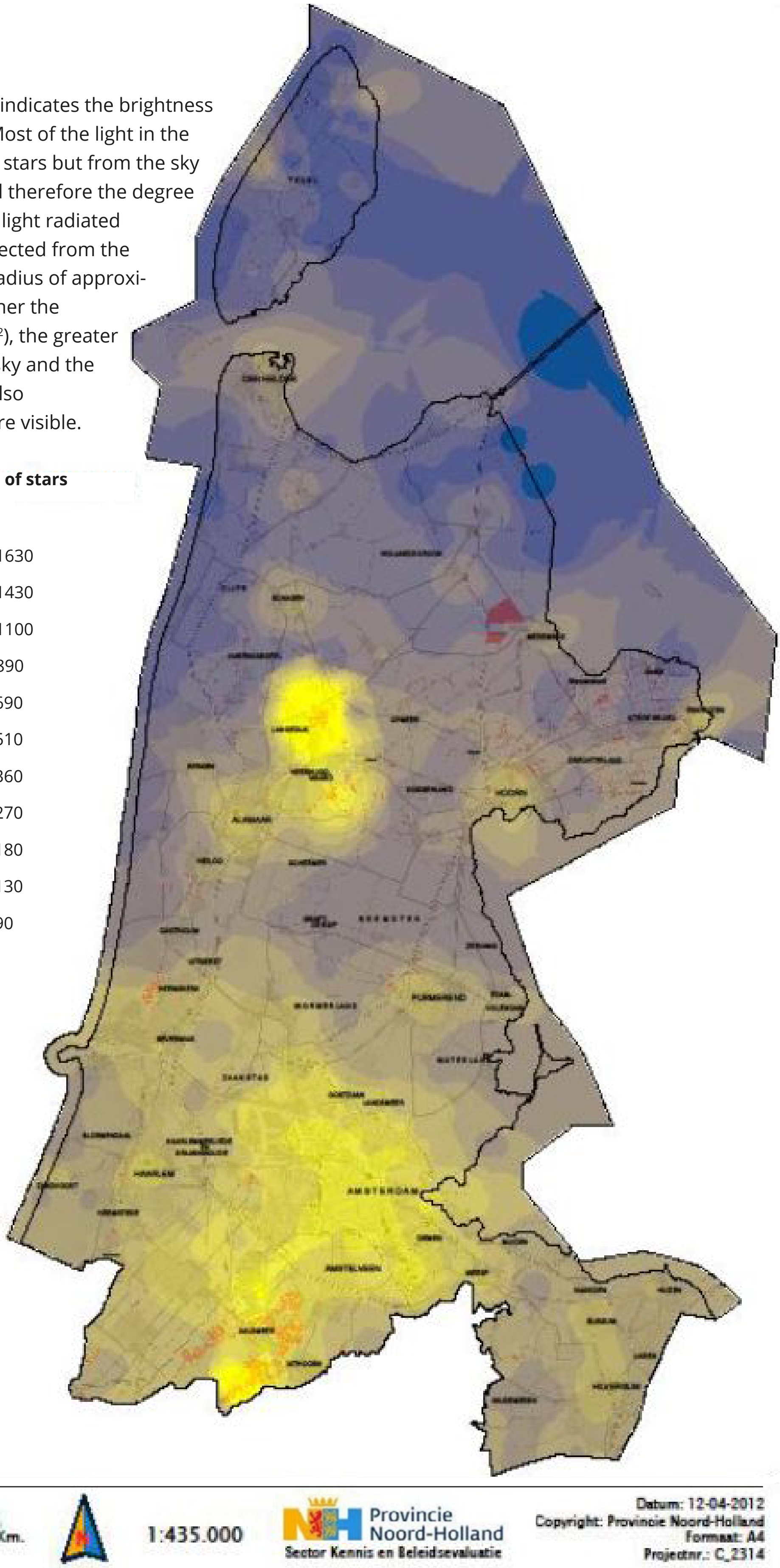

Figure 35 Night sky brightness map of the Province of Noord-Holland

12.3 Environmental impact

12.3.1 Impact description

Construction phase

Construction activities will primarily take place in the daytime period from 7.00 to 16.00 hours. Artificial lighting will not be necessary in the summer period. During the winter period, artificial lighting will be deployed from 7.00 to 8.30 hours. Construction activities may occasionally take place on a 24-hour basis.

The use of artificial lighting will, in principle, be limited. Due to the precise location of the LDA and cooling water pipelines not yet been known, they have been modeled according to the least favorable location within the search area, for the purpose of the study. The locations under consideration may have a negative impact.

Figure 36 shows the impact of vertical illuminance[33] during the construction phase.

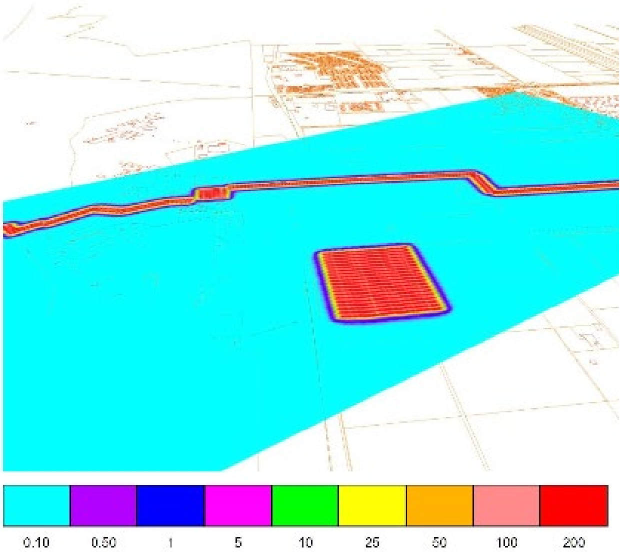

Figure 36 Vertical illuminance during the construction phase

The calculation results show the illuminance, caused by LDA lighting required for construction of the PALLAS-reactor and cooling water pipelines (cooling variants K1, K2 and K3), to be maximum 1.4 lux at the location of the housing. This illuminance was calculated on the facades of the house at Westerduinweg 22. This complies with the design value of 5 lux for houses in a rural area during the daytime period (7:00-21:00 hours). If the construction activities take place during the nighttime period (21:00-7:00 hours), the 1 lux norm will be exceeded during that period. An illuminance of 30 lux may occur at the bungalow park on the Belkmerweg 54, as the result of lighting required for installation of the cooling water pipeline to the canal. This only applies in the case of cooling variants K1 and K2, and will exceed the norm by a very large margin. This can be prevented by keeping a distance of at least 30 m between the light source required for the cooling water pipeline construction work and the bungalow park.

The illuminance at the Natura 2000 North Sea coastal zone as a result of construction activities at Research Location Petten and the LDA is well under the 0.1 lux norm. The installation work for the cooling water pipeline to the sea runs straight through the Natura 2000 area. The 0.1 lux is approximately 50 m from the light source(s). For further details on the impact on nature, see section 13 and the background report on Nature (Appendix F8).

Transition phase and operating phase

As described in paragraph 12.1.2, the construction phase is the reference situation in terms of impact. In this reference situation, light emission and immission will increase locally around the PALLAS-reactor. The light immission will be lower in the transition phase than in the construction phase. The impact is negligible at light-sensitive objects at a relatively great distance.

The construction height variants have no differentiating impact for the Light aspect, due to the light emission not changing. The local light immission may vary if the light masts or light sources are installed at a greater height in variants B2 and B3. A slightly different light immission might only occur locally due to higher light masts or higher light sources, but this impact is negligible for the light-sensitive objects at a relatively large distance. The cooling variants have no influence on the Light aspect.

12.3.2 Impact assessment

Construction phase

The increase in illuminance at the houses will be maximum 1.4 lux on the basis of the current search area for the LDA. At one house, the illuminance can increase to 30 lux on the basis of the search area for the cooling water pipelines to the canal in cooling variant K1. The route of cooling variant K2 and the location of the air cooling variant K3, are relatively far away from light-sensitive objects. The impact of these variants is therefore negligible. In accordance with the assessment scale described in Table 59, the scope of the illuminance is scored as slightly negative (-) for the construction height variants due to the LDA, as neutral (0) for cooling variants K2 and K3 and as extremely

Table 60 Impact assessment on Light, construction phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Increased light intensity in light-sensitive objects	-	-	-	- -	0	0

33 The illuminance is the amount of incident light illuminating a surface, per surface unit (unit: lux).

Table 61 Impact assessment on Light, transition phase and operational phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Transition phase and operating phase						
Increased light intensity in light-sensitive objects	0	0	0	0	0	0

Transition phase and operating phase
In the transition phase, light emission and immission will increase locally around the planning area of the PALLAS-reactor. When considering the light contours around the planning area during the construction phase, the illuminance as a result of the transition phase is negligible at light-sensitive objects. In accordance with the assessment scale described in Table 61, the scope of illuminance is scored as neutral (0) during the transition phase. The illuminance of the construction height and cooling variants has no differentiating impact for the Light aspect at light-sensitive objects. An overview of the impact assessment during the transition phase is shown in Table 61.

12.4 Mitigating measures

Mitigating measures
In order to prevent the impact caused by artificial lighting at the LDA during the nighttime period, a distance of approximately 30 m (in relation to housing) must be taken into account upon realization of the LDA. This is the minimum distance from the light source to the housing. In the installation of cooling water pipelines too, the light masts must be erected at a minimum distance of 30 m from the housing in order to prevent a negative impact.
The following measures can be taken to further reduce the illuminance in the surrounding area:

- The light masts must not be too high.
- The radiation direction of the fittings must be positioned as far away as possible from the housing and nature area.
- The use of LED lighting is a possibility, as LED lighting is spot lighting with less radiation to the surrounding area.
- Lighting should be omitted wherever possible.

Impact assessment following mitigating measures
It is simple enough to find a location for the LDA and cooling water pipelines within the search area, which will not have any impact in terms of Light. The impact of the Light aspect following mitigating measures is therefore scored as neutral (0).

Table 62 Impact assessment on Light following mitigating measures

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Increased lighting brightness for local residents	0	0	0	0	0	0

12.5 Gaps in knowledge

The light radiation to the surrounding area depends on various factors. It depends, for example, on the type of lamp, the radiation direction, intensity of the lighting, height of the light masts, the degree of shielding of the lamp, the shielding by objects on the site, etc.
The actual light radiation to the surrounding area may deviate from the calculations now made. The calculated illuminance must be regarded to be a design value. There may be less impact in the actual situation (a worst case approach has been applied, see paragraph 12.1.2).
If fittings with LED lighting are applied and the area is only illuminated where necessary, there will be less impact than now calculated.

13 Nature

The following description of the Nature aspect is based on the Nature background report (see Appendix F8). Please refer to this background report for a more detailed description.

13.1 Assessment framework

13.1.1 Policy framework

Table 63 summarizes the relevant policy and relevant legislation and regulations for the Nature aspect, along with an indication of their relevance for the project. The Dutch Nature Protection Act and Provincial Spatial Planning Decree are then discussed in more detail. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Nature.

Nature Protection Act

The Dutch Nature Protection Act came into force on 1 January 2017, replacing the previous 1998 Nature Protection Act, the Flora and fauna Act and the Woodlands Act. The Nature Protection Act regulates the protection and conservation of Natura 2000 areas, protected species and their regular habitats, as well as woodland and vegetation. Further legislation is detailed in the Nature Protection Decree and the Nature Protection ruling.

Regional protection: Natura 2000 area

Natura 2000 areas are areas designated on the basis of the European Birds and Habitats Directives. In designating these areas, conservation targets were formulated for species and habitats already at the required (qualitative and quantitative) level, and expansion or improvement targets for species and habitats not yet at the required level.

Natura 2000 areas are strictly protected by law. Without a specific permit, it is forbidden to realize projects or conduct other activities which may damage the quality of the natural habitats or the habitats of species in that area, or which may significantly disturb the species for which the area is designated, according to the conservation targets for a Natura 2000 area. For control purposes, the law requires approval for plans (such as the PALLAS zoning plan), which might have significant consequences for Natura 2000 areas, while projects are subject to permits being granted. The approval or permit will only be granted if there is certainty that the natural characteristics of the area will not be damaged. If such certainty cannot be offered upon global assessment of a plan or project (the preliminary appraisal), a more detailed study, known as the appropriate assessment, must provide scientific information in support of the decision.

If damage to the natural characteristics cannot be excluded, a positive decision will only be taken if all three of the following criteria are met (AIC test):

- A: Alternative solutions are not available.
- I: there are Imperative reasons of overriding public interest.
- C: Compensatory measures are timely implemented prior to the intervention being undertaken.

The preliminary appraisal and appropriate assessment must also take account of cumulative effects. Like the Habitat directive (art. 6 paragraph 3), the Nature Protection Act requires the consequences of other plans, projects and activities to be included in assessment of the significance of any negative consequences of a plan. There must be appraisal of whether the combination of all interventions may have a significant negative impact.

Species protection

The Dutch Nature Protection Act regulates the protection of wild plants and animals. Legislation distinguishes between

Table 63 Policy, legislation and regulations on Nature

Policy plan, law, regulation	Description/ Relevance for PALLAS
Nature Protection Act, Dutch government, 2017	The Dutch Nature Protection Act arranges the protection of Natura 2000 areas, wild plants and animals and their natural habitat. PALLAS is located close to the Natura 2000 areas: “Zwanenwater & Pettemer dunes” and “North Sea coastal zone”. The facilities for the cooling water supply lie within the delineation of these nature areas, while the PALLAS scope of influence is also home to various protected species. The Dutch Nitrogen Action Program (PAS) is embedded in the Nature Protection Act. According to this program, projects which result in nitrogen deposition in Natura 2000 areas may be allocated room for development. PALLAS has been registered as a priority project, and is therefore expected to have room for development reserved within the Dutch Nitrogen Action Program. This would also improve the feasibility of the zoning plan in relation to nitrogen.
NNN Netherlands Nature Network, province of Noord-Holland, 2016	The NNN is the national network of nature areas, which includes the dunes, the coastal zone of the North Sea and certain areas in the polders. This network is protected in terms of planning, according to the rules of the Provincial Spatial Planning Decree. The 'no, unless' and compensation principles are applied to the NNN. Any interventions in the NNN which result in degradation of actual characteristics or values are not admissible, unless a number of conditions are met: the plan must concern overriding public interest and there must be no realistic alternatives. The impact on these actual characteristics and values must be compensated.
Red Lists	The Netherlands has national Red Lists for 18 endangered species, including mammals, birds, reptiles, amphibians, fish, butterflies and dragonflies. The Red Lists are an important tool when establishing priorities in the nature area and are indicative for the degree of significance of the prevailing natural values. Although the Red Lists have no direct effect on policy, and Red List species do not automatically enjoy protected status, they do however indirectly influence the management and monitoring of nature areas. Changes in populations of Red List species are also indicative for changes in the natural value of an area. Various Red List species can be found within the PALLAS scope of influence.

three categories of protected species, namely:
- Birds Directive species;
- Habitat Directive species;
- Other species.

Prohibitions

With regard to Birds Directive species, legislation prohibits intentional killing or capture (art. 3.1 paragraph 1), intentional destruction of nests, resting places and eggs (art. 3.2 paragraph 2), collection or possession of eggs (art. 3.1 paragraph 3) and intentional disturbance of birds (art. 3.1 paragraph 4). The prohibition against intentional disturbance does not apply if the disturbance has no actual impact on the conservation level of the bird species in question (art. 3.1 paragraph 5).
With regard to the Habitat Directive species, legislation prohibits intentional killing or capture (art 3.5 paragraph 1), intentional disturbance (art 3.5 paragraph 2), intentional destruction or collection of eggs (art 3.5 paragraph 3) and damaging or destruction of breeding places or resting places (art 3.5 paragraph 4).
With regard to the Habitat Directive species, legislation prohibits intentional picking and collection, cutting, uprooting and destruction (art 3.5 paragraph 5).
With regard to Other species, the prohibition only concerns intentional killing or capture (Art 3.10 paragraph 1 under a) and intentional damage or destruction of breeding places or resting places (Art 3.10 paragraph under b). With regard to the nationally protected plant species, it is prohibited to intentionally pick and collect, cut, uproot or destroy them (art 3.10 paragraph 1 under c).

Behavioral codes, exemptions and dispensations

The Provincial Council and the Minister for Economic Affairs can grant an exemption from the prohibitions (art 3.3 paragraphs 2-4; 3.8 paragraphs 2-5, 3.10 paragraph 2). In so far as this concerns the prohibitions described above, an exemption may be granted for the prohibitions of articles 3.1, 3.5 and 3.10, therefore with regard to all protected species, for the purpose of spatial development and design of land use.
An exemption may only be granted when certain conditions have been met. These are equal to the conditions under which dispensation may be granted (see hereafter).
The species to which such an exemption applies very per authoritative body (Ministry of Economic Affairs and the individual provinces). The list of exempted species applied by the Ministry only concerns those actions for which the Minister for Economic Affairs is the authoritative body. Those actions for which the Provincial Cancel is the authoritative body, are covered by the exemption list of the province in question. On 3 October 2016, the province of Noord-Holland published the decree on exemption of species in Noord-Holland, which details the regulations with regard to exemptions and dispensations, among other things. (Province of Noord-Holland, 2016c). This exemption applies to spatial developments, in relation to generally occurring species of mammals (such as rabbits, hares, hedgehogs, various mice and shrews) and amphibians (common frogs, common toads, small newts, marsh frogs and edible frogs).
In the case of species for which there is no exemption (in the province in question), an application must be made for dispensation for any action in violation of the prohibitions of articles 3.1, 3.5 or 3.10 of the Netherlands Nature protection act (art 3.3 paragraph 1.3; 3.8 paragraph 1.3; 3.10 paragraph 2). Whether or not dispensation is granted depends on the conditions being met. The conditions to be met very per category. The first requirement made is that there may be no other satisfactory solution available. In combination with the duty of care described in article 11.1, this means that dispensation is not possible if a violation can be reasonably avoided. The work must then be carried out in such a manner that there is no violation of the law. This may include felling trees outside of the nesting season, or the blocking or trapping of species in the work area. Furthermore, dispensation may only be granted when there is proof of no degradation of the favorable conservation level of the species in question. Various supplementary conditions also apply per category.

Duty of care

Supplementary to the protective rules for Natura 2000 areas and protected species, a general duty of care applies for these areas and for all wildlife, which obliges all persons to take sufficient care of Natura 2000 areas, areas of particular national interest, and wildlife and their direct habitats.

Netherlands Nature Network (NNN) – Provincial Spatial Planning Decree

The national Spatial Policy provided for a national ecological structure in the past, which has since been renamed the NNN Netherlands Nature Network. The Spatial Policy was replaced by the Dutch Spatial Planning Decree (Barro) and National Policy Strategy for Infrastructure and Spatial Planning in 2012. The nature network comprises habitat corridors and protected reserves, and Natura 2000 areas. Its purpose is to enlarge and connect nature areas, while the corridors enable the exchange of plants and animals between various areas. The NNN is strictly defined and delineated. The protection regime is governed by the national Policy Strategy for Infrastructure and Spatial Planning, and implemented via provincial decrees and municipal zoning plans. Spatial interventions with a significant negative impact are not admissible. The 'no, unless' regime defined in the Spatial Policy only allows spatial development under certain conditions. This applies particularly to land use within the NNN. Land bordering on but not contained within the NNN, is not subject to limitations. Unlike the Natura 2000 areas, the NNN has no 'external influence' requiring appraisal of use of land bordering the nature area in the province of Noord-Holland.
Together with the provincial authorities, the national Dutch government has established a policy framework of Game Rules for the EHS (main ecological structure). The national government has requested that the provincial authorities embed the EHS Game Rules, including the eco-balance approach, in their provincial spatial planning policies.
Relevant documents for Noord-Holland are: the Provincial Spatial Planning Decree [22] and the accessory Nature management plan [26]. Besides the NNN, the province of Noord-Holland also distinguishes green corridors and meadow bird habitats via a protection regime comparable to that for the NNN.

The provincial planological policy is aimed at protection of the natural values (the actual characteristics and values) in the NNN Netherlands Nature Network, the green corridors and the meadow bird habitats. Spatial interventions are therefore only admissible if they do not damage the actual characteristics and values. However, interventions which do damage these values are admissible under certain circumstances. There must be imperative reasons of overriding public interest, there must be no alternatives for the intervention, and the impact of the intervention must be moderated by means of landscape incorporation and mitigating measures. If incorporation and mitigation have insufficient result, compensation will be required.
Based on article 2.10.1 paragraph 2 of the Dutch Spatial Planning Decree, the NNN title does not apply to the North Sea, among other waters. The waters named in this article are not covered by title 2.10 in the sense that the provincial authorities need not designate these areas to be NNN. The planological protection regime of the Spatial Planning Decree therefore does not apply to these waters, as these waters are largely appointed Natura 2000 areas, according to the Habitat and Birds Directive. The regime of the Nature protection act therefore applies in full to these areas.

Red List
In order to actively protect nature, the extinction risk of species is monitored. A global standard is available for this purpose, in the form of the IUCN (International Union for the Conservation of Nature) Red List of endangered species. This is a comprehensive inventory of those plants and animals under threat of extinction.
Although the Red Lists have no direct effect on policy, and Red List species do not automatically enjoy protected status, they do however indirectly influence the management and monitoring of nature areas. Changes in populations of Red List species are also indicative for changes in the natural value of an area.

13.1.2 Assessment framework and methodology

Study set-up
The description and assessment of the impact of the construction and operation of the PALLAS-reactor is linked to the various statutory and policy frameworks applicable for the Nature aspect in the area, and which are described in paragraph 13.1.1. These frameworks comprise all natural values in the study area which have social relevance:

- The natural characteristics of Natura 2000 areas (Dutch Nature Protection Act).
- Protected species of plants and animals (Dutch Nature Protection Act).
- The actual characteristics and values of the NNN Netherlands Nature Network (Noord-Holland Provincial Spatial Planning Decree [22]).
- Endangered and vulnerable species of plants and animals (Red Lists).

The description and assessment of the impact of the PALLAS-reactor took place according to the following steps:

- Scoping: selection of the type of impact which may be foreseen, and determination of the maximum spatial reach of this step. The results of the scoping step determine the study set-up and the scope of the study area for the various types of impact.
- Description of the current situation and autonomous development within the study area. This description is aimed at the natural values which are relevant to the various protection frameworks, which may be sensitive to the impacts selected in the scoping process, and which occur within the maximum reach of these impacts.
- Description of the impact of the building blocks for the nuclear island, cooling and Lay Down Area during the respective phases.
- Assessment of the impact based on the assessment framework related to the various protection frameworks.
- Description of mitigating measures which are necessary or desired in order to prevent negative impacts or reduce them to an acceptable level (according to the protection frameworks). The mitigating effect of these measures has been described, followed by a final impact assessment.

Study area
The Nature aspect is assessed according to the assessment framework given in Table 64. The scope of the study area varies per impact, and reaches way beyond the planning area for some potential impacts, see Figure 37.

Figure 37 Global delineation of study area (red outline)

Scoping
The Nature background report is a detailed explanation of the results of the scoping phase. A study set-up has been formulated on the basis of an analysis of the impact chains which may occur as the result of construction and operation of PALLAS, the possible reach of the impacts and the location of protected areas and distribution of protected and Red List species. (Table 64). This table shows the assessment criteria applied in describing the impacts applicable to the Nature aspect on the basis of the various frameworks.

Impact description and assessment
The impact has been determined and described for the various construction height and cooling variants of the proposal. Wherever uncertainties or bandwidths are expected, a worst case scenario impact has been deployed. The impacts have been assessed according to the applicable protection frameworks, in order to determine whether there is a risk of conflict with statutory provisions. If this is indeed the case,

mitigating measures have been defined (see paragraph 13.5). With a view to permit admissibility and the impact with regard to nature, the choice was made to only state an impact score, along with the statutory measures to be taken. After all, the activity would not be admissible (or only with great difficulty) without application of such measures. This implies that these measures will be a component of the activity and they have therefore been assessed as such.
The simultaneous operation of both reactors will only have possible consequences for the discharge of cooling water into the North Sea. No further differentiation has been made between the transition phase and the operational phase therefore, in terms of all other impacts. Unless otherwise stated, all impacts described in this section apply to both the transition and operational phases.
Table 66 up to Table 68 describe the criteria for assessment of the impact of construction and operation of PALLAS, based on the named statutory and policy frameworks (paragraph 13.1.1).
The tables indicate the significance of the impact scores in the five-point scale used for this purpose.

Table 64 Assessment framework for Nature

Framework	Assessment criteria
Regional protection Dutch Nature Protection Act	Surface area loss/mechanical impact
	Disturbance
	Nitrogen deposition
	Suction of fish
	Hydrological changes
	Thermal changes in the surface water
	Chemical changes in the surface water
NNN	Surface area loss/mechanical impact
	Disturbance
	Hydrological changes
Species protection Nature Protection Act Red List	Surface area loss/mechanical impact
	Disturbance
	Suction of fish
	Hydrological changes
	Thermal changes in the surface water
	Chemical changes in the surface water

Table 65 Scoring of assessment for Nature, regional protection Nature Protection Act

Score	Meaning	Explanation
++	Extremely positive impact	Great improvement of the quality of habitats and living environments in Natura 2000 areas. Makes an important contribution to the conservation targets.
+	Positive impact	Slight improvement of the quality of habitats and living environments in Natura 2000 areas. Makes a limited contribution to the conservation targets.
0	No impact	No (worthwhile) effect on the conservation targets of Natura 2000 areas.
-	Negative impact	Slight decrease in the area, quality and/or population scope of types of habitat or species within Natura 2000 areas. Significant negative impact on conservation targets can be excluded beforehand.
- -	Extremely negative impact	Great decrease in the area, quality and/or population scope of types of habitat or species within Natura 2000 areas. Significant negative impact on conservation targets cannot be excluded.

Table 66 Scoring of assessment for Nature, regional protection Noord-Holland Provincial Spatial Planning Decree

Score	Meaning	Explanation
++	Extremely positive impact	Great improvement of the actual characteristics or values and/or considerable expansion of NNN.
+	Positive impact	Improvement of the actual characteristics or values and/or considerable expansion of NNN.
0	No impact	There is (virtually) no damage for actual characteristics or values of NNN.
-	Negative impact	Actual characteristics or values of NNN are damaged and/or a limited portion is lost. No compensation is required.
- -	Extremely negative impact	Actual characteristics or values of EHS are seriously damaged and/or a considerable portion is lost. Compensation is required.

Table 67 Scoring of assessment for Nature, species protection Nature Protection Act

Score	Meaning	Explanation
++	Extremely positive impact	Considerable improvement or expansion of living environments of strictly protected (Habitats Directive) species and birds (Birds Directive) with a year-round protected brooding area.
+	Positive impact	- Considerable improvement or expansion of living environments of moderately protected (Other species, non-exempt) species and birds (Birds Directive) without a year-round protected brooding area. - Slight improvement or expansion of living environments of strictly protected (Habitats Directive) species and birds (Birds Directive) with a year-round protected brooding area.
0	No impact	(Virtually) no damage or improvement of living environments of protected species, or only violation of prohibitions for species for which there is exception in case of spatial development (Other species, exempt).
-	Negative impact	- Serious damage to or loss of living environments of moderately protected (Other species, non-exempt) species and birds (Birds Directive) without a year-round protected brooding area. Violation of prohibitions for aforementioned species and the conservation level is possibly at risk. - Slight damage to or loss of living environments of strictly protected (Habitats Directive) species and birds (Birds Directive) with a year-round protected brooding area. Violation of prohibitions for aforementioned species and the conservation level is possibly at risk.
- -	Extremely negative impact	(Extremely) serious damage to or loss of living environments of strictly protected (Habitat Directive) species and birds (Birds Directive) with a year-round protected brooding area. Violation of prohibitions for aforementioned species and the conservation level is possibly at risk.

Table 68 Scoring of assessment for Nature, species protection: Red List

Score	Meaning	Explanation
++	Extremely positive impact	A considerable improvement or expansion of habitats of occurring Red List species.
+	Positive impact	Improvement or expansion of habitats of occurring Red List species.
0	No impact	(Virtually) no damage to or improvement of habitats of occurring Red List species.
-	Negative impact	Serious damage to or loss of habitats of occurring Red List species.
- -	Extremely negative impact	(Extremely) serious damage to or loss of habitats of occurring Red List species.

13.2 Current situation

The Nature background report gives a detailed explanation of the current situation in the study area. The following text describes the main ecological values of the area.

13.2.1 Natura 2000 area

The planning area for the PALLAS-reactor borders two Natura 2000 areas. The cooling water pipeline routes between the nuclear island and the North Sea intersect both Natura 2000 areas:

- Zwanenwater & Pettemer dunes
- North Sea coastal zone

Zwanenwater & Pettemer dunes

Figure 38 shows the delineation of the Natura 2000 area of Zwanenwater & Pettemer dunes.

The Zwanenwater & Pettemer dunes are among the best preserved shore dunes of the Netherlands. The area comprises two rows of dunes parallel to the coast, with variegated wet dune valleys and two large dune lakes in between. Unlike most other shore dunes, Zwanenwater has never been used for water extraction purposes, which is one of the reasons for the exceptionally well developed valley vegetation.

Various qualifying natural values can be found in and around the planning area within the delineation of the Natura 2000 area.

The eastern section of the Zwanenwater features large patches of dune heathland vegetation with crowberry. The moss layer is generally also well developed, with various species of liverwort. The scope of this heathland makes it the best example of habitat type 2140 in the shore dunes.

In this area, arid dune grasslands are mainly found, in a gray club-awn grass community with abundant lichen species (Violo-Corynophoretum). Roughage development due to wood small-reed and sand sedge has put the vegetation under great pressure however, though well-developed examples can still be found throughout the area. The sand lizard, Northern wheatear, shelduck, curlew, European stone chat and an occasional woodlark breed in the open sections of the dunes, while a few hundred pairs of herring gulls, lesser black-headed gulls and common gulls have colonies here.

Besides the crowberry vegetation, the species-rich, arid Nardus grasslands of the dune valleys are one of the most important natural values of the Zwanenwater region. They are home to species such as the three-nerved sedge, crossed-

Figure 38 Delineation (yellow) of the Natura 2000 area of Zwanenwater & Pettemer dunes.

Figure 39 Delineation (yellow) of the Natura 2000 area of the North Sea coastal zone

leaved heath, heath dog-violet, petty whin, lesser butterfly-orchid, common milkwort, rigid eyebright, common moonwort, fairy flax, tormentil, lousewort, heath-grass, and carnation sedge. Truly rare species of vegetation in the acidic grasslands are green-winged orchid and flea sedge. The areas housing the species are characteristic of marshy grasslands (Cirsio dissecti-Molinietum), where star sedge and adder's tongue are also found. These exceptional patches of vegetation are under great pressure.
The wet valleys house a large population of natterjack toads. In the wet and humid dune valleys influenced by seepage, the (mown) grasslands are mainly mesotrophic marsh marigold grasslands. Thousands of plant species grow here, including the broad-leaved marsh orchid and the southern marsh orchid. Associative species are the marsh lousewort, bogbean, blunt-flowered rush, scorpion moss, fine-leaved feather-moss and giant spearmoss. Besides arid heathland elements such as the lesser butterfly-orchid, peat moss also grows prolifically here. This makes the Zwanenwater the only significant habitat in the dunes for this bog moss.
The dune lakes (Eerste Water and Tweede Water) are very important for the bird population, and the Zwanenwater is best known for its spoonbill colony.

Habitat types and species in the study area
Various types of habitats and species protected within the Natura 2000 area can be found in and around the planning area within the delineation of the Natura 2000 area. This section describes the occurrence of qualifying natural values and possible relevance for a more detailed study, based on their occurrence.
Many types of habitat are found in the Natura 2000 area, Zwanenwater & Pettemer dunes. They are all located within the potential impact reach of PALLAS (particularly as a result of nitrogen deposition). The LDA also houses forms of vegetation which meet the vegetation criteria for types of habitat, though these are not protected as they are not within the delineation of the Natura 2000 area.
As far as breeding birds specifically protected in the Natura 2000 area are concerned, the Northern wheatear can be found in the vicinity of the planning area. The other species (cormorant, bittern and spoonbill) are marsh birds which

breed in the dune lakes of the Zwanenwater, outside of the impact reach of PALLAS. The same applies to the two types of non-breeding birds (lesser white-fronted goose and shoveler) found there.

North Sea coastal zone

In the Netherlands, the transition from open sea to land takes place along the North Sea coastal zone. A section of this coastline between Bergen and the Eems estuary has been designated a Natura 2000 area. Figure 39 shows the delineation of the Natura 2000 area of the North Sea coastal zone.
This dynamic sandy coastline is an internationally rare biotope and houses large volumes of shellfish locally. This is one of the reasons for it being an important foraging area for species such as the common scoter and common eider duck during the winter months. The region is also an important breeding ground for marine fish species. It is a dynamic area, with a high water flow velocity, great fluctuations in salinity (influenced partly by the rivers) and great temperature variations throughout the year. Functionally speaking, the area is interconnected with the deeper parts of the North Sea and the Wadden sea: sediment is freely exchanged between the three. There is constant accretion and shifting of material within the North Sea coastal zone, as a result of tidal flows and wave action.
Pioneering species in particular soon feel at home under the dynamic conditions in this coastal zone. Very few species of animals have adjusted to the extreme conditions, but the species which live here are generally extremely prolific: the coastal zone has the highest biomass of benthos of the complete Netherlands Continental Shelf (NCP). Molluscs (Mollusca) and bristleworms (Polychaeta) are the main contributors to the biomass.
Further, there is a greater biodiversity of fish fauna in the entire coastal sea than on the NCP. Virtually all Dutch saltwater fish can be found in the Natura 2000 area, some of which are even nearshore fish which are hardly found (at all) further afield on the NCP. This coastal zone is also one of the most important bird areas of the NCP.
The North Sea coastal zone has been registered for the Permanently flooded sandbanks (H1110) and Mudflats and sand flats (H1140) habitats. Both habitats are mainly located on the outer edge of the wide channels between the Wadden Islands, though the coastal zone along the Holland Coastline also comprises the former habitat. So-called outer deltas are formed here, with alternating sand flats and deeper channels. The tidal flats are an ideal resting ground for harbor seals and gray seals. Harbor porpoises are also increasingly frequent visitors to the Dutch coastal waters, sometimes even with calves. As they are mainly found in the northern half of the NCP, the North Sea coastal zone is the most important Natura 2000 area registered for this species in the Netherlands so far.

Habitats and species in the study area

Various habitats and species can be found close to the planning area within the delineation of the Natura 2000 area.
The zone off the Noord-Holland coastline is entirely comprised of habitat type H1110B Permanently flooded sandbanks. Other types of habitat do not occur in the study area.
The coastal zone is the habitat for the sea lamprey, river lamprey and twait shad. These species are well distributed throughout the North Sea, and migrate via the coastal waters and Wadden Sea to spawn.
The entire coastal zone is also a habitat for sea mammals (harbor porpoises, harbor seals and gray seals). Harbor porpoises can be found all around the North Sea, from far offshore to close to the beach [23]. They tend to frequent the coast most often in the months of February and March [24]. The closest resting grounds for seals are at a distance of 18 km [23], though there is a chance of them occasionally foraging or migrating along the coast.
The protected species of breeding birds (common ringed plover, Kentish plover, little tern) of the North Sea coastal zone are only found on the Wadden Islands, and not within the study area for PALLAS.
The coastal waters are the habitat for various types of waterbirds, and the red-throated loon, black-throated loon and common scoter have particularly strong ties with the North Sea coastal zone, where they forage for fish and shellfish. Other types of waterbirds (common eider, cormorant, greater scaup, little gull) are also regular visitors. The area is occasionally of significance for the common eider, particularly during cold winters when the Wadden sea freezes.
There are no high tide refuges for waders in the vicinity of the study area, and the beach has a limited foraging function. The most commonly encountered birds are sanderlings, while Eurasian oystercatchers and ruddy turnstones regularly forage among the groynes.

13.2.2 Species protection

The planning area and vicinity does not contain any plants protected by the Dutch Nature Protection Act. Nesting birds are however found at various locations in and around the planning area. They are not limited to those sections with vegetation: gulls and waders are actually more likely to brood in the non-vegetated areas. The roofs of some of the present buildings also offer nesting opportunities for lesser black-headed gulls, herring gulls and common goals. These species are only distributed around Research Location Petten, as eggs and chicks on the ground outside the Research Location Petten fencing are insufficiently protected against predation.
Various species of small mammals are distributed within the planning area. Common species in the dune area include the bank vole, wood mouse and common vole. The rarer Eurasian water shrew is restricted to the marsh to the west of Zwanenwater. The planning area is not suitable for this species, as it lives on richly vegetated sloping banks.
As far as reptiles are concerned, the sand lizard is the only one found in the dunes at and around Research Location Petten, at a low population density. Of the amphibians, the natterjack toad is a strictly protected species which can be found in the area.
The planning area and vicinity does not contain any species of fish protected by the Nature Protection Act.

13.2.3 Red list

Red List species are species of plants and animals classified as vulnerable to extremely endangered, and therefore paid special attention in the biodiversity policy and the management of nature areas. Not all Red List species are protected by the Nature Protection Act. Table 69 gives a summary of all Red List species found in the study area. Braad et al, 2015, provides distribution maps [23].

13.2.4 Regional protection: Noord-Holland Provincial Spatial Planning Decree

Figure 40 shows that the dune area in the vicinity of the planning area has been designated an NNN. The province of Noord-Holland has included the North Sea as a Large Water Bodies ecological network (now NNN). Research Location Petten is not part of the NNN.

Actual characteristics and values

The actual characteristics and values of the NNN are largely reflected in the nature management habitats of the area. Figure 40 gives the nature management habitats map for the current situation.

Table 69 Red List species found in the study area [23]

Species group	Species
Flora	Few-flowered spike-rush, field scabious, quaking grass, wild strawberry, broad-leaved marsh orchid, slender sedge, carlin thistle, chaffweed, allseed, great fen-sedge, fairy flax, common moonwort, fen orchid, common twayblade, lousewort, heath dog-violet, crested dog's-tail, spiny restharrow, common wintergreen, yellow rattle, least bur-reed, ivy-leaved crowfoot, black bog-rush, marsh willowherb, marsh lousewort, oriental salsify, grasp of parnassus, red bartsia, round-leaved wintergreen, round-leaved sundew, knotted pearlwort, meadow thistle, maiden pink, petty whin, lesser water-plantain, rigid eyebright, early marsh-orchid, flea sedge, marsh cinquefoil, bogbean, lesser butterfly-orchid, bog myrtle, sea rush
Breeding birds	Meadow pipit, house sparrow, common linnet, cuckoo, nightingale, gray partridge, long-eared owl, northern wheatear
Amphibians	Natterjack toad
Reptiles	Sand lizard
Mammals	Serotine bat, common noctule, Eurasian water shrew
Butterflies	Brown argus, ilex hairstreak, niobe fritillary, rock grayling, Queen of Spain fritillary

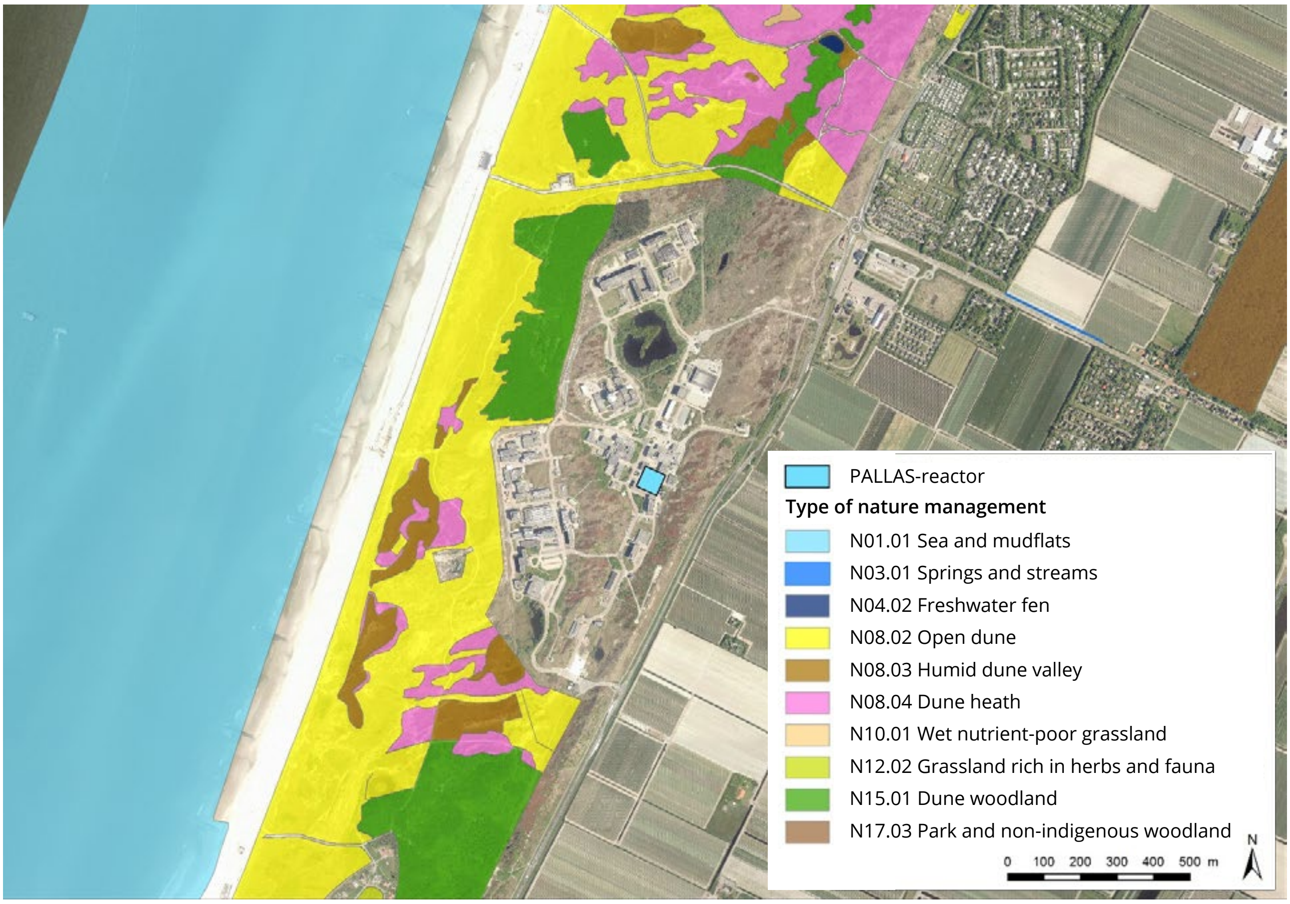

Figure 40 Nature management habitats map of the NNN in the vicinity of the planning area. Source: Map viewer Nature management plan 2016 Noord-Holland[34]

34 https://maps.noord-holland.nl/GeoWebSilverlight/Viewer.html?ViewerConfig=https://maps.noord-holland.nl/Geocortex/Essentials/GeoWeb50/REST/sites/NATUURBEHEERPLANNEN/viewers/NBP_Silverlight/virtualdirectory/Config/Viewer.xml.

13.3 Autonomous developments

Natura 2000 area

Zwanenwater & Pettemer dunes.

A management plan has been established for the Natura 2000 area of Zwanenwater & Pettemer dunes [24]. This plan details the conservation targets for the area, and describes the measures required to achieve these targets. The priorities for the Zwanenwater & Pettemer dunes are given in three core tasks, which particularly concern the general ecological system, and the types of habitat and species which are under pressure and/or for which the Netherlands is of (extreme) international significance (see text box 3.1). The core tasks apply to the entire area and former framework for the conservation targets, which are aimed at specific habitats and species. These core tasks are:

- Expansion and recovery of the quality of gray dunes (H2130), also as the habitat for the Northern wheatear, short-eared owl and hen harrier, through prevention of colonization by grasses and shrubs. Grey dunes bordering Research Location Petten.
- Conservation of Wet dune valleys (H2190) as the habitat for bittern, spoonbill, hen harrier, short-eared owl, tundra vole, narrow-mouthed whorl snail and fen orchid. While there are dune valleys in the direct vicinity of the planning area, the aforementioned species are not found there.
- Development of Arid grasslands (H6230), Arid gray dunes (H2130C) and Marshy grasslands (H6410) at favorable locations. These are mainly located in the northern section of the area, the Zwanenwater, outside the scope of influence of PALLAS.

Further, the Nitrogen Action Program is aimed at taking measures in the area to improve the quality of those habitats sensitive to nitrogen [25].

As a result of these measures, expectations are that the quality of the habitats in the area will remain stable or improve slightly in years to come. The distribution of the habitats will remain more or less unchanged, within the natural fluctuations which may occur.

The Northern wheatear is showing a very negative trend in terms of population scope, and this also applies in the Natura 2000 area of Zwanenwater & Pettemer dunes. In 2015, there was only 1 nesting pair left. The population is only expected to recover very slowly, so that the population scope will remain very limited for the time being.

North Sea coastal zone

A management plan has also been established for the Natura 2000 area of the North Sea coastal zone [26]. In this area, the core task is formulated as: Conservation of the sea ecosystem with Permanently flooded sandbanks (H1110B), as the habitat for the common scoter, red-throated loon, greater scaup and common eider, with beds of varying ages and a more natural composition of fish populations.

The conservation target for the habitat type H1110B Permanently flooded sandbanks will not be achieved if the current management practice is continued. Bottlenecks are the lack of a natural composition of seabed fauna and fish populations, inadequate numbers of fish and shellfish, and human disturbance. The measures given in the management plan are not expected to achieve the conservation target within the first management plan period of six years, but are expected to have more success in the second or third period. This also applies to the harbor porpoise. The conservation targets will be achieved for the other sea mammals and fish. Other improvements may occur in the populations as the result of measures elsewhere (migratory fish) or a natural increase in the populations (seals).

It is unclear whether the current management plan will result in achievement of the conservation target for the various types of water birds feeding on shellfish. The bottlenecks are unclear, in terms of the trend and insufficient food and resting places in the area. The measures of the management plan are expected to achieve the conservation target within the coming management plan periods.

Prospects are good for the various types of waders, whose population is expected to remain stable.

Protected species

The planning area is divided into five sub-areas. The presence of protected species in the autonomous development is deter-

Table 70 Relevant changes in the autonomous development for the sub-areas

Sub-area	Presence of protected species
1 Location of reactor	The location of the reactor and accessory buildings is already a developed area in the current situation. These buildings are to be demolished. The site will then be intensively managed (greenfield). This =management process will hinder the establishment of protected species of plants and animals.
2 Possible location of air cooling	The air cooling system will be located to the south of the reactor. Part of the site is already a developed area. These buildings are to be demolished. The site will then be intensively managed (greenfield). In the autonomous development, all other parts of the site would undergo no real change in comparison with the current situation.
3 Pipeline Noordhollandsch Kanaal	The pipeline to the Noordhollandsch Kanaal runs through the inner dune edge and agricultural areas. The inner dune edge is not subject to real change, and the same applies to the agricultural areas behind the dunes, where autonomous developments will not result in any real change.
4 North Sea pipeline	The pipeline runs through the dune area, which theoretically is a dynamic landscape in the Netherlands, though the natural dynamics are limited for water safety purposes. There may be minor shifts in types of vegetation, but there will be no real changes.
5 LDA	The LDA is located in the agricultural area behind the dunes. This area is not subject to real change,

mined by 1) the current presence of protected species and 2) the development of habitats (landscape and the surrounding area). Table 70 indicates the expected changes per sub-area.

Red List species
As described, there is no real change in the conditions in the planning area and surrounding area. The principle is therefore that the species given in Table 69, will occur at comparable locations in comparable densities.

Regional protection: Noord-Holland Provincial Spatial Planning Decree
The ambition map for the NNN in the vicinity of the planning area is comparable to the current situation (see Figure 40), and the autonomous development therefore assumes preservation of the current situation.

13.4 Environmental impact

13.4.1 Impact description

13.4.1.1 Construction phase

Loss of land surface area

Nuclear island
The nuclear island with accessory facilities, including the air coolers in cooling variant K3, are within Research Location Petten and outside the delineation of the Natura 2000 area of Zwanenwater & Pettemer dunes and the NNN. In the current situation, the location is still mainly developed and paved. Upon commencement of construction, this developed area will be demolished, and designed and managed as a greenfield. This prevents establishment of protected species. The construction location is therefore not a habitat for protected and Red List species of plants, (nesting) birds, mammals and reptiles. Any impact is therefore excluded.

Lay Down Area
The LDA is also located outside the Natura 2000 area and the NNN. There are no protected species or Red List species at the location. Any impact by the LDA is therefore excluded.

Installation of cooling water pipelines (variants K1 and K2)
Upon installation of pipelines for the extraction and/or discharge of cooling water between the nuclear island and the North Sea, there will be a (mainly) temporary loss of land surface area of various types of habitat in the Natura 2000 areas of Zwanenwater & Pettemerduinen and North Sea coastal zone. These areas are also not part of the NNN. The types of habitat are part of the actual characteristics and values of the NNN in these areas. Careful construction and recovery of the land and vegetation will allow the various types of habitats to recover to a certain extent over the course of time. On top of the search area for cooling water pipe routes, other routes were sought which, in the form of open excavation, would lead to the least possible damage in the Natura 2000 area. Figure 41 gives the location of the routes studied. The following text also indicates the consequences of possible routes on the Natura 2000 area. The following principles are assumed:

- The pipelines will be installed by means of an excavated trench; the insulation of pipelines by means of directional drilling is not preferential, when considering their location in the coastal defense structure (the dune area). The possibilities for their installation are still under investigation. In principle, a trench will be dug, possibly reinforced with walls, and the sand temporarily stored adjacent to the trench.

Figure 41 Location of the routes studied.

- Determination of the new pipeline routes has not yet taken account of technical or spatial limitations, resulting from the location of other pipelines, buildings and other facilities at or beyond Research Location Petten. Neither has account been taken with any inaccessible or usable sites at or beyond Research Location Petten, with the exception of the HFR site.
- Attention has mainly been paid to those types of habitat which forms the greatest restrictive factor for the permit procedure. This concerns those types of habitat for which a conservation target applies, aimed at increasing the surface area and/or improving the quality, and which will not quickly recover in case of damage. These are particularly the gray dunes (H2130) and wet dune valleys (H2190) types of habitat. In accordance with the current assessment practice, surface area losses in excess of 100 m² of a habitat type, are regarded to be significant damage.

Table 71 gives the types of habitat in the search area for the cooling water pipelines between the PALLAS-reactor and the discharge point in the North Sea, which may be damaged as a result of their installation.
Table 72 indicates the degree of impact on the various types of habitat and the possibilities for damage limitation. The recovery strategies drawn up per habitat type for the PAS for the [27] show that good recovery is possible in the more dynamic habitat types of the seabed and the drifting dunes (H1110B and H2120). These habitat types will recover fully

Table 71 Types of habitat influenced by installation of cooling water pipelines in the dune area.

Habitat type	A	B	C1	C2	D	E	F
H2110	X	X	X	X	X	X	X
H2120	X	X	X	X	X	X	X
H2130A			X	X	X	X	X
H2130B	X			X	X	X	
H2140A			X	X	X		
H2140B		X	X	X	X		
H2170		X	X	X	X		
H2190B						X	X
H2190C						X	

within a number of years. The other habitat types have a moderate recovery factor. Recovery can be encouraged by removing the layer of vegetative sod beforehand and storing it separately (habitat types H2130, H2140 and H2170), or adding a layer of lime-deficient sand to the damaged dune valleys. Due to the damage occurring over a narrow zone, the damaged zone can be relatively quickly colonized from the non-damaged habitat types occurring in the direct vicinity. According to this assessment, routes A and B are the only ones which intersect the dune area in such a manner that the habitat types H2130B (lime-deficient) and H2130A (lime-rich) can be spared and/or possibilities created for considerable recovery. Damage to these habitat types cannot be avoided in the other routes, and the possibilities for recovery are limited. These routes can only be used if recovery measures are applied for the Grey dune habitat type. Recovery can be encouraged by removing the layer of vegetative sod beforehand and storing it separately (habitat types H2130, H2140 and H2170), or adding a layer of lime-deficient sand to the damaged dune valleys. Due to the damage occurring over a narrow zone, the damaged zone can be relatively quickly colonized from the non-damaged habitat types occurring in the direct vicinity. The

Table 72 Impact of the possible routes. The final column also indicates options for damage limitation.

Route	Effecten op kwalificerende natuurwaarden	Mogelijkheden om effecten te beperken
A	There is damage to gray dunes. This is however a limited surface area in comparison with other routes, though it does exceed 100 m². Upon completion of the work, gray dunes can redevelop along the route. However, recovery is foreseen in the longer term.	The surface area upon which Grey dunes can develop in the longer term will increase due to woodland being felled. While the development will initially be White dunes, species from surrounding dunes will expand over the route in due time. This concerns general species such as sand sedge, gray hair-grass and mosses.[35]
B	This route will have relatively little impact on sensitive habitat types, with no damage to Gray dunes and dune valleys. There will however be a minor impact on a number of other habitat types.	The damage can be limited if the pipeline is installed under the tiled path, though this is probably not possible due to the HFR pipeline already being located here. In both options, recovery of the vegetation will only be possible after a long period of time, if at all.
C1 en C2	When the route is located on one side of the tiled path, this will be at the expense of a considerable surface area of Grey dunes (> 100 m²). The surface area of C1 is larger than C2, due to the alternating dune heaths with crowberry in C2.	More detailed specification of the route can limit the damage, though it cannot be completely avoided. Recovery of the Grey dunes will only be possible after a long period of time, if at all.
D	There is a considerable surface area of Gray dunes within the search area, particularly to the West. This can entail loss of a considerable surface area (< 100 m²).	More detailed specification of the route can limit the damage, though it cannot be completely avoided. Recovery of the Grey dunes will only be possible after a long period of time, if at all.
E	If this route is utilized, only a limited surface area of Grey dunes will be damaged. Depending on the manner of installation, this may exceed 100 m². There will also be an impact in the dune valley, which can have considerable consequences if water is also extracted during the work.	A considerable part of the current Gray dune can be spared by installing the first section of pipeline under the road to the firing range. If water must be temporarily extracted, this should preferably take place outside the growth season (autumn).
F	If this route is utilized just north of the firing range, a considerable surface area of Grey dunes will be damaged. There will also possibly be a reduction in the dune valleys, which can have considerable consequences if water is also extracted during the work.	A considerable part of the current Gray dune can be spared by installing the first section of pipeline under the road to the firing range and if possible under the northern section of the firing range. If water must be temporarily extracted, this should preferably take place outside the growth season (autumn).

35 Damage to the woodlands can be avoided by installing the pipeline under the current footpath. The felling activities to the east of the cycle path can then be limited to a number of trees.

recovery factor is good for the more dynamic habitat types of the seabed and drifting dunes (H1110B and H2120). The seabed life in H1110B will have recovered along the pipeline route within a few years. These habitat types will recover fully within a number of years.

Upon installation of the pipeline for discharge of cooling water to the North Sea, there is a risk of impact on various protected and Red List species in the dune area. The area between the Noordhollandsch Kanaal and Research Location Petten has no significance for special protected species, due to it being used intensively for agricultural purposes. Variant K1 may possibly have an impact on generally occurring species of mammals and amphibians. When intersecting the drift dike between the N508 road and the construction location, the habitat of the sand lizard may be temporarily damaged, depending on the choice of pipeline route. The impact for the dune area is greater in variant K2 than in variant K1, due to the larger total area required for the two pipelines to be installed in variant K2. The following applies regarding the roots in the dune area (Figure 41):

- For protected species:
  - Protected flora: is not found along the routes.
  - Nesting birds: comparable numbers are found along all routes. The work will result in destruction of nests.
  - Mammals: small terrestrial mammals are found along all routes. The work will result in their death and in destruction of their habitats. The routes have no particular impact on bats; flying routes and foraging areas will be unaffected.
  - Reptiles: The sand lizard has been spotted as a number of locations in the dunes. This species may well be found along all routes. Death and destruction of a small part of its habitat cannot be precluded.
  - Amphibians: The routes do not intersect habitats of the natterjack toad. The work may however encourage the presence of this species, as it is attracted by shallow water. In that case, individual deaths and the destruction of eggs cannot be precluded. This applies to all routes.
  - Butterflies: The ilex hairstreak is not found along the routes, though the niobe fritillary has been spotted in the dune valleys. The occurrence of this butterfly cannot be precluded in any of the routes. The work may result in individual deaths, destruction of eggs and habitats.
- For Red List species: Red List species are mainly found in the dune valleys.

No true distinction can be made in the impact on protected and Red List species for the various routes. Following recovery of the land and vegetation, growth locations and habitats can fully recover in most cases.

Air cooling (variant K3)
The air cooling location is outside the Natura 2000 area and the NNN. There are no protected species or Red List species at the location. Any land surface loss impact due to installation of the air cooling is therefore excluded.

Mechanical impact
There may be mechanical impact during the construction phase, due to:

- Trucks, vehicles and excavator movements in the dune area for the installation of cooling water pipelines.
- Damage to the seabed when digging in cooling water pipelines.

Vehicle movements in the Grey Dunes H2130B habitat type in the Natura 2000 area of Zwanenwater & Pettemerduinen (also NNN) can result in temporary damage to the vegetation. However, the larger total area required is more significant than the mechanical impact.
This mechanical impact may also have a positive impact on the biodiversity of this type of habitat, when the vegetation is dominated by taller grasses. It will result in open patches in the vegetation, allowing the establishment of characteristic species and animals. Vehicle movements in other types of habitat, especially the dune valleys, may result in an irreversible negative impact.
Vehicle movements in dune grasslands can result in damage to regular nesting, resting and habitats, and the death of protected and endangered species such as the Northern wheatear and other ground-nesting species, the sand lizard, natterjack toad, niobe fritillary and plants.
Digging in cooling water pipelines in the seabed of the North Sea coastal zone will result in a temporary deterioration of the quality of habitat type H1110B (of less than 1 ha).

Disturbance
The impact of disturbance during the construction phase can manifest itself in various ways. A distinction must be made between the impact on land and at sea.

Impact on land
Noise is the reference factor for impact on land, as it reaches further than the impact of visual disturbance or vibrations on land. The impact as a result of light on natural values is excluded within Research Location Petten, due to the already present lighting and the hilly nature of the site, which shields the light. The worst case scenario here is in construction variant B1 for the nuclear island (due to the longer construction time and greater sand transport) and cooling variant K1 for the cooling (due to greater distribution in areas worked).
A limiting value of 0.1 lux is applied for the impact of illuminance on nature. Any impact on nature is excluded below this illuminance. This limiting value is reached at a short distance around the working locations (nuclear island, cooling water pipelines, LDA). See Figure 36 in section 12). Within these zones, the impact of noise caused by the equipment used, is much greater. Noise is therefore the reference factor for impact on nature.
When describing the impact of disturbance through noise, a distinction is made between continuous noise as the result of using motorized equipment, etc., and impulse noise caused by pile driving of foundation piles.
For continuous noise, a limiting value of 47 dB(A) applies for the noise-sensitive species in the vicinity of the planning area. Any negative impact is excluded below this noise level, while higher levels result in a gradual decrease in the density of (nesting) birds. This is assumed to apply likewise to non-nesting birds and other disturbance-sensitive animals (amphibians, mammals).

The location of the 47 dB(A) contour has been calculated for various phases of the construction process. The Nature background report gives more detailed information. The calculations show that, with the exception of work on the cooling water facilities in the dunes and the North Sea, the reference contour of 47 dB(A) remains almost entirely within Research Location Petten, and therefore hardly reaches the delineation of the Natura 2000 area of Zwanenwater & Pettemer dunes and the NNN. At the entrance to Research Location Petten, a small section of the drift dike along the Westerduinweg falls within the contour. This part of the area is not a habitat for qualifying species within the Natura 2000 area (such as the Northern wheatear).
Upon installation of the cooling water pipelines in the dunes and the North Sea, the noise hinder will exceed the 47 dB(A) limiting value in a small section of the Natura 2000 areas of the North Sea coastal zone and Zwanenwater & Pettemer dunes. The maximum land surface area temporarily disturbed in the Pettemer dunes is 10 ha, and 12.5 ha in the North Sea coastal zone.
The Natura 2000 area qualifying Northern wheatear was not found nesting within the disturbance zones, during the nature studies of 2012 and 2015. More common species do however nest here: woodlark, lesser whitethroat, buzzard, meadow pipit, common linnet, cuckoo and European stone chat [23] [28]. These species will be disturbed as a result of the construction work, if such work takes place during the nesting season. They will not nest in the disturbed area, or nesting pairs already established in the area may breed less successfully.
Various species of (nesting) birds, mammals and amphibians are found within the 47 dB(A) contour at Research Location Petten. Most of these species are tied to the human environment and have become established at Research Location Petten where there is already continuous disturbance due to noise and visual stimuli. It may be assumed that the species are insensitive to an increase in the noise hinder during construction of PALLAS. Research Location Petten is a foraging area for various types of bats, which forage in spring, summer and autumn from dusk to dawn. Work is not carried out on PALLAS during this period of the day, with the exception of occasional situations. Disturbance of foraging bats is therefore excluded.
The area surrounding the LDA is used intensively for agricultural purposes. Common species of birds, mammals and amphibians can be found here. They are generally accustomed to human use of the area and are not particularly sensitive to disturbance due to noise and visual hinder. No impact is therefore expected for these common species. Any impact on foraging bats is once again excluded, due to there being no activities at the LDA during the foraging period.
The Design framework for PALLAS assumes that piles will be driven for the concrete plant at the LDA, at the pumping station for cooling water near the canal (variant K1) and at the North Sea extraction platform (variant K2). This work will have a limited duration of a few days at most. The location of the LAeq 24-hour contours of 42, 47 and 50 dB(A) as a result of this pile driving work, has been calculated (the Nature background report gives more detailed information). It is apparent from the location of these contours that the noise hinder increases above the limiting value of 47 dB(A) in large sections of the Pettemer dunes. This is a temporary impact of a number of days at most. If the pile driving work is conducted outside of the nesting season, birds may be temporarily disturbed and may move to other nearby localities. If the pile driving work is conducted during the nesting season, disturbance of the nesting birds and consequently less successful breeding, cannot be excluded. This also applies to the Northern wheatear, which is covered by the conservation targets of the Natura 2000 area.
The temporary increase in noise hinder as a result of pile driving work for the pumping station at the canal, does not reach as far as the Natura 2000 area. However, there will be temporary disturbance in a large section of the polder. Once again, birds may avoid this area outside the nesting season, and the breeding process may be less successful during the nesting season. This concerns only common birds found in the agricultural man-made landscape, parks and woodland (the latter in the recreational sites and gardens in the region).

Impact at sea
Visual disturbance above water is the reference factor for impact on the North Sea, more predominantly than the impact of noise and light. Noise is the reference factor for impact under water.

▪ Impact above water
The worst case scenario occurs in cooling variant K2 and depends on the construction height variants. In cooling variant K2, both the inlet and outlet points of the cooling water facility are installed within the Natura 2000 area of the North Sea coastal zone, while an extraction platform is built in the North Sea.
Ships and cranes will be used for construction of the platform and installation of the cooling water pipelines (cooling variants K1 and K2). This results in disturbance of birds and sea mammals in the direct vicinity of the work. The maximum disturbance distance is 1200 m (disturbance distance of resting seals).
Birds which forage for benthos (common eider, greater scaup and common scoter) rely on the occurrence of shellfish, and are therefore less flexible than fish-eating birds.
The occurrence of shellfish can vary annually in terms of scope and location, and this forms a limiting factor for the population scope of these species of ducks in the North Sea coastal zone. If the location of the extraction platform and pipelines overlaps with the occurrence of shellfish, a negative impact on these birds cannot be excluded.
The North Sea coastal zone is a refuge area for the greater scaup and common eider in situations when there is limited availability of food (mussels, cockles) in the Wadden Sea. Relatively large concentrations of common eider ducks were found in the North Sea coastal zone at the location of the project area, during the 2000-2005 period. The greater scaup is only occasionally found. The common scoter is particularly dependent on the North Sea coastal zone in the Netherlands, and is mainly found in great concentrations to the north of the islands of Terschelling, Ameland and Schiermonnikoog, and (to a lesser degree) to the south of the project area.

A study of the occurrence of various shellfish, including Spisula, was conducted in the Dutch coastal waters in 2012. The scope of Spisula found in the Natura 2000 area of the North Sea coastal zone is approximately 4% of the total occurrence in the Dutch coastal waters (expressed as biomass). A fraction of that scope potentially occurs in the area where PALLAS activities are planned [31]. In recent years (2008-2010), winter counting moments have shown very limited numbers of common eider, greater scaup and common scoter to be found along the coastline of Noord-Holland. This too indicates that other sections of the North Sea coast and the Wadden See are currently more important foraging and resting locations for these species. If this situation continues in the period to come, the number of disturbed animals as the result of shipping movements for PALLAS will be negligible, and a negative impact can therefore be excluded.
The pile driving work for foundations of the sea platform will result in a considerable area being disturbed by noise above water. However, very few species which are sensitive to this type of noise hinder are found here. Any foraging birds, such as the common eider and common scoter, may avoid the area temporarily during the limited working period. This will last 2 days at most. This period is so brief that it will have no permanent impact on these species.

- Impact under water

During the construction phase, cooling variants K1 and K2 will produce continuous underwater noise and possibly also impulse noise. The continuous noise will disturb fish and sea mammals within a radius of maximum 5 km. This is an extremely small portion of the total habitat of sea mammals and fish. The planning area has no specific function for these species which cannot otherwise be provided by other sections of the North Sea coastal zone.
During pile driving for construction of the extraction platform, the impact will depend very much on the pile driving schedule (duration, frequency, capacity deployed). Although the noise will probably decrease quickly due to the relative shallowness of the water, the possibility of a negative impact on birds and sea mammals cannot be excluded beforehand. A temporary impact may result in these species deviating to other sections of the North Sea coastal zone. Physical degradation to species in the vicinity of the planning area upon commencement of pile driving cannot be excluded. This concerns the temporary (TTS) or permanent (PTS) hearing threshold shifts in seals and harbor porpoises and physical degradation to fish and fish larvae as a result of greatly increased pressure. This impact can be prevented through the application of mitigating measures.

Nitrogen deposition

The impact of nitrogen deposition is only relevant for Natura 2000 areas. It is irrelevant for the remaining scope.
Nitrogen is emitted during the construction phase through the use of vehicles, ships and motorized equipment. Via the atmosphere, nitrogen is transported to the surrounding nature areas, where it may have negative consequences for those habitats in the Natura 2000 areas which are sensitive to eutrophication and acidification.

The partial review of the Dutch Nitrogen Action Program (PAS) came into force on 17 March 2017, and lists PALLAS as one of the priority projects with a reservation for nitrogen deposition. Extensive analysis has been conducted regarding the use of nitrogen-emitting equipment during the construction and operational phases for the purpose of the priority application [29]. Based on analysis of these emissions, a calculation has been made using the AERIUS program which is obligatory according to the PAS. Table 73 gives an overview of the maximum deposits in the various Natura 2000 areas around the PALLAS-reactor planning area. The most sunken variant B1 results in the most deposits. This is due to the relatively large volume of excavation work and deployment of excavators, trucks and other equipment for that purpose. When cooling, the installation of a cooling system which uses seawater (variant K2) has the most impact.

Table 73 Maximum increase of deposits in Natura 2000 areas as a result of the variance for reactor and cooling (in mol/N/ha/year)

Variant	Zwanenwater & Pettemer dunes.	Den Helder – Callantsoog dunes	Schoorl dunes
Nuclear island variant B1 including cooling variant K2	15.25	0.11	0.06

The maximum deposits will take place in the Natura 2000 area of Zwanenwater & Pettemer dunes, at a short distance from the most important activities. The deposits in the Natura 2000 area of Den Helder – Callantsoog dunes and Schoorl dunes are extremely limited (maximum 0.11 and 0.06 mol N/ha/annum, respectively).
Upon construction of the nuclear island, the largest deposits will take place in the dunes directly adjacent to Research Location Petten entrance (Habitat type H2130B, lime-deficient gray dunes). Upon installation of the cooling water system, the maximum deposits will be found along the route of the cooling water pipeline in the dune area (various types of habitat). The largest deposit as a result of the construction phase as a whole, will be found at the entrance to Research Location Petten, and will be maximum 15.25 mol/ha/year for a combination of the nuclear island construction height variant B1 and cooling variant K2.

Hydrological changes

The ecological impact as the result of hydrological changes is relevant for Natura 2000 areas and the NNN, as well as for protected and Red List species.
The principle when determining the impact is that the nuclear island will be constructed by means of the caisson method in construction height variant B1, that construction height variant B2 makes use of a concrete wall construction pit, and that this construction pit is excavated in a wet work environment. Wellpoint dewatering will not be necessary. There will be no fall in the phreatic water table nor the hydraulic head of the groundwater in the surrounding area. Construction of the reactor will therefore have no impact on dehydration-sensitive

natural values in the Natura 2000 area of Zwanenwater & Pettemer dunes. There are no wet sections of site in the direct vicinity of the construction location, where dehydration-sensitive plants and animal species might be found. Any impact on protected and Red List species is therefore also excluded.
Drainage of an open trench for installation of cooling water pipelines between the PALLAS-reactor and the North Sea will have a relatively great impact on the surrounding area. The water table will fall by more than 5 cm in a radius of a few hundred meters from the trench. Various dune valleys with hydrologically sensitive types of habitat can be found in this zone. Depending on the duration of the dehydration, this can result in irreversible damage to the ground of these habitat types, which in turn will lead to deterioration of the quality of habitat types H2140A, H2170 and H2190C. The various Red List species found in these areas will also be negatively affected by this fall in the water table. All other activities for the purpose of the PALLAS-reactor have no actual consequences for the groundwater and surface water systems of the dunes and polder.

13.4.1.2 Transition phase

During the transition phase, both the HFR and the PALLAS-reactor will be operational. This will impact the extraction and discharge of cooling water.
In cooling variant K1, both reactors extract cooling water from the Noordhollandsch Kanaal. The impact of suction of fish will therefore temporarily increase versus the current situation. In cooling variant K2, the transition phase will have an impact on suction of fish from both the Noordhollandsch Kanaal (HFR) and from the North Sea (PALLAS).
During the transition phase, there are two discharge points for discharge of the cooling water into the North Sea. It is assumed that these points are sufficiently far apart to prevent the two resultant mixing zones from becoming mixed together. This results in an increased total surface area influenced by the cooling water discharges within the North Sea coastal zone.

13.4.1.3 Operational phase

Disturbance

The nuclear island

The use of the PALLAS-reactor and surrounding buildings will result in an extremely limited noise emission. The (reference) contour of 47 dB(A) remains limited to Research Location Petten. Any impact on the Natura 2000 areas in the vicinity is therefore excluded, as is any impact on protected and Red List species in the vicinity of the PALLAS site.
No significant vibrations will occur during the construction and operational phases, and no vibrations can be detected in the vicinity of the reactor.
The lighting of the PALLAS-reactor is comparable to the lighting of other buildings at Research Location Petten. The background report on Light (and Section 12) shows that the target value of 0.1 lux relevant to nature is not exceeded in the area directly outside the fence and parking area of the location. The presence of PALLAS therefore does not increase the illuminance in Natura 2000 areas, and the impact on protected and Red List species is therefore also negligible.

Cooling water extraction

There will be a very slight increase in the noise hinder as a result of cooling water being pumped up from the sea (cooling variant K2). This will be extremely limited versus the existing noise at sea, both above water and underwater. Discharge of cooling water takes place without the use of pumps along the Natura 2000 area of the North Sea coastal zone. The discharge of cooling water in cooling variants K1 and K2 will therefore not cause any disturbance.
Any impact of continuous underwater noise on natural values during the transition and operational phases can therefore be excluded.

Air cooling

The use of air cooling will not result in the reference contour of 47 dB(A) being exceeded in the surrounding Natura 2000 areas and the NNN.
The increase in noise hinder will be limited to Research Location Petten and the western section of the polder. Most of the species found here are accustomed to human disturbance and will not suffer any real negative impact. There may be an impact on bats active during nighttime, depending on the frequency of the air cooler noise. However, there is a very low density of foraging bats in Research Location Petten.

Nitrogen deposition

Nitrogen will be emitted during the transition and operational phases, due to heating and hot water facilities in buildings, and transport of equipment and personnel. During the transition and operational phases, the deposits will be limited to the Natura 2000 area of Zwanenwater & Pettemer dunes. The maximum value will be 1.66 mol N/ha/year in habitat type H2130B lime-deficient gray dunes. The largest deposits will be found along the edges of the Natura 2000 area around Research Location Petten and along the Westerduinweg.

Suction of fish and other organisms

Suction of fish and other organisms is a relevant aspect for Natura 2000 areas and protected and Red List species. External impacts on the NNN are not included or are irrelevant in the North Sea. This impact is only relevant for variants K1 and K2 for the cooling water supply, whereby cooling water is extracted from the Noordhollandsch Kanaal (variant K1) or the North Sea (variant K2).
The scope of influence of suction is limited due to the limited volume of flow. The flow speed is less than 15 cm/s at some distance from the inlet point, so that most fish will be able to escape the suction force of the inlet point. Only very small numbers of individual fish will be sucked in therefore. Some of these fish will be released again to open water by means of the fish return system, though a number of these fish will not survive the process or will become seriously injured.
It therefore cannot be entirely excluded that the water extraction process will not negatively impact individual fish protected species such as sea lamprey, river lamprey and twait shad (qualifying species for the North Sea coastal zone). However, this will not have consequences for the populations of the species, due to the limited numbers involved and the large habitat.

Water extraction in the Noordhollandsch Kanaal will have no impact on protected fish species, as they are not found in the canal.

Thermal changes in the surface water

A simple test conducted within the scope of the background report on Soil and Water assessed whether or not a more extensive numerical model study is required for the new PALLAS cooling water discharge system. As far as the saline coastal water (designated as) shellfish water is concerned:

- The temperature increase must be limited to 3°C versus the background temperature, up to a maximum of 25°C, and;
- The mixing zone, the area in which the temperature exceeds 25°C, must not reach the seabed.

The mixing zone is that section of the surface water which is heated to more than 25°C as a result of discharged heat, and which is enclosed by the spatial 25°C isotherm.

There is no effective test to assess the scope of the impact of cooling water discharge on seawater. Due to the limited volume of the discharge (3300 m^3/h = 0.92 m^3/s), the background report on Soil & Water applied the principles of the test for rivers and canals, to determine whether the mixing zone remains limited to 25% of the cross-section of the water system, whereby an extremely conservative value of 5 m (equal to the water depth) was deployed for the cross-section. The test showed the mixing zone to remain limited to 2.2 to 14.2 %, thereby remaining well below the critical limit of 25%. The discharge point has not yet been designed, so that no assessment can be made of whether the mixing zone reaches the seabed. The risk is in any case smallest in the winter (greatest difference in density as a result of greatest temperature difference) when using cooling water from the canal (cooling variant K1; even greater difference in density due to freshwater-saltwater), resulting in a great upward force. The risk is greatest in the summer, when using cooling water from the sea (cooling variant K2). When considering the results of the test, as described above, an effective design is expected to be able to prevent the cooling water plume reaching the seabed. If, despite such measures, the mixing zone cannot be prevented from reaching the seabed, this will have the following impact on the zone in question, which will only concern an extremely small section of the North Sea coastal zone, thanks to the limited dimensions of the mixing zone.

- A considerable increase in the temperature of the seabed would have consequences for the composition of bed fauna. Higher temperatures will impoverish the bed fauna, rendering the bed less significant for benthos-eating species of fish and birds. For that matter, these species will themselves avoid the zone due to the high temperatures. The composition of the bed fauna will be altered in case of limited temperature increases to just above 25 °C, which will not necessarily result in a decrease in the biodiversity and biomass. This change may however result in a decrease in species characteristic to the habitat type H1110B.
- Fish in the vicinity which do not appreciate this increased temperature, will migrate to other locations, while fish for which the higher temperatures are agreeable, will be attracted. In all cases, there will be a sufficiently large area available for fish avoiding the mixing zone.
- Sea mammals are not expected to be directly influenced by the temperature increase, as the temperature fluctuations are not large enough for that purpose. Moreover, they can easily avoid the plume of warm water.
- Temperature changes may result in visibility changes due to the influence of temperature on the sedimentation rate. Generally speaking, higher temperatures will increase the sedimentation rate, thus improving visibility. However, there is a low concentration of sediment in this area, and relatively high visibility. This means that, at most, the water will become slightly clearer, but that this will not have any impact on conservation targets.
- The oxygen concentration in seawater depends on its temperature. The higher the temperature, the lower the oxygen concentration in the water. It can generally be assumed that oxygen concentrations of less than 5 mg/l can result in damage to the ecosystem.
  Based on an average seawater temperature of 20°C in the summer months, an increase up to maximum 47.5°C at the discharge point, and a rapid decrease in this temperature due to mixing, this critical limit is hardly ever reached. Any ecological impact of temperature on the oxygen level can therefore be excluded, as can any impact on the quality of the habitat type H1130B and protected species of fish and sea mammals.

Chemical changes in the surface water

In the secondary cooling water system, chlorine is actively added in the cooling variants K1 and K2 as a means of combating growth (bio fouling). As a result, the cooling water to be discharged contains residual free available chlorine and its hazardous conversion products (mainly chloroform and bromoform). This can have potentially negative consequences for the chemical and/or ecological water quality. Targets have been established for this purpose, within the scope of the European Water Guideline.

Both cooling variants comply with the effluent test for bromoform and chloroform. In other words, the concentration of the substance in the cooling water to be discharged is lower than the physical-chemical water quality norm. As the substances decompose quickly and there is no further indication that they are harmful to organisms, a temporary increase in the concentration will have no consequences for protected or Red List species of fish, birds and sea mammals.

13.4.2 Impact assessment

This paragraph assesses the severity of the impacts described above. Each impact is assessed according to the various relevant statutory frameworks, in order to determine an impact score. The assessment is always based on the variant which has the greatest impact in terms of the nuclear island and cooling system. The Nature background report gives a more detailed impact assessment. As mentioned, the choice has been made to only state an impact score, along with the statutory measures to be taken. After all, the activity would not be admissible (or only with great difficulty) without application of such measures. This implies that these measures will be a component of the activity and they have therefore been assessed as such.

13.4.2.1 Assessment according to the Dutch Nature Protection Act: regional protection

Construction and use of the PALLAS-reactor has an impact on natural values in the Natura 2000 areas of the Zwanenwater & Pettemer dunes and the North Sea coastal zone.
The following impacts cannot be excluded during the **construction phase**:

Zwanenwater & Pettemer dunes.

- Loss of land surface area for various types of habitat.
- Mechanical damage to various types of habitat.
- Nitrogen deposition in various types of habitat.
- Disturbance of the Northern wheatear due to pile driving work and due to installation of cooling water pipelines in the dunes.
- Dehydration of wet and humid dune habitats due to installation of cooling water pipelines.

North Sea coastal zone

- Loss of land surface area in habitat type H1110B Permanently flooded sandbanks (North Sea).
- Mechanical disturbance of habitat type H1110B.
- Physical degradation due to underwater noise, for sea mammals and fish.
- Disturbance of the common eider and common scoter due to installation of cooling water facilities in the North Sea.

The following impact is possible during the **transition and operational phases**:

Zwanenwater & Pettemer dunes.

- Nitrogen deposition in various types of habitat.

North Sea coastal zone

- Suction of migratory fish into the cooling water inlet.
- Quality deterioration of habitat type H1110B due to thermal pollution.

Impact of loss of land surface, mechanical impact, disturbance and hydrological impact

Installation of cooling water pipelines results in loss of land surface area of habitat type H2130B, and a possible permanent impact on other types of habitat. The nature and scope of the impact depends on the precise routing. The impact is limited for routes A and B because of the possibilities for recovery, whereas the possibilities for recovery are limited in routes C1, C2, D, E and F (see Figure 41). There is however an expansion target for these habitat types and they have priority. The area affected may be larger than the minimum area above which there is a significant impact of loss of land surface, according to the Guide to determining Significance (0.1 are or 10 m²). This value is based on the minimum surface area with which the occurrence of a habitat type can be determined. This loss of land surface may therefore represent a significant negative impact.
The mechanical disturbance of the habitat type H2130B occurs locally and has a temporary impact on the vegetation. This impact may also positively influence the biodiversity, as it adds variation in terms of the degree of openness of the vegetation. The vegetation will soon recover as the vehicle movements do not cause any changes to the site conditions. Vehicle movements on other types of habitat may influence them permanently, due to the vulnerable ground in these types of habitat becoming damaged. The scope of such an impact also depends on the routing of the pipelines, and may exceed the limiting value for a significant impact. The mechanical impact can similarly be significantly negative.
Installation of the cooling water pipeline will result in a temporary and strong fall in the water table in the area. Dune valleys with such sensitive types of habitat occur in the direct facility of the routes. Depending on the duration of the dehydration, this can result in irreversible damage to the ground of these habitat types, which in turn will lead to deterioration of the quality of the habitat types. The habitat types H2140A, H2170 and H2190C are covered by conservation targets. The deterioration in quality is in violation of these targets, and these impacts may therefore possibly be significantly negative.
Vehicle movements may result in a minor risk of damage to Northern wheatear nests or brood. The Northern wheatear may also be disturbed by work conducted on the cooling water pipelines and by pile driving work at the reactor location. Although this species does not currently nest in the planning area, this may well occur if the population in the Natura 2000 area recovers. Damage to the brooding area and disturbance may result in the Northern wheatear breeding less successfully, with an inherent impact on the population.
Upon pile driving the foundations for the concrete plant at the LDA, there is a risk of disturbing the Northern wheatear, if this work is conducted during the nesting season. This may result in the nesting pairs breeding less successfully.
The conservation status of the Northern wheatear in the Netherlands and in the area in question, is extremely unfavorable, with the number of nesting pairs having declined strongly over recent decades. A negative impact on the Northern wheatear will therefore have significant negative consequences for the Natura 2000 area. This impact can be prevented through the application of mitigating measures.

Impact of nitrogen deposition

During the construction phase, the nitrogen deposition in the area will be maximum 15.25 mol N/ha/year during construction (3-4 years). The total deposits (background value + project) exceed the critical deposits value for 10 types of habitat in the area. During the transition and operational phases too, (permanent) nitrogen deposition will occur, though at a much lower level (1.66 mol N/ha/year). Once again, this will result in exceeding the critical deposits value in the same types of habitat.
In May 2016, PALLAS was registered as a priority projects in the PAS Nitrogen Action Program, by the province of Noord-Holland. The project may therefore be allocated room for development, in segment 1. The maximum requested allocation is 16.02 mol N/ha/year, which is sufficient to facilitate the operational phase.
Upon allocation of the room for development, it is known beforehand that the nitrogen nitrogen deposition resulting from the project will not damage the natural characteristics of the Natura 2000 area, as the PAS requires sufficient measures to

be taken to that end. The appropriate assessment conducted for the PAS showed that implementation of the PAS will not have a significant negative impact on Natura 2000 areas [30]. Significant negative consequences of PALLAS for the Natura 2000 area of Zwanenwater & Pettemer Dunes can therefore also be excluded.
The PAS cannot allocate any room for development to the zoning plan for PALLAS. As the concrete execution of the project is identical to the maximum (spatial) possibilities offered by the zoning plan, it may be derived that, when sufficient room for development is allocated, the maximum execution of the PALLAS zoning plan will not result in damage to the natural characteristics of the area. The zoning plan is therefore viable with regard to the impact of nitrogen, according to the Dutch Nature Protection Act.
As the precise route of the cooling water pipelines is not yet known, the construction of PALLAS entails a risk of significant impact for various types of habitat and for the Northern wheatear. Mitigating measures must be taken.

Assessment of impact on Natura 2000 area of the North Sea coastal zone
There will be a limited impact on the habitat type H1110B Permanently flooded sandbanks, as a result of loss of land surface and a mechanical impact upon installation of cooling water pipelines, as well as quality deterioration of the habitat when the mixing zone of the cooling water discharge plume cannot be prevented from reaching the seabed.
Construction of the extraction platform results in a loss of 0.25 ha of the habitat type H1110B. The seabed and water column are still available for marine fauna however, due to the platform being built on piles.
The habitat type H1110B is found in large sections of the Natura 2000 area of the North Sea coastal zone. This represents a surface area of 123,000 ha. There is a surface area of approximately 590,000 ha of this habitat type in Natura 2000 areas within the Dutch segment of the North Sea. Moreover, dynamic processes in shallow sections of the North Sea render this habitat type liable to great fluctuation, in terms of both quality and surface area.
The loss of 0.25 ha and temporary damage of maximum 1 ha of the habitat type H1110B represents an extremely small part of the total occurrence of the habitat type within the Natura 2000 area of the North Sea coastal zone and beyond. This surface area is irrelevant in comparison with the variations in the occurrence of the habitat type as a result of natural processes in the North Sea. The impact is therefore insignificant.
Discharge of cooling water will result in a mixing zone in which the temperature of the seawater exceeds 25°C in the habitat type H1110B. This mixing zone is limited in size, and if it cannot be prevented from reaching the seabed, this may have a negative impact on the seabed fauna. Thermal pollution has a negative impact on the quality of habitat type H1110B and on fish found on or close to the seabed, such as sea lamprey and river lamprey.
The surface area of that part of the seabed which may be reached by the mixing zone is very limited versus the surface area of the habitat type H1110B and the habitats of the river lamprey and sea lamprey. Both species of fish are also found outside the Natura 2000 area in the North Sea.
Extraction of cooling water in variant K2 results in a risk of suction of fish in the North Sea coastal zone. It cannot be excluded that individual river lamprey, sea lamprey and twait shad are sucked in. The scope of influence of the extraction point is probably extremely small, while the distribution area of the species in the North Sea is extremely large (also beyond the Natura 2000 area of the North Sea coastal zone). Moreover, the location is not in the direct vicinity of estuaries to which these species of fish migrate in order to reach their spawning grounds. Suction of individual fish of the species will therefore only take place incidentally and will have no impact on the conservation status of the populations. The risk can be reduced even further by applying mitigating measures.
The conservation status of habitat type H1110B, sea lamprey and river lamprey is moderately favorable. There is an improvement target for the quality of the habitat type H1110B, along with an improvement target for the population of the two species of fish, though this improvement target mainly pertains to improvement of the migration route elsewhere and improvement of saltwater-freshwater transitions. Any locally occurring impact as a result of increased temperatures, will not influence this.
Due to the moderately favorable conservation status, it cannot yet be entirely excluded that the impact on the habitat type H1110B, sea lamprey and river lamprey will not be significant.
When pile driving is required for the construction of the extraction platform, the physical impact of underwater noise on sea mammals and fishes cannot be excluded. Although unlikely, the occurrence of this risk may have a significant negative impact on species with an unfavorable conservation status (all sea mammals and fish with the exception of the harbor seal). This impact can be mitigated.
Work conducted for the purpose of installation of cooling water facilities in the North Sea may result in disturbance of foraging common eiders and common scoters, when concentrations of shellfish occur in the planning area at the time of the work. The conservation status of the common eider is extremely unfavorable, and that of the common scoter moderately favorable. Availability of food can limit the population development for both species. During colder winters in particular, (when the Wadden sea freezes), both species rely on the North Sea coastal zone. Under these conditions, disturbance of these duck species can result in a major impact on the population. This impact is therefore significantly negative.
Significant negative consequences cannot be excluded for the habitat type H1110B, the harbor porpoise, gray seal. river lamprey, sea lamprey, twait shad, common eider and common scoter. The table shows the conservation status and conservation targets for the habitat types and species influenced by PALLAS.

Mitigating measures
In order to prevent significant impact or to reduce it to an insignificant level, the following mitigating measures must be taken.

Loss of land surface and dehydration of habitat types upon instal-

lation of cooling water pipelines
The loss of land surface and mechanical impact on habitat types in the dune area can be prevented or limited as follows:

- Careful routing of the pipelines, preferably in the direct vicinity of the existing cooling water pipelines for the HFR; This route will limit the impact to white dunes and dune grasslands which can recover relatively quickly. This is the case for routes A and B in Figure 41.
- Avoidance of routes which cross low-lying dune areas characterized by habitats such as (humid) dune heaths and dune valleys;
- Transport of equipment and materials via existing infrastructure (road from Reseach Location Petten to the firing range, Noordzeeroute cycle path, possibly via the beach);
- Minimization of the space required for excavation.
- Careful repair of the soil and turf, based on a repair plan drawn up by an expert body.

Dehydration of habitat types can be prevented or limited by:

- Conducting work outside the growth season (March – October).
- Conducting excavation within sheet piling which is sunk down to the clay/peat-type deposits under the dune sand. This will largely reduce the surplus water and water table reduction in the surrounding area.
- Opting for an alternative construction method in the vicinity of sensitive habitats (drilling of pipelines).

When drawing up the drainage plan, we recommend that the impact on the water table and chloride concentrations be recalculated using a specific model, once there is more detailed information on the routes, depths, construction method, etc.

Disturbance of Northern wheatear upon installation of cooling water pipelines and pile driving work
Disturbance of nesting Northern wheatears upon installation of cooling water pipelines in the dune area of the Pettemer dunes can be prevented by means of the following measures:

- Conducting work outside the Northern wheatear nesting season (April – June).
- When conducting work during the nesting season, an inventory must be made of the planning area to identify the nesting sites of the Northern wheatear. When nesting sites are discovered, the working schedule must be adjusted.

Disturbance of nesting Northern wheatears during pile driving work in the LDA can be prevented by means of the following measures:

- Conducting work outside the nesting season (April – June).
- The use of alternative methods for installation of piles (drilling, vibration).

Such measures can completely prevent a significant negative impact on the Northern wheatear.

Thermal pollution of habitat type H1110B and migratory fish
When a mixing zone is formed at the cooling water discharge point, it must be prevented from reaching the seabed. Furthermore, the scope of the mixing zone will be limited when it is influenced by tidal flows and turbulence. The cooling water discharge point should therefore preferably be located high up in the water column, whereby the cooling water is discharged in an upward direction.

If either of the cooling water variants K1 and K2 are included in the preferred alternative, further model studies must determine the scope and distribution of the mixing zone, and the degree to which the location and design of the discharge point can prevent an impact on the marine ecosystem.

Physical degradation due to underwater noise
Sea mammals and fish will avoid areas in which there is great noise hinder. However, when animals are surprised by sudden impulse noises of a level exceeding the limiting value for hearing damage, they cannot flee quickly enough. This can result in temporary or permanent damage to hearing organs. It can be prevented by initiating pile driving work in a so-called slow start. When the pile driving process is started at a low capacity, any animals in the vicinity will flee, after which the capacity can be gradually increased to the required level. This measure has no consequences for fish larvae, which particularly depend on tidal flows and cannot independently flee the scope of influence of the pile driving.
The impact of pile driving can also be prevented by opting for alternative construction methods (such as vibration) or sound-limiting measures (such as bubble screens). A method can also be applied in which the capacity of the pile driving blows is gradually increased, giving animals enough time to flee.

The impact partly depends on the period in which work takes place. Gestating seals migrate during summer months, while the January-May period is important for fish larvae. The impact of pile driving is therefore smallest during the August-December period, which is also when the density of harbor porpoises is relatively low along the coastline [31].
By applying (a combination of) the above measures, physical degradation to sea mammals and fish can be prevented, and the damage to fish larvae can be minimized.

Impact on fish as a result of suction
Various measures can be taken in order to limit the suction of fish. Measures to limit the flow speed of the water in which the fish occur, to maximum 15 m/s are preferred, rather than (simply) a fish return system. The latter can usually not prevent a number of the fish dying or being wounded.
Generally speaking, the following types of systems can be used (Bruijs et al, 2007):

- Mechanical barriers, partly also for adjustment of the inflow speed (stopping the fish physically, such as grilles, screens, nets and filters).
- Separation systems (separating the fish from the cooling water flow towards a bypass in order to guide them back to the surface water).
- Behavioral systems (changing or utilizing the natural behavior of fish in order to attract them or repel them, with light, sound or bubble screens, for example).

Disturbance of benthos-eating waterbirds
Disturbance of the common eider and scoters which forage for shellfish in the North Sea coastal zone can be prevented by conducting research into the occurrence of shellfish within the area of influence of the work, prior to the work being conducted. When concentrations of shellfish (particularly the subtruncate surf clam (Spisula subtruncata) are found in the area, the work must take place outside the period in which the ducks forage here (particularly in the winter months, during cold winters).
Application of this measure can completely prevent disturbance of common eiders and common scoters.

Assessment of impact following mitigation
All impacts on the Natura 2000 area of Zwanenwater & Pettemer dunes can be excluded following the mitigation measures. Significant consequences can be prevented in the Natura 2000 area of the North Sea coastal zone, if the outlet of the cooling water pipeline is constructed in such a manner that the mixing zone cannot reach the seabed. Further research in the next phases of the study must provide insight into this. The impact of underwater noise and disturbance can be completely mitigated.

Cumulation test
Only the impact of thermal pollution in the North Sea coastal zone cannot be excluded following mitigation measures. All other impacts can be completely prevented, and therefore need not be the subject of a cumulation test.
A cumulation test of the impact of thermal pollution will be conducted at a later stage of the preparatory study for PALLAS, if cooling variant K1 or K2 is part of the preferred alternative and a detailed design of the cooling water outlet is available.

Conclusion
Assessment of the effects of the construction and operational phases results in the following conclusions:

- Following application of mitigating measures, the construction and exploitation of the PALLAS-reactor and its accessory systems and necessary infrastructure changes, will not damage the natural characteristics of the Natura 2000 area of Zwanenwater & Pettemer dunes.
- Following mitigation, the construction of the PALLAS-reactor and its accessories systems and necessary infrastructure changes, will not damage the natural characteristics of the Natura 2000 area of the North Sea coastal zone.
- The operation of the PALLAS-reactor may result in deteriorated quality of the habitat type H1110B Permanently flooded sandbanks, and may have a negative impact on migratory fish, as a result of thermal pollution. It must be apparent from the design of the cooling water outlet whether the mixing zone can be prevented from reaching the seabed at all times. A significant negative impact can therefore be excluded for the K1 and K2 variants for secondary cooling for the time being, as long as such a design proves possible.
- None of the variants for construction of the reactor and cooling water facilities will have consequences for Natura 2000 areas in the vicinity as the result of nitrogen deposition, as long as the project is allocated sufficient room for development according to the priority status requested for the project.
- The construction and operation of the cooling water system (variants K1 and K2) may result in a (non-significant) negative impact on both Natura 2000 areas.

The zoning plan for the PALLAS-reactor (which only relates to the location for the nuclear installation) can be determined in accordance with the Dutch Nature Protection Act.

13.4.2.2 Assessment according to the Dutch Nature Protection Act: species protection

Assessment according to prohibitions
The consequences of the construction and operation phases for protected species are offset against the prohibitions with regard to protected species in the Dutch Nature Protection Act.
The following impacts have been identified for protected species in this background report. It does not pay any further attention to those species for which there is an exemption:

- Loss of habitats of protected species in the dune area as the result of installation of cooling water pipelines. This concerns the sand lizard and natterjack toad (both Habitat Directive species).
- Damage to nests and/or regular resting locations and habitats, and the death of protected or endangered species such as the Northern wheatear and other ground-nesting species (Birds Directive species), the sand lizard (Habitat Directive species) and niobe fritillary (Other species, for which there is no exemption) as a result of vehicle movements. Individual animals may be killed or injured in the process.
- Disturbance of (nesting) birds (Birds Directive species), mammals and amphibians (Other species, for which there is an exception) in the dune area upon installation of the cooling water pipelines.
- Disturbance of sea mammals in the North Sea (Habitat Guideline species and Other species, for which there is no exemption) upon installation of the cooling water facility.

Table 74 Impact assessment for impact on Natura 2000 areas (following statutory measures)

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase	0	0	0	-	-	0
Transition phase	0	0	0	-	-	0
Operational phase	0	0	0	-	-	0

The following tables indicate which prohibitions of the Wnb may be violated as a result of the work, based on the impact description of the previous paragraph, per species (group). They do not yet take account of any possible mitigating measures.

A Dutch Nature Protection Act dispensation is required for the impact on a number of species. However, the project must meet a number of conditions, as follows:

- There must be no other satisfactory solution. In this case, it has been detailed in the SEA, with various alternatives having been discussed and described in terms of whether or not they are viable. There has been attention for more than simply the natural values in the vicinity.
- There must be a relevant statutory interest. The statutory interests (may) very per protection category:
  - For Birds Directive species: "1° in the interests of public health or public safety" applies. After all, the new reactor is necessary for the production of isotopes for medical use and is therefore in the interests of public health.
  - For Habitat directive species: "3° in the interests of public health, public safety or other imperative reasons of overriding public interest, including reasons of a social or economic nature and including significant favorable effects for the environment." After all, the new reactor is necessary for the production of isotopes for medical use and is therefore in the interests of public health.
  - For Other species:
    - "3° in the interests of public health, public safety or other imperative reasons of overriding public interest, including reasons of a social or economic nature and including significant favorable effects for the environment," After all, the new reactor is necessary for the production of isotopes for medical use and is therefore in the interests of public health.
    - "a. within the framework of the spatial design or development of areas, including the subsequent use of the design or developed area." The new reactor is a spatial development and this is therefore also a relevant interest.
- It is important that the project does not result in degradation of the conservation level of protected species. The conservation level will not be degraded for any of the species for which an exemption has been requested. When there is damage to habitats, this concerns a very limited part of the habitat being damaged. There are sufficient fallback options in the vicinity of the habitats of protected species (dune areas and North Sea). Moreover, the majority of impacts are limited and the current habitats will be suitable for use again in due time, upon completion of the work. There is no degradation of the conservation level.

Table 75 Possible violation of the prohibitions of article 3.1 with regard to Birds Directive species.

Type	Paragraph 1	Paragraph 2	Paragraph 3	Paragraph 4	As a result of
Nesting birds during the brooding period	X	X			Work at Research Location Petten and in the dune area

Prohibitions:
Paragraph 1: killing or capture;
Paragraph 2: intentional destruction or damage of nests, resting places and eggs, or removal of birds' nests;
Paragraph 3: collection and possession of eggs;
Paragraph 4: intentional disturbance; disturbance is admissible if it has no actual impact on the conservation level.

Table 76 Possible violation of the prohibitions of article 3.5 with regard to Habitat Directive species

Type	Paragraph 1	Paragraph 2	Paragraph 3	Paragraph 4	As a result of
Sand lizard	X	X	X	X	Work in the dune area
Natterjack toad	X	X	X	X	Work in the dune area
Harbor porpoise	X	X			Work in the North Sea

Prohibitions:
Paragraph 1: intentional killing or capture;
Paragraph 2: intentional disturbance;
Paragraph 3: intentional destruction or collection of animals' eggs;
Paragraph 4: destruction or damage of animals' breeding places or resting places;
Paragraph 5: intentional picking and collection, cutting, uprooting and destruction.

Table 77 Possible violation of the prohibitions of article 3.10 paragraph 1 with regard to Other species.

Type	a	b	c	As a result of
Niobe fritillary	X	X		Work in the dune area
Harbor seal				Work in the North Sea
Grey seal				Work in the North Sea

Prohibitions:
a: intentional killing or capture;
b: destruction or damage of regular breeding places or resting places;
c: intentional picking and collection, cutting, uprooting and destruction.

Duty of care applies in all cases, in which all persons are obliged to exercise sufficient care with regard to wild plants and animals, and where necessary to take measures which can be reasonably expected of them to prevent or limit or undo any harmful consequences for plants and animals. This means that, in principle, mitigating measures must be taken to limit any impact.

Mitigating measures

Within the framework of species protection, the following matters are to be taken:

- General (within the scope of duty of care):
  - The loss of habitat of protected species can be (partially) prevented by means of careful routing of the cooling water pipelines.
  - The impact of vehicle movements on animal species in the dunes can be (partially) prevented by:
    - Using existing roads and paths whenever possible.
    - Minimizing the distance to the construction location.
    - Using relatively lightweight vehicles.
    - Using regular routes and determining these routes beforehand, on the basis of the occurring vegetation and biotope characteristics of vulnerable species.
- The impact on nesting birds of the Birds Directive species can be fully prevented:
  - Disturbance of nesting birds in the dune area can be prevented by conducting any disturbing work outside of the brooding period (March-July). This will at the same time avoid general species of mammals being disturbed during their vulnerable period (outside of hibernation, when rearing young). If the work cannot be conducted outside this period, the vegetation can be removed outside of the sensitive season in order to prevent the presence of birds.
- As far as Habitat Directive species are concerned, measures can mainly prevent an impact on individuals. There will always be an impact on habitats, though only for the duration of the work in most cases:
  - In the dunes:
    - Amphibian screens can be fitted between the dune areas and work areas prior to the work, in order to prevent sand lizards and natterjack toads migrating to the planning area from the surrounding dune area, during work.
    - Prevent the formation of shallow bodies of water in the work area and depot. This will prevent natterjack toads migrating to the work area or depot. The impact on natterjack toads can be fully prevented if colonization can be avoided.
  - In the north sea: see mitigating measures in § 0.
- As far as Other species re concerned, measures can mainly prevent an impact on individuals. There will always be an impact on habitats, though only for the duration of the work in most cases: The measures have been given under measures in the framework of the duty of care and for Habitat Directive species.

Application of the above mitigating measures will limit the impact on protected species. All other impacts only occur locally and temporarily. Following mitigation therefore, there will be no negative impact on any of the favorable conservation states of protected species of plants and animals in the planning area. The remaining prohibitions which may be violated after taking mitigating measures are given in Table 78 and Table 79.

Conclusion

The construction and operation of the PALLAS-reactor with its accessory systems and necessary infrastructure changes may have an impact on protected species, resulting in violation of general prohibitions of the Nature Protection Act,

- As far as Birds Directive species are concerned, the impact on protected species can be fully prevented by taking mitiga-

Table 78 Possible violation of the prohibitions of article 3.5 with regard to Habitat Directive species after taking mitigating measures.

Type	Paragraph 1	Paragraph 2	Paragraph 3	Paragraph 4	Paragraph 5	As a result of
Sand lizard				X		Work in the dune area
Natterjack toad						Work in the dune area
Harbor porpoise						Work in the North Sea

Prohibitions:
Paragraph 1: intentional killing or capture;
Paragraph 2: intentional disturbance;
Paragraph 3: intentional destruction or collection of animals' eggs;
Paragraph 4: destruction or damage of animals' breeding places or resting places;
Paragraph 5: intentional picking and collection, cutting, uprooting and destruction.

Table 79 Possible violation of the prohibitions of article 3.10 paragraph 1 with regard to Other species after taking mitigating measures.

Type	a	b	c	As a result of
Niobe fritillary		X		Work in the dune area
Harbor seal				Work in the North Sea
Grey seal				Work in the North Sea

Prohibitions:
a: intentional killing or capture;
b: destruction or damage of regular breeding places or resting places;
c: intentional picking and collection, cutting, uprooting and destruction.

ting measures. There is no threat to the favorable conservation state of any of the species found in the planning area.
- For Habitat Directive species, an exemption must be requested for the sand lizard before undertaking excavation of a cooling water pipeline in the dune area. The destruction of habitat can be precluded, although a sufficient area of habitat will remain. No degrading of the conservation level. The other conditions in order to gain exemption have also been met.
- For Other species, an exemption must be requested for the niobe fritillary before undertaking excavation of a cooling water pipeline in the dune area. The destruction of habitat can be precluded, although a sufficient area of habitat will remain. No degrading of the conservation level. The other conditions in order to gain exemption have also been met.

Based on the above, the construction and operation of the PALLAS-reactor can be conducted in accordance with the Dutch Nature Protection Act.

Table 80 assesses the impact on protected species described in this paragraph, for the various nuclear island and cooling variants and for the various phases.
The only impact will be as a result of installation and use of the cooling water facility in variants K1 and K2.

13.4.2.3 Assessment according to the Provincial Spatial Planning Decree

Assessment according to the protection regime
The impact on the NNN will theoretically be comparable to that on the Natura 2000 area of Zwanenwater & Pettemer dunes, as the two areas largely overlap.
The North Sea is a part of the NNN but is not covered by the planological protection of the Provincial Spatial Planning Decree [22]. The protection regime of the Dutch Nature Protection Act will therefore be applied here. Other parts of the NNN are beyond the scope of influence of the project.
As concluded in the previous paragraph, the impact on the Natura 2000 area of Zwanenwater & Pettemer dunes will be extremely limited and there will be no significant negative consequences for habitat types and the Northern wheatear. The impact on protected and Red List species is also extremely limited and can be mitigated. The actual characteristics and values of the NNN in the dune area will therefore not be damaged.

Mitigating measures
Any impact on the NNN can either be excluded or mitigated by measures taken within the scope of Natura 2000 or protected species. Additional specific mitigating measures are therefore not necessary.

Conclusion
The construction and operation of PALLAS will not damage the actual characteristics of the Natuurnetwerk Nederland (NNN). Supplementary mitigating and compensatory measures are not necessary. The zoning plan for PALLAS and execution of the project can take place in accordance with the Spatial Planning Decree of the province of Noord-Holland [22].
Table 81 assesses the impact on the NNN described in this paragraph, for the various nuclear island and cooling variants and for the various phases. The only effects will be during the construction phase of the cooling water facility.

13.4.2.4 Red List

The impact on endangered Red List species mainly corresponds with that on the protected species of plants and animals, also occurring locally and often also temporarily. The mitigating measures taken for Natura 2000 and protected species are also effective for the protected species of plants and animals in the planning area, so that any further impact will remain limited. Damage to the habitat of the river bullhead fish can be limited by minimizing the working area in the wet profile of the canal.
Suction of (Red List species) fish in the Noordhollandsch Kanaal and the North Sea can be prevented by a large number of possible measures and techniques [32]. Generally speaking, the following categories of measures can be deployed:
- Mechanical barriers (stopping the fish physically).
- Collection systems (actively collecting the fish in order to guide them back to the surface water).
- Separation systems (separating the fish from the cooling water flow towards a bypass in order to guide them back to the surface water).
- Behavioral systems (changing or utilizing the natural behavior of fish in order to attract or repel them).

Table 80 Impact assessment for impact on protected species (following statutory measures)

Assessment criteria	B1	B2	B3	K1	K2	K3
Construction phase	0	0	0	-	-	0
Transition phase	0	0	0	0	0	0
Operational phase	0	0	0	0	0	0

Table 81 Impact assessment for impact on Netherlands Nature Network (following statutory measures)

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase	0	0	0	-	-	0
Transition phase	0	0	0	0	0	0
Operational phase	0	0	0	0	0	0

Table 82 Impact assessment for impact on protected species (following statutory measures)

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase	0	0	0	-	-	0
Transition phase	0	0	0	0	0	0
Operational phase	0	0	0	0	0	0

The choice of specific techniques depends on the behavior and lifestyle of the specific species which require protection, and the water inlet system used. The use of these measures can prevent a substantial part of the impact of suction. There is no available measure which can prevent all death or injury of fish.
No specific assessment framework exists for Red List species as far as spatial development and design of land use is concerned. The Red Lists are a policy instrument aimed at being able to apply specific measures which may promote the conservation status of vulnerable and endangered species, upon the design and management of specific areas.
As there is only extremely limited impact on Red List species, the construction and operation of PALLAS does not stand in the way of policy regarding vulnerable and endangered species, see Table 82.

13.5 Mitigating and compensatory measures

Mitigating measures
The mitigating measures have already been described in paragraph 13.4.2. All the proposed mitigating measures are related to the installation and use of the cooling water system in variants K1 and K2. Following application of these mitigating measures, the construction and operation of the PALLAS-reactor with its accessory systems and the necessary infrastructure changes will not result in significant negative consequences for Natura 2000 areas and the NNN.
No mitigating measures are required so far, for the construction of the nuclear island, the LDA and the air cooling installations. These project components do not result in loss of land surface in Natura 2000, NNN or the habitats of protected species. The impact of any disturbance will remain within the borders of Research Location Petten. Species found here are already accustomed to human activity at Research Location Petten. The impact of hydrological changes is extremely local and will have no influence on site sections which are sensitive to dehydration. The impact of nitrogen is mitigated within the PAS control program framework.
The mitigating measures result in the following areas of attention for the design and realization of the cooling water facilities:

- Design and depth of the cooling water outlet in the North Sea for the various variants (variants K1 and K2). The resultant mixing zone must be prevented from reaching the North Sea bed.
- Design and location of the water extraction point in the Noordhollandsch Kanaal, including facilities for limitation of fish intake (variant K1).
- Design, location and construction method of North Sea water extraction point (variant K2).
- Routing of the cooling water pipelines (variants K1 and K2) in the dune area in relation to the prevention of the impact on protected habitats and species. Routes A and B as given in Figure 41 result in the least loss of habitat types.
- Prevention of dehydration impact upon construction of the cooling water pipelines, by deploying alternative realization methods or installation of sheet piling.
- Route structure for work in the dunes.
- Connecting pile driving work in the LDA.

Compensatory measures
Following mitigation, the construction and operation of the PALLAS-reactor will not have significant negative consequences for the Natura 2000 areas and the NNN. Compensatory measures in the form of the design of new nature areas are therefore not necessary.
Following application of these mitigating measures, the construction and operation of the PALLAS-reactor with its accessory systems and the necessary infrastructure changes will not damage the favorable conservation status of protected species or Red List species. Compensatory measures in the form of the design of new habitats and/or resting places are therefore not necessary.

13.6 Gaps in knowledge

The impact description and assessment for the Nature aspect is based on a comprehensive and up-to-date inventory of habitat types and species in the dune area of the Zwanenwater & Pettemer dunes, Research Location Petten and the adjacent inner dune edge in the Zijpe Polder. There are therefore no knowledge gaps with regard to the natural values occurring in these areas. This data was collected in 2015, and is sufficiently current and representatives of the area for a 3 to 5-year period. Although the protective status of species has changed upon introduction of the new Nature Protection Act, the research is still applicable. This is because the research was not only focused on species previously protected within the framework of the Flora and fauna Act, but also on other rare species.

The North Sea coastal zone has not been included in this study. There is limited detailed data available for the North Sea coastal zone, with regard to the occurrence of fish, birds, sea mammals and the ecological factors which determine distribution of the species (such as variation in the occurrence of food sources). While there is global information on the occurrence of birds and sea mammals in the North Sea region, this information is often too general to be able to reach detailed conclusions on the impact of PALLAS activities in the North Sea coastal zone. Based on this global information and applying the precautionary principle, there is however insufficient insight into any possible impact and related mitigating measures, to be able to guarantee that the activities can be conducted in accordance with legislation.

For the time being [19], the Design framework for PALLAS gives an extremely general picture of the design, the construction method and the operation of PALLAS. This partly suffices in order to exclude certain impacts (loss of land surface, hydrological impact), but no more than an indication can be given for other impacts at this stage in the process.
An extensive inventory has been made of the use of nitrogen-emitting equipment and installations during the construction and operational phases, in order to determine the nitrogen deposition and register PALLAS as a priority project in the nitrogen control program. This inventory has allowed a reliable calculation to be made of the nitrogen deposition for the various construction height and cooling variants during the construction phase and the operational phase.

14 Recreation and tourism

The following description of the Recreation and Tourism aspect is based on the Recreation and Tourism background report (see Appendix F9).

14.1 Assessment framework

14.1.1 Policy framework

Table 83 summarizes the relevant policy and relevant legislation and regulations for the Recreation and Tourism aspect, along with an indication of their relevance for the project. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Recreation and Tourism.

Table 83 Policy, legislation and regulations on Recreation and Tourism

Policy plan, law, regulation	Description/ Relevance for PALLAS
National Coastal Vision, Dutch Ministry of Infrastructure & Environment, 2013	The Dutch National Coastal Vision gives an integrated perspective of future-proof development scenarios for the Dutch coastline. It details the 5 development principles of the National Coastline Framework, whereby principles 3 (natural dynamics) and 4 (spatial quality) are relevant. The National Coast Vision means that each development must be aimed at maintenance or improvement of the (spatial) quality and identity of the living environment (housing, beaches, recreational areas), greater quality of mutually connected nature areas and greater ecological and landscape qualities.
National Structural Vision on Wind energy at Sea, Dutch Ministry of Infrastructure & Environment, 2014	The Dutch National Structural Vision on Wind energy at Sea designates areas for the construction of wind farms at sea. Both the IJmuiden Ver and Hollandse Kust zones lie within the scope of influence of the planning area and may in time influence the degree of unspoiled views at sea.
Structural Vision for Noord-Holland 2040, Province of Noord-Holland, 2010	The Structural Vision for Noord-Holland describes the spatial policy of the province and defines the provincial interests: climate resilience, spatial quality and sustainable land use. These three interests are taken into consideration in any spatial planning decisions by the province of Noord-Holland. The province applies the following principles for its planning area and general region. • Dunes: priority for safety and nature with room for recreation/tourism. • Zijpe Polder: Large-scale agriculture and bulb growing concentration.
Strategic Coastline Agenda, Province of Noord-Holland, 2012	The Agenda states that there must be reinforcement of the identity of the coast as a whole and the landscape relationship between the diverse nature areas and coastal community. Another aim is to achieve zoning in which qualities are intensified, such as the intensification of “activity” in the recreational zones and where possible also the intensification of “tranquility” in nature areas.
Accessibility of Bergen-Zijpe coastline 2006-2008, Province of Noord-Holland, 2006	The purpose of this program was to improve accessibility to the coastline on sunny days, together with the coastal municipalities involved. At the same time, this would reduce the nuisance factor for local residents and increase accessibility for emergency services.
Coastal Choices (in Dutch: Keuze aan de Kust), identity project for the coastal community of Noord-Holland, Province of Noord-Holland, 2010	In this multi-year coastal identity project, the province is supporting integrated development of the coastal area. The aim of the province of Noord-Holland is a safe, economically strong and spatially attractive coastline. Sufficient, differentiated space for recreation and tourism is believed extremely important. The project is in keeping with the provincial target to revitalize the seaside resorts, and served as input for the Delta program and the National Coastline Vision.
Lifestyle Atlas, Province of Noord-Holland, 2012.	The Lifestyle Atlas links demographic data to interests, wishes and needs in terms of recreation activities. The province wishes to deploy this knowledge on recreational behavior to support policymakers, entrepreneurs and non-profit organizations in the recreational sector, enabling them to become more demand oriented during spatial development and the establishment of recreational facilities. The holiday accommodation in Petten is quiet and modest in nature.
Multicolored landscape, landscape development plan, municipality of Zijpe, 2009	The landscape development plan of the municipality of Zijpe describes how the landscape quality of Zijpe can be reinforced. It is intended as a source of information and inspiration, as well as an assessment and consideration framework for developments. It is also intended to promote the integration of nature, environment, housing, recreational, zoning and water plans.
Visual quality plan for Petten coastal zone, municipality of Schagen, 2015	This visual quality plan describes the desired spatial and visual quality and level of ambition of Petten coastal zone, based on various spatial aspects. The visual quality plan sketches a beach development which provides for various types of use, resulting in a number of distinctive types of beaches, varying from sporty/active to quiet/nature. The most northerly zone (to the south of Research Location Petten), is designated as a zone for nature, rest and relaxation. With regard to any new seasonal use of the site, such as (sales) pitches and kiosks, they must be limited in size and situated close to the entrances to the beach and open areas where comparable facilities are neither present nor expected.
Structural vision for Petten Village in the Dunes, municipality of Zijpe, 2012	The structural vision is intended as a framework for spatial developments, and its primary target is to achieve cohesion between the various initiatives.
Regional vision for Sint Maartenszee, municipality of Zijpe, 2012	The regional vision sketches the spatial developments for Sint Maartenszee and the surrounding landscape in their mutual relationship. It places the developments in a larger landscape framework, while steering developments and existing initiatives. Great priority is given to quality improvement in the existing holiday parks, and expansion of the recreational options serves only to enable reorganization and diversity in the available range.

Policy plan, law, regulation	Description/ Relevance for PALLAS
Schagen Beach policy, municipality of Schagen, 2016	The Beach policy explains the game rules for use of the municipal beaches, so that various forms of beach use are afforded their own space without getting in each others' way. The Beach policy is a further refinement of the recreational identity/profiling as given in the Coastal Choices identity project, but is more limited to the relationship with ECN in terms of sustainable development.

14.1.2 Assessment framework and methodology

The Recreation and Tourism aspect concerns daytime recreational activities and recreational accommodation. Table 84 gives the assessment framework for the Recreation and Tourism aspect. An explanation of the assessment criteria and assessment method is then given.

Study area

The study area is located outside and close to Research Location Petten, particularly where construction traffic will intersect tourist/recreational routes and where the PALLAS-reactor is clearly visible.

Table 84 Assessment framework for Recreation and Tourism

Assessment criteria	Description
Recreational usage possibilities	The degree of influence on the recreational use of the Research Location Petten surroundings.
Recreational experiential value	The degree of influence on recreational activities by the spatial perception of the proposed activity.
Accessibility	The degree of influence on access roads to and parking facilities at recreational day activities.
Economic value	The degree of influence on employment and income in the area (as a result of tourist spending).
Identity	The degree of influence on the reputation and identity of Petten and Sint Maartenszee as a tourist area and the possibilities for (further) development in that sense.

Assessment framework

Recreational usage possibilities

This assessment criterion considers the degree to which the recreational use of the area around Research Location Petten is influenced. A decline in the recreational usage possibilities in the area around Research Location Petten is scored as negative. Retention of the existing possibilities is scored as neutral. An increase in the recreational usage possibilities is scored as positive.

A distinction is made between daytime recreation usage possibilities and recreational accommodation usage possibilities. The following daytime recreation activities are under consideration:

- Beach activities (sunbathing, bathing, strolling) and water sports activities (surf canoing, kite surfing). The impact assessment considers whether and if so, to what degree beach activities and water sports activities are influenced.
- Cycling and walking (in the dunes, in the polder). The impact assessment considers whether and if so, to what degree walking and cycling paths are influenced.

The following recreational accommodation possibilities are under consideration:

- Range of products for recreational accommodation (hotels, guest houses, holiday homes, campsites). The impact assessment considers whether and if so, to what degree the range of products for recreational accommodation is influenced.

Recreational experiential value

This assessment criterion calculates the degree to which recreational activities are influenced by the spatial perception of the proposed activity. The recreational experiential value follows on from the experiential value criterion determined for the Landscape and Cultural history aspect (see section 15). There, the experiential value concerns the visible characteristics of/in the landscape, as experienced by users of the area. Whereas the experiential value is considered in a general sense for the landscape and cultural history aspect, the Recreation and Tourism aspect looks specifically at the experience and perception of recreational visitors and therefore at the type of visitors and recreational areas (beach, dunes, polder, accommodation sites, etc.).

We can refer to a positive impact if the experiential value is reinforced by adding new spatial qualities for example, by hiding unattractive objects from view or rendering them more attractive. A negative impact can arise if the experiential value deteriorates as the result of occurring or changing spatial qualities.

Accessibility

This assessment criterion concerns the degree of influence on access roads to and parking facilities at recreational day activities and recreational accommodation. Does the access become better or worse? Is traffic temporarily obstructed during the construction phase? Deterioration of accessibility is scored as negative.

Economic value

This assessment criterion considers the degree of influence on employment and income in the area (as a result of tourist spending). A social costs and benefits analysis (CBA) has not been carried out, and a qualitative estimation has therefore been made of the impact.

Identity

This assessment criterion concerns the degree of influence on the reputation and identity of Petten and Sint Maartenszee as a tourist area and the possibilities for (further) development in

Table 85 Scoring of assessment on Recreation and Tourism

Score	Meaning	Explanation
++	Extremely positive impact	Great and/or permanent and/or regional improvement of the current recreational product or the recreational attractiveness in line with the policy framework.
+	Positive impact	Limited and/or local improvement of the current recreational product or the recreational attractiveness in line with the policy framework.
0	No impact	No influence or extremely limited and/or extremely temporary influence on the current and/or policy-planned recreational product or recreational attractiveness
-	Negative impact	Limited and/or local deterioration of the current and/or policy-planned recreational product or recreational attractiveness
- -	Extremely negative impact	Great and/or permanent and/or regional deterioration of the current and/or policy-planned recreational product or recreational attractiveness

that sense. The Coastal Choices policy document [33] is used as reference material here.

Relevant phases
The impact on the Recreation and Tourism aspect is described for the construction phase and operational phase. The transition phase has not been separately assessed, as the activities during this phase, in which both the HFR and PALLAS-reactor will be operational, will have no other impact than during the operational phase.

SEA assessment scale
There has been qualitative assessment of all assessment criteria for the Recreation and Tourism aspect, based on expert judgment. The following qualitative assessment scale was used for impact assessment:
An explanation is given below of the assessment criteria and their translation into the assessment system, per assessment criterion.

14.2 Current situation and autonomous development

14.2.1 Current situation

Recreational value of the area
Research Location Petten itself is a secure, closed industrial site with various partly clustered, partly individual company buildings, which jointly form a themed campus in the field of energy and nuclear research. Research Location Petten is not a recreational destination for the general public.
Research Location Petten surroundings are particularly interesting for recreational visitors and tourists because of the coastline (sea, beach, dunes) and the bulb fields. They attract both daytime recreational visitors and tourists who stay in the area at holiday parks, campsites or in hotels in and around Sint Maartenszee and Petten. There are various facilities for recreational visitors, varying from beach pavilions to (small-scale) theme parks. The beach and the bulb polder are determining factors here. The polder is of particularly great recreational value during the flowering period of the bulb fields. The surrounding dunes form a nature area which, together with the uninterrupted stretch of beach, is of recreational value all year round, though with a peak during summer months. However, there is no strongly diverse and vast dune landscape here, unlike the southern dunes (in Schoorl and Bergen). There is a clearly defined division between the beach and polder, in the form of the Westerduinweg. The coastal defenses are relatively narrow in northern Noord-Holland, and often only constitute a single row of dunes or large dike. The green hinterland has plenty of room for attractive routes and facilities which offer a valuable extra feature for the 'beach' product [34].

Recreational possibilities
Daytime recreational possibilities
The beach alongside Research Location Petten can be described as moderately intensive and quietly recreational, and the beach entrances as strongly intensive. There are relevant beach entrances at three points:
1. The official beach entrance to the north of Research Location Petten, at the Sint Maartenszee New Zuid beach pavilion.
2. The official beach entrance to the south of Research Location Petten at Petten, at the Zee en Zo beach pavilion.
3. There is an unofficial beach entrance halfway between the two. This is where the Noordzeepad is closest to the beach (approximately 120 m, greatest distance at Research Location Petten is approximately 330 m).

There are no specific recreational facilities on or near the beach, with the exception of the beach pavilions. Recreational visitors can hire sun beds from the beach pavilions. To the south of Petten is the new Hondsbossche and Pettemer coastal defense structure, a dune and beach landscape.
In terms of water sports activities, Petten has a surfing school which offers lessons in wave surfing, body boarding and paddle boarding. A separate zone is designated for these activities during the bathing season, but they are allowed freely along the entire beach out of season. Sint Maartenszee is also a designated surfing location where people can wave surf and kite surf, though there is no separate zone for this purpose. There is however an activity zone designated for kite buggies on the beach. The use of kite buggies is limited to the activity

zones during the bathing season, but they too are allowed freely along the entire beach out of season. There is a general prohibition on water skiing. Recreational visitors can hire sun beds from the beach pavilions.
The coastal recreation in the area is influenced both spatially and in terms of tranquility, by the Royal Marines firing range between Research Location Petten and the beach. This site is used for (target) firing tests and testing small explosive components of weaponry systems.
Target firing tests are held on maximum 20 days per year. The number of shots fired per year is limited for other weapons and explosive devices, and varies per weapon/explosive device. Firing tests are held at least 19 days per year during the daytime period (9 hours to 19 hours). they may also take place in the evening period (19 hours to 21 hours) occasionally (when tests are delayed, on no more than 13 days per year).

Firing tests are not held during the holiday period from 1 June to 1 September, unless dictated by extreme situations. All shots are fired in the direction of the North Sea. Red flags in the dune and on the beach indicate the unsafe area. Outside the firing test season, the location is used by Maartenszee Lifeboat Association [35].
The following walking and cycling routes can be found here:

- The Noordzeeroute, also known as the Noordzeepad and part of the International North Sea Cycle Route. This is a long distance walking/cycling route around the North Sea, running from Scotland via England, Belgium, the Netherlands, Germany, Denmark and Sweden to Norway. In the Netherlands, the walking route follows the E9 Walking route and the Hollands Kustpad long-distance walking route (LAW 5-2). The Westerduinweg is the cycling route for the Noordzeepad.
- The Water Authority for Northern Holland has developed the GPS cycling route titled 'Sea, dune, dike and polder' (18 km'. This route runs via the new cycle path along the Hondsbossche and Pettemer coastal defense structure to the hinterland.
- Existing routes in the network of cycle paths are: Petten, Camperduin and Groet cycle route (37.2 km), Petten and Schagen cycle route (29.8 km), Petten, Sint Maartenszee and Groet cycle route (21.3 km).
- Besides these routes, the Top of Holland tourist information center also offers four day trips, walking or cycling routes in 'Zijpe Landscape' (17-25 km). The route on day 1 runs from Petten via Sint Maartenszee to Burgerbrug.

Recreational accommodation possibilities
A large number of recreational accommodation sites can be found in the direct but also wider vicinity of Research Location Petten, which serve as a 'home' base for coastal recreational visitors. When walking around the area however, it is hard to imagine that there are approximately 1200 holiday homes and various campsites housing Dutch and German visitors. People visiting this area come here for the tranquility, the dike, the beach or the countryside. The range of accommodation therefore only comprises a number of enterprising campsites and holiday parks (according to Identity of Coastal Community). There are also additional recreational facilities such as the

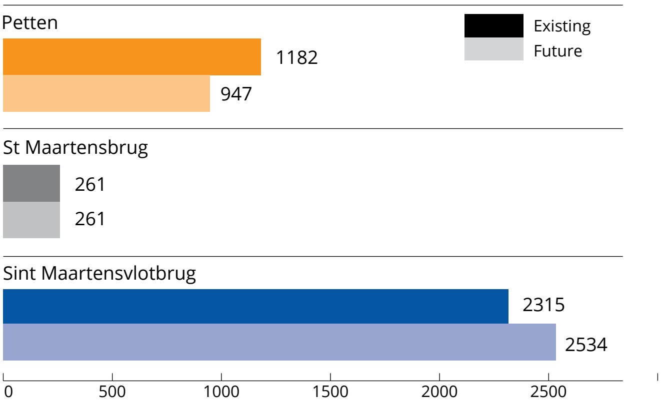

Figure 42 Supply of recreational accommodation per community [36]

(small-scale) Goudvis theme park with its outdoor play area and indoor playground, along with a number of bicycle rental companies. Figure 42 gives an overview of the recreational accommodation possibilities, hotels, guest houses, campsites and holiday parks found close to Research Location Petten (Petten/Sint Maartenszee).

Recreational experiential value
Recreational visitors can experience the site in various ways: from the polder, dune area, from the beach and from the sea. Important aspects are the heights of the buildings at Research Location Petten and the surrounding dunes. Most of the buildings are a similar height to the higher dune crests, A number of buildings are higher than the highest dune crests, including the dome of the current HFR and the chimney at the HFR. The concrete base of the wind turbine is unique in that it is located on top of a dune, making it very visible (Figure 43).
The height of the HFR and the various chimneys makes them easily visible from various viewpoints in the surrounding area. The sight lines given in Figure show that the HFR is more visible from one or two viewpoints than from elsewhere, due to it being less shielded as a result of low-lying areas in the dunes. In the polder, the wind turbines are sometimes more spatially dominant than the HFR.

Figure 43 Photo of view to the south with base of wind turbine – by Arcadis 2007

There is limited visibility of Research Location Petten from the coast, with the occasional building sometimes protruding just above the dunes. Research Location Petten is however very visible from both beach entrances and from the recreational cycle path through the dunes. The visibility of the buildings on the polder side depends very much on the combination of building height, dune height and viewpoint. Closer to the site, the view of many of the buildings, including the HFR, is often limited, as it becomes difficult to "look over the dune". The viewing angle is different at a greater distance, allowing a better look. When viewed from a great distance, it merges as an object with the other objects on the horizon. This effect is more

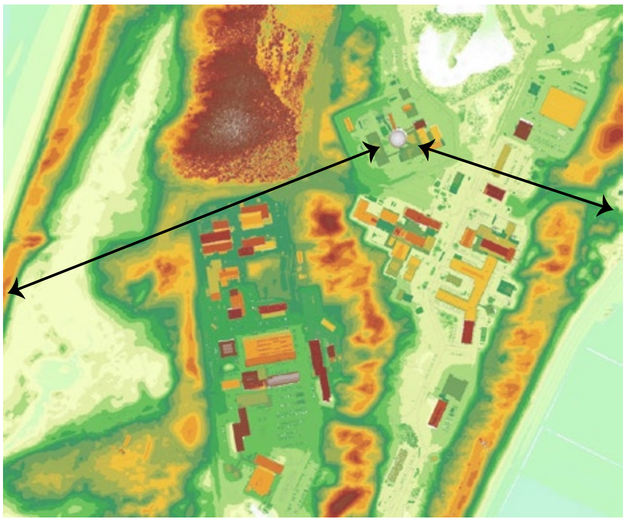

Figure 44 Altitude map of current site situation with views (arrows)

or less likely to occur depending on the weather / clarity. The openness of the polder landscape gives views of the HFR in an extremely large area.
Industrial sites are experienced to be relatively disturbing elements in the landscape [37], and recreational visitors/ tourists certainly do not expect to discover an industrial site in a natural environment such as a dune area. In the case of Research Location Petten, the nuclear dimension is an added factor. Despite the site varying in terms of its visibility, each component is more likely to be perceived to be disturbing and therefore negative.

Accessibility
Accessibility by bicycle and on foot is explained in "daytime recreational possibilities". Accessibility of Research Location Petten by car is described in the Traffic section (see Section 17). The same routes are used for Recreation and Tourism around Petten and Sint Maartenszee. Figure 45 shows the access roads.

Economic value
Approximately 905,000 overnight stays are estimated to take place annually in the municipality of Schagen. In 2011, Schagen was home to approximately 400 tourist-based enterprises. In that same year, there were 1290 jobs in the tourism and recreation sector. Of all the jobs in the municipality, 5 to 6% is in the leisure economy [38] [39]. These percentages have remained stable between 2011 and 2015 [38]. The tourist sector is more dominant in Petten and Sint Maartenszee than in the municipality of Schagen, due to the former two being located on the seaside.

Figure 45 Access to Research Location Petten

Identity
The identity has been established on the basis of the Coastal Choices policy document [33]. The profiles given in this policy document for Sint Maartenszee and Petten are relevant for this report for the benefit of the SEA. Individual profiles have been established for the two communities, though they are both also part of the 'Wadden-polder landscape' geographical cluster. The future challenge in this cluster is to create diversity. Petten is clustered together with Camperduin and Hargen aan Zee, the central theme being the battle with the water, and coastline constructions.

Profile of Sint Maartenszee
Sint Maartenszee is characterized as a small, somewhat unobtrusive seaside resort which is particularly visited by families with young children and by pensioners. They return each year to enjoy the tranquility, beach and countryside. There is also a large percentage of German visitors. The strength of Sint Maartenszee's identity lies in its simplicity – tranquility, spaciousness, the beach and clean air. Self-sufficiency, independence, far from the rat race, are profile characteristics of Sint Maartenszee. Beautiful panoramic views (beach, dunes, polder) are particularly appreciated. However, the recreational profile of Sint Maartenszee is becoming less and less distinctive versus other coastal resorts in the vicinity. Sint Maartenszee is not a village and therefore has no village center. It is an area where you stay temporarily, and comprises a number of enclaves, holiday parks facing away from the road. Visitors prefer not to see the recreational activities (nor other built-up areas, such as Research Location Petten), but the landscape and countryside are all the more popular. Besides this surrounding area, there is no mutual connection between the holiday parks.
While the total range of activities appears quite substantial, it is however extremely seasonal. Weekend rentals are sometimes possible, but it is not financially viable to organize activities all year round. With a view to the trend of guests becoming more critical and looking for an experience or holiday themes, it is questionable whether this can be adequately offered by the current identity of the area, as a bundle of individual enclaves. The surrounding seaside resorts make optimum use of the local countryside thanks to good accessibility. There is an extensive network of cycle paths in Sint Maartenszee and the vicinity, but the walking routes currently only run from the holiday parks to the sea. The lack of walking paths in the polder means that there is also little opportunity to take a round trip. The poor accessibility of dunes, polder and nature areas from Sint Maartenszee is a weakness.

Profile of Petten
Petten is small, located on a monumental dike and has a large new dune and beach on its doorstep. Everything is available on a small scale in Petten. Simplicity and modesty are profile characteristics of Petten: no busy tourism, massive events or extensive culinary facilities. The tourist facilities in Petten mainly comprise a number of enterprising campsites. Petten visitors generally come here because of the dike or the countryside, rather than the village. These same factors also attract 'less affluent German visitors' due to the affordability of the village. The coastal defense structure offers an opportunity for Petten to take advantage of its Coastal Constructions identity. Research Location Petten should also be seen as an opportunity, and the challenge lies in introducing the energy know-how and products to the outside world. It may then become an exciting and therefore distinctive visit for tourists, instead of having a scary undertone. In the beach policy, this is further qualified into a sustainability experience, linked to ECN.

14.2.2 Autonomous development
The following autonomous developments are relevant for Recreation and Tourism:

- Petten beach huts: Fifty seasonal beach constructions (beach huts) are to be built on the North Sea beach at Petten.
- Petten sports pavilion: The south beach in Petten will have a pavilion aimed at (water) sports. This pavilion is part of the total tourist impulse offered by the new beach for Petten. The sports pavilion will offer various sports, the main ones being kite surfing, blow-carting, beach sports days for schools and various group lessons, such as a bootcamp and cross-fit training sessions on the beach.
- Bohemian Estate Sint Maartenszee: The Bohemian Estate project is to be built approximately 200 m from the base of the dunes in Sint Maartenszee. This project comprises a hotel offering 121 rooms, 71 holiday apartments, a parking basement and a large patio area. The Bohemian Estate is situated on the Zeeweg, between Petten and Callantsoog in the municipality of Schagen.
- Former hotel opposite De Goudvis theme park: The vacant, former Sint Maartenszee hotel opposite De Goudvis is to make room for holiday apartments. Fourteen apartments and five penthouses are planned here.
- Hondsbossche and Pettemer coastal defense structure: There was no insight into the autonomous developments such as increased tourism or daytime recreation as a result of completion of the Hondsbossche and Pettermer coastal defense structure, in 2015. This development has therefore not been included in the impact assessment.
- Artificial dunes of Sint Maartenszee: The Dutch Labor Party fraction of the municipality of Schagen proposed that artificial dunes be created in order to hide the Research Location Petten buildings from view. However, there proved to be a lack of political support for such plans in the municipal executive of Schagen, in August 2016. This development has therefore not been included in the impact assessment.
- Wind farms at sea: Permits have already been granted and zones designated for wind energy along the coastline. Depending on the design details, this may influence the degree of unspoiled views of the sea. The impact may be relatively limited for the planning area, as the zones close to shore are somewhat more southerly while the zones opposite the planning area are further offshore.
- There are plans to extend the range of recreational units in Sint Maartenszee, while the range will decline in Petten (see Figure 42).

14.3 Environmental impact

14.3.1 Impact description

Any impact on the Recreation and Tourism aspect will take place during the construction phase and operational phase. The transition and operational phases have no differentiating impact in terms of the Recreation and Tourism aspect and are therefore not separately described.

14.3.1.1 Construction phase

Recreational usage possibilities

During the construction phase, the LDA in the polder will have a limited impact on the recreational usage possibilities of the area. The work traffic for Research Location Petten will cross the (recreational) cycle path along the dunes, which may result in traffic nuisance. There is limited noise impact. The installation work on and near the beach for cooling variants K1 and K2 is temporary but will make it extremely difficult to use the beach at least part of the time during that period. This is extremely undesirable in the bathing season. All construction height and cooling variants will result in a negative impact on the recreational usage possibilities.

Recreational experiential value

During the construction phase, all variants will have impact on the visibility of construction work at Research Location Petten, and also at the LDA in the open polder. Both will be visible due to the relative openness of the polder landscape. The disturbance caused by the LDA will depend very much on the design of this site, but will be limited to the period of construction.

Accessibility

During the construction phase, traffic will increase on the access roads leading to recreational facilities. The number of traffic movements per 24 hours will be limited during the construction phase however, and will not result in greatly increased intensity (see the Traffic aspect, Section 17). The roads in the planning area (N502, N503 and N9) have plenty of residual capacity to absorb and process a minor increase in (construction) traffic without negative consequences for the traffic flow.
No access roads leading to recreational facilities will be closed off during the construction phase and the number of parking spaces for visitors will not change as a result of the construction work.

Economic value

The impact on the economic value is difficult to predict, as comparable cases are not available or because there has been no visualization of the impact on recreation and tourism. During the construction phase, both positive and negative impacts can potentially occur. Many temporary employees will be working to construct the PALLAS-reactor, and a percentage of this workforce will stay in the surrounding area during the construction period. This will allow otherwise vacant holiday accommodation (especially out of season) to be rented out, while the catering industry and local businesses can also benefit from this temporary workforce.

A potentially negative impact is that tourists may avoid the area during the construction phase, due to the nuisance caused. Noise and visual nuisance may deter tourists.

Identity

During the construction phase, the construction work and certainly also the LDA will be detrimental to the profile of Sint Maartenszee. Besides the construction work at Research Location Petten, the installation of cooling water pipelines in the polder, beach and dunes in cooling variant K1 may be perceived to be disturbing, as may the installation of cooling water pipelines in the beach and dunes in cooling variant K2. After all, the identity here particularly concerns tranquility and the experience of landscape and natural qualities.

The work with regard to cooling variant K3 takes place at Research Location Petten and is therefore insignificant versus the impact of construction height variants B1, B2 and B3. There will be no impact on Petten's profile.

14.3.1.2 Transition phase and operating phase

Recreational usage possibilities

The building height variants will have no impact on the recreational usage possibilities during the transition and operational phases.
Cooling variant K1 is expected to have very little impact on the recreational usage possibilities in the area, as there will be no disturbance of recreation once the cooling water pipelines are in place. In cooling variant K2, the platform required for the inlet station will have a negative impact on the recreational usage value of the beach, both physically and in terms of attractiveness. Whereas people could previously quite literally turn their backs on Research Location Petten, the platform is now a permanent reminder of the installations. Due to its location at a relatively short distance from the coast, the platform is also potentially a hazardous object for (kite) surfers and other water sports enthusiasts, for example. This only applies outside the bathing season, when water sports are less popular than during the bathing season of course. Cooling variant K3 will result in increased noise at many of the holiday parks and campsites in Sint Maartenszee and at the Corfwater campsite in Petten (see Noise aspect, Section 11).

Recreational experiential value

During the transition and operational phases, the new PALLAS-reactor buildings will be more or less visible from the surrounding area. The impact will be greatest when the bulb fields are flowering, as most recreational visitors/tourists then visit the area specifically to see them.
The visualization study conducted within the scope of the Landscape and Cultural history aspect (included in Appendix F10) showed the construction height variant B3 to be a dominantly large volume with much more of an explicit presence than the current HFR, when viewed from virtually all locations. This is not so much the case for construction height variant B2. From many locations, the new construction is in line with the current building. However, it is more visible than

the current HFR from a number of important viewpoints in the polder. This is mainly due to the scope (height in combination with width) of the new construction volume. Construction height variant B1 is much lower and cannot be seen from many locations. The building volume is completely in line with the existing building volumes.
The height of the cooling units will not really have any impact, regardless of the choice of variant. The compensation produced will have impact, however. The height of the cooling units for cooling variant K3 (14.5 m + NAP[36]) is comparable with the average height of the row of dunes between the installation and the polder (approximately 11 – 14 m + NAP). It is therefore hard to see them "over the dune" from close by, while the limited height difference versus the dunes also makes the cooling units indistinctive from a greater distance. The cooling units are explicitly lower than many of the surrounding buildings. In terms of disturbance, the cooling installation is not expected to be regarded any differently to the standard buildings.
Cooling variant K1 mainly concerns pipelines. This will not be visible for recreational visitors, though there will be a relatively small pumping station on the Noordhollandsch Kanaal. This is outside the main recreational/tourist area and will therefore have little impact on the recreational experiential value. Cooling variant K2 which uses water from the North Sea, will have a strong impact on the experiential value, due to the platform of the extraction point being visible from the beach. This has a negative impact on the natural and unspoiled image of the area. For recreational visitors at the seaside, it represents a confrontation with Research Location Petten and PALLAS which are otherwise largely concealed behind the dunes.

Two aspects are important for the cooling variant which uses cooling units based on water evaporation (cooling variant K3):

- The visibility/perception of the installation itself.
- The visibility/perception of condensation (water vapor as a result of evaporation).

Condensation may result in an association with smoke, which in turn has a negative tone because it gives a sense of harmful substances being emitted. This will be particularly negative in the case of a nuclear installation, despite this only concerning water vapor in reality. Condensation can be formed during 50% of the time per year, with concentration during the winter period[37] . Approximately 75% of the time per year when condensation can be formed, will be in the winter period. It is also slightly more common in the nighttime than in the daytime. This is relevant in terms of the perception of condensation, as the largest numbers of recreational visitors in the area who will experience the condensation, will be during the summer period and daytime. Parallel to the row of dunes, the conversation will be as wide as the installation itself (approximately 50 m[38]). In height, it will be approximately 10 m to 15 m and therefore 25 m to 30 m + NAP. It is difficult to predict a precise maximum or average height, as this depends greatly on local weather conditions. The condensation is only visible from the polder.

Accessibility
The number of traffic movements will not increase during the operational phase. As is apparent in the current situation, there is plenty of road capacity to absorb and process the traffic movements during the operational phase.

Economic value
No impact is expected during the operational phase. The current installation will then have been replaced by the PALLAS-reactor. The situation will be stable again, and tourists and recreational visitors will notice little difference versus the current situation[39].

Identity
The operational phase will have a contradictory impact on Petten and Sint Maartenszee. Based on the Petten profile, the Research Location Petten activities represent an opportunity. The construction of the new PALLAS-reactor, but also the pumping station of cooling variant K1, may even represent a positive development. The nuclear activities at Research Location Petten can be seen as an opportunity to reinforce the recreational identity of Petten, particularly by linking the sustainability theme in relation to ECN.
This is not the case for Sint Maartenszee. Even more than in the construction phase, the operational phase will represent long-term damage to the perception of the landscape and natural qualities due to new and non-indigenous industrial objects. This certainly also applies to the sea platform for cooling variant K2 and the condensation formed by cooling variant K3.

14.3.2 Impact assessment

Construction phase
Table 86 gives the impact assessment for the Recreation and Tourism aspect, during the construction phase. The assessment is then explained, per assessment criterion.

Recreational usage possibilities
There is limited negative impact on the recreational usage possibilities during this phase. The impact score is therefore negative (-).

Recreational experiential value
The impact with regard to the experiential value of the construction height variants is limited to the presence of the LDA in the polder. This is a temporary impact of limited scope in an area of relatively limited value, partly because the area is already negatively influenced by the presence of wind turbines and the visible Research Location Petten. There is however some degree of impact, which results in a negative score (-). There is no differentiating impact between the variants. In cooling variants K1 and K2, the installation of pipelines in the dunes and beach will negatively influence the beach experience. In K2, the construction of the inlet point platform is an added factor. However, this requires relatively short-term work, therefore with a limited negative impact (-). K3 does not

36 According to the Design framework [19], the maximum height of a cooling unit is 11 m. The cooling units are at 3.5 m + NAP.
37 See the Background report on Landscape, Cultural history and Spatial quality
38 According to the Design framework [19], a single cooling unit is 12.5 m wide. There are four of these units at a short distance from each other.
39 The impact assessment does not take into consideration whether or not the HFR is in operation in the reference situation.

Table 86 Impact assessment for Recreation and Tourism, construction phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Influencing of recreational usage possibilities	-	-	-	-	-	-
Influencing of recreational experiential value	-	-	-	-	-	0
Accessibility	0	0	0	0	0	0
Economic value	0	0	0	0	0	0
Identity	-	-	-	-	-	0

have any clearly significant negative impact on the experiential value during the construction phase.

Accessibility
The number of traffic movements will increase slightly, though this will not have negative consequences for traffic flow or accessibility. The impact is scored as neutral (0).

Economic value
Potentially, there are positive and negative impacts, but the principle is that they counterbalance each other. The impact is therefore scored as neutral (0).

Identity
The impact mainly concerns the profile of Sint Maartenszee. However, any negative impact with regard to tranquility and perception of the landscape and natural values will be relatively limited and temporary. The impact is therefore scored as negative (-) for all construction height and cooling variants, with the exception of K3 which is scored as neutral (0). After all, the work with regard to cooling variant K3 takes place at Research Location Petten and is therefore insignificant versus the impact of construction height variants B1, B2 and B3. This does not result in any change in the Petten profile.

Transition phase and operating phase
Table 87 gives the impact assessment for the Recreation and Tourism aspect, during the transition and operational phases. The assessment is then explained, per assessment criterion.

Recreational usage possibilities
The nuclear island, and consequently all construction height variants, hardly has any impact on the recreational usage possibilities during this phase. The same applies to cooling variant K1. The impact score for these variants is therefore neutral (0). In variant K2, the platform required for the inlet point will have a negative impact on recreation, both in terms of attractiveness of the area for coastal recreation, and the platform potentially being a hazardous object for (kite) surfers and other water sports enthusiasts. The area remains usable in both cases however, so that the impact will eventually be limited and is therefore assessed as negative (-). Cooling variant K3 will result in limited noise impact at a number of campsites and holiday parks. This cooling variant is therefore scored as negative (-).

Recreational experiential value
With regard to the experiential value, there is a clear difference in impact between the construction height variants. There is no significant difference between construction height variant B1 and the reference situation. The impact score is therefore neutral (0). Construction height variant B3 results in a large and dominant volume which will have a strongly negative recreational experiential value even at a great distance, also due to it being associated with nuclear activities. When considering this volume, the color or design will have little or no effect on a more or less positive perception. Due to the great impact, this is scored as extremely negative (- -). Construction height variant B2 is between these two variants.

Table 87 Impact assessment on Recreation and Tourism, transition and operational phases

Assessment criterion	B1	B2	B3	K1	K2	K3
Transition phase and operating phase						
Influencing of recreational usage possibilities	0	0	0	0	-	-
Influencing of recreational experiential value	0	-	- -	0	- -	-
Accessibility	0	0	0	0	0	0
Economic value	0	0	0	0	0	0
Identity	0	-	-	0	-	-

It is certainly more visible than variant B1 and therefore more negative, but certainly not to the same degree as variant B3, in that it is visible but not dominant. Variant B2 is therefore scored as negative (-).

Cooling variant K1 is not expected to have any significant impact with regard to the recreational experiential value. It is therefore scored as neutral (0). Variant K2 will have a strongly negative effect on the experiential value, due to the platform being extremely visible in an open, virtually unspoilt natural landscape in front of the inlet point, clearly referring to the nuclear activities, which are otherwise concealed behind the dunes. Despite the fact that the horizon will not remain unspoiled in the future due to the autonomous development of wind farms at sea, this installation located so close to the coast is much more visible and dominant. It can only be scored as extremely negative (- -), especially considering the great value attributed to the unspoiled, empty, vast, natural coastline in the various policy documents, whereby violation of part of the coastline is also regarded to be violation of unity of the entire coastline. The condensation formed by variant K3 will not be particularly visible to recreational visitors and tourists, as there is the least chance of condensation being formed during the summer period which is so relevant for recreation and tourism. The scope of condensation formed is comparable with the impact of construction height variant B2. Unlike the building, this is a dynamic situation which depends very much on the weather conditions.
The compensation will have less impact than the construction height variant B2, though it is of such a scope and frequency but it must however be scored as negative (-). The combination of construction height variants and this cooling variant is relevant. In B1, the formation of condensation will be the representative element for PALLAS in the surrounding area. The formation of condensation is therefore extremely relevant and its impact weighed more strongly. B2 will result in a visibly wide "block" on the horizon. Its length makes it less of a point-based element and more of a line-based element, therefore more in keeping with the line of the dunes located between the installation and the polder. B3 will always be more conspicuous than the condensation formed. The impact of the formation of condensation is therefore extremely insignificant versus the great negative impact of B3. The impact of condensation formed in K3 remains negative in all cases (-).

Accessibility
The number of traffic movements will increase slightly during the operational phase, but this has no negative consequences for traffic flow and accessibility. The impact is therefore scored as neutral (0).

Economic value
No impact is expected during the operational phase. The assessment is therefore neutral (0).

Identity
There will be a contradictory impact on Sint Maartenszee and Petten. Neither construction height variant B1 nor cooling variant K1 will have any impact on the identity, and they are therefore scored as neutral (0).
However, the negative impact on the perception of landscape and nature at Sint Maartenszee is considered more important than the (possible) positive impact at Petten. In Petten, it is still an opportunity which needs to be utilized and is therefore not yet an integral part of the recreational identity of Petten, see paragraph 14.3.1. The impact on Sint Maartenszee more or less resembles the criterion for the recreational experiential value. However, even in the case of construction height variant B3, it cannot be said that the complete identity of Sint Maartenszee has been irreversibly damaged. It will indeed be a serious violation, more so than construction height variant B2, but the impact is scored as negative (-) for both variants. The visible impact of K2 and K3 will also contribute negatively to the identity based on tranquility, landscape and natural values without visibly disturbing activities. Once again, there is no irreversible impact on the identity. Here too, the impact is therefore scored as negative (-).

14.4 Mitigating measures

Mitigating measures
The impact assessment has identified a negative impact for a number of criteria. However, there are still possibilities for optimization in terms of detailing and incorporation, even when the score was already neutral. The following mitigating measures are proposed:

LDA
When designing the LDA located outside of Research Location Petten, measures can be taken to limit the negative image of the site, for example by treating the site as a (farm)yard and using (temporary) landscape planting around the boundary. Storage facilities and buildings should be kept as low as possible. The construction activities will however continue to form a nuisance, and although these design measures will greatly improve the recreational experience, the impact score will remain negative.

The nuclear island
- When detailing the design of the nuclear island, the lower and more compact the buildings are, the better they will score in terms of experiential value. It also helps if the buildings are in keeping with the existing buildings wherever possible, in terms of scope, shape and orientation. The architectonic detailing strongly determines the result. The more inconspicuous (in color and shape), the better. This need not contradict the quality of the construction, as a well-designed building is always more easily incorporated in its context. The new construction will also be more readily accepted if it is not immediately associated with a nuclear installation. The PALLAS Visual quality plan already provides a guideline for most of the above recommendations. An optimal architectonic design will certainly result

in a great improvement, but not to the extent that this will change the impact scores for experiential value, due to these being mainly linked to the visibility of the building mass.
- Besides optimization of the buildings, the surrounding area can also be adapted in order to keep the buildings out of sight wherever possible, for example by raising the dunes at strategic spots and possibly even adding natural vegetation. This adaptation may result in the B2 score for the recreational experiential value improving to neutral, due to the nuclear island itself being largely hidden from view.

Cooling variants
- For K1 and K2, the construction work in the coastal zone must take place outside the bathing season, as the nuisance factor will then have the least possible impact. It cannot be estimated beforehand whether the nuisance factor can be reduced to such an extent that it no longer has any significant impact on the recreational experiential and usage value, which might even result in a neutral impact score.
- Should a sea platform be required for the inlet point, a great deal of attention must be paid to its location (distance from the coast, etc.) and its architectonic design, with a view to the recreational perception and therefore also the recreational usage value of the coastal zone. The object must be as inconspicuous as possible. The impact score could become neutral if it is constructed underwater or at a great distance from the coast, as there will then be no visible experience from the beach. While optimal architectonic design, limitation of the visibility of the platform, also by limiting the illumination of the platform, and other such measures represent important improvements, they cannot deter from the fact that a (virtually) unspoiled situation is negatively influenced in an undesirable manner. The impact score therefore remains extremely negative. In terms of usage value on the other hand, the inlet platform should be rendered extremely visible and well lit, in order to safeguard the safety of water sports activities. Although this would improve the situation, the impact score remains negative due to the platform remaining an obstacle.
- When opting for a cooling variant with cooling units (K3), the installation could be optimized to such an extent that the condensation formed is as small as possible (lower than the dunes) and as infrequent as possible. In the optimum situation, there would be no condensation. A dry cooling system would then need to be used, instead of the current wet cooling system. However, a dry cooling system does not work if the outdoor air temperature is too high. A hybrid cooling system which combines the two, will never result in compensation being formed, as the temperatures at which wet cooling is applied, exceed the target value of 11 ºC. If no condensation is formed, the score for the recreational experiential value can possibly be adjusted to neutral, as long as the noise levels are also limited. Think in terms of the deployment of low-noise cooling units or condenser units and shielding measures.

Impact assessment following mitigating measures
To summarize the above, mitigating measures may result in the impact assessment being adjusted for the following points:
- Adaptation of the surrounding area can improve the incorporation of the nuclear island for construction height variant B2, to such an extent that this results in a neutral (0) score instead of a negative score (-) for the 'impact on recreational experiential value' criterion during the operational phase.
- Limitation of condensation and the noise level in cooling variant K3 will result in a neutral (0) score instead of a negative (-) score for the 'impact on recreational usage possibilities' and 'impact on recreational experiential value' during the operational phase.

14.5 Gaps in knowledge

The following knowledge gaps have been identified during the study of the impact of the PALLAS-reactor on recreation and tourism.
- It is unclear whether tourists will avoid the area because of the work conducted during the construction phase and whether these tourists will return once the construction phase is complete. This possible impact has therefore not been taken into account in the impact assessment for the economic value during the operational phase.
- At this stage of the plan formation, the precise conditions for and scope of condensation formed cannot be given. The permit application will require further detailing regarding the conditions and duration of condensation based on various weather conditions (temperature, humidity, wind, light/dark, etc.)

15 Landscape and cultural history

The following description of the Landscape and Cultural history aspect is based on the Landscape and Cultural history background report (see Appendix F10).

15.1 Assessment framework

15.1.1 Policy framework

Table 88 summarizes the relevant policy and relevant legislation and regulations for the Landscape and Cultural history aspect, along with an indication of their relevance for the project. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Landscape, Cultural history and Spatial quality.

Table 88 Policy, legislation and regulations on Landscape and Cultural history

Policy plan, law, regulation	Description/ Relevance for PALLAS
European Landscape Convention (ELC), European treaty, 2005	This treaty takes an integral approach to the European landscape, its main aim being to promote the protection, management and planning of all landscapes and to organize European cooperation on landscape issues. The degree to which the Netherlands complies with the ELC depends on the manner in which landscape issues are supported in policy at the various levels of government.
Heritage Act, Dutch government, 2016	The Dutch Heritage Act harmonizes existing legislation and regulations to form a single Heritage Act for the management and conservation of cultural heritage. Until the Dutch Environmental Planning Act comes into force, those articles of the Dutch Monuments Act 1988 which are not included in the Heritage Act (such as rules regarding environmental permits and zoning plans) will continue to apply.
Monuments Act, Dutch government, 1988	The Monuments Act regulates the protection of buildings (national or municipal monuments), of heritage towns or villages and of objects / combinations listed on the (provisional) UNESCO World Heritage list. Archaeological monuments are also designated at the national level. Finally, municipal authorities are entitled to formulate a monuments regulation as the basis for designation of municipal archaeological monuments.
Dutch National Policy Strategy for Infrastructure and Spatial Planning (SVIR), Ministry of Infrastructure and Environment, 2012	The national policy for landscape issues has been decentralized, for application by the provincial authorities, due to the national government wishing to afford provincial authorities more freedom in the urbanization/landscape balance, and therefore for regional customization. The National Water plan states that unimpeded views of the horizon from the coast to the sea, remains a spatial quality of national significance.
Dutch National Structural Vision on Wind energy at Sea, Ministry of Infrastructure and Environment and Ministry of Economic Affairs, 2014	In the National Structural Vision on Wind energy at Sea of September 2014, the cabinet designated areas for the construction of offshore wind turbine farms. Both the IJmuiden Ver and Hollandse Kust zones lie within the scope of influence of the planning area and may in time influence the degree of unspoiled views at sea.
National Coastline Vision, Delta Program Coast, 2013	The Dutch National Coastal Vision gives an integrated perspective of future-proof development scenarios for the Dutch coastline. It details the 5 development principles of the National Coastline Framework, whereby principles 3 (natural dynamics) and 4 (spatial quality) are relevant for this aspect. In accordance with the National Coast Vision, each development must be aimed at conservation or improvement of the (spatial) quality and identity of the living environment (housing, beaches, recreational areas), greater quality of mutually connected nature areas and greater ecological and landscape qualities.
Structural Vision for Noord-Holland 2040, Province of Noord-Holland, 2015	The Structural Vision for Noord-Holland describes the spatial policy of the province and defines the provincial interests: climate resilience, spatial quality and sustainable land use. These three interests are taken into consideration in any spatial planning decisions by the province of Noord-Holland. The province applies the following principles for its planning area and general region. • Dunes: priority for safety and nature with room for recreation/tourism. • Zijpe Polder: Large-scale agriculture and bulb growing concentration.
Guideline for Landscape and Cultural history, Province of Noord-Holland, 2010	The guideline for Landscape and Cultural history contains the provincial vision on spatial quality and the core qualities of the various landscapes and villages of Noord-Holland. This guideline describes the core qualities of the landscape for the various types of landscapes distinguished. It names provincially significant structuring elements, which include: • Defense networks (incl. the Atlantic Wall). • Historic dikes (Westfriese Omringdijk). • Canals (Noordhollandsch Kanaal).
Policy framework for Landscape and Cultural history, Province of Noord-Holland, 2010	The policy framework for Landscape and Cultural history is a further detailing of the policy rules established in the regional plans, with regard to the landscape, cultural history and spatial quality. The detailing for the 'Kop van Noord-Holland' region is relevant for the planning area and surrounding area, characterized by the sharp contrast between dunes and polder. Together with the series of dams, this is relevant in order to retain recognizability of the hydraulic engineering history.

Policy plan, law, regulation	Description/ Relevance for PALLAS
Provincial Environmental Decree Noord-Holland, Province of Noord-Holland, final amendment (section 9) 2015	IThe Provincial Environmental Decree names geological monuments. This concerns areas whose ground composition and/or topography is so special that they are designated as having protected status. While Research Location Petten itself is not designated a geological monument, the dune system around the site is a monument. An exemption is required for any activities which might damage the geological values of such areas with monument status.
Strategic Coastline Agenda, Province of Noord-Holland, 2012	The Agenda states that there must be reinforcement of the identity of the coast as a whole and the landscape relationship between the diverse nature areas and coastal community. Another aim is to achieve zoning in which qualities are intensified, such as the intensification of "activity" in the recreational zones and where possible also the intensification of "tranquility" in nature areas.
Multicolored landscape, landscape development plan, municipality of Zijpe, 2009 (now part of the spatial policy of Municipality of Schagen)	The landscape development plan of the municipality of Zijpe describes how the landscape quality of Zijpe can be reinforced. It is intended as a source of information and inspiration, as well as an assessment and consideration framework for developments. It is also intended to promote the integration of nature, environment, housing, recreational, zoning and water plans.
Zoning plan for rural Zijpe region, Municipality of Schagen, 2014	In the zoning plan for rural Zijpe, Research Location Petten is designated an Exceptional industrial estate. This means that the site is intended only for companies and organizations involved in energy and radiation research and in the resultant production of goods and services including any accessory facilities. Research Location Petten is an extra value zone with regard to geological values. An exemption procedure is required for those activities which may negatively influence those geological values.
Visual quality plan for Petten coastal zone, Municipality of Schagen, 2015	This visual quality plan describes the desired spatial and visual quality and level of ambition of Petten coastal zone, based on various spatial aspects. The visual quality plan sketches a beach development which provides for various types of use, resulting in a number of distinctive types of beaches, varying from sporty/active to quiet/nature.
Guide to spatial quality, Municipality of Schagen, 2016	Research Location Petten is covered by the planning regime working field. This is a regular planning level, for which general and regionally oriented planning criteria apply. Regular constructions are assessed by a delegated member on behalf of the Environmental quality adviser.

15.1.2 Assessment framework and methodology

The Landscape and Cultural history aspect is assessed according to the assessment framework given in Table 89, followed by an explanation of the assessment scale per criterion.

Study area

The study area for Landscape and Cultural history is largely determined by the 11 visualized viewpoints, which were chosen as representatively as possible in order to give optimal insight into a possible future situation, to clearly determine the spatial impact from various points (dunes, polder landscape, etc.), see Figure 46.

Assessment framework

The Landscape and Cultural history aspect is quantitatively

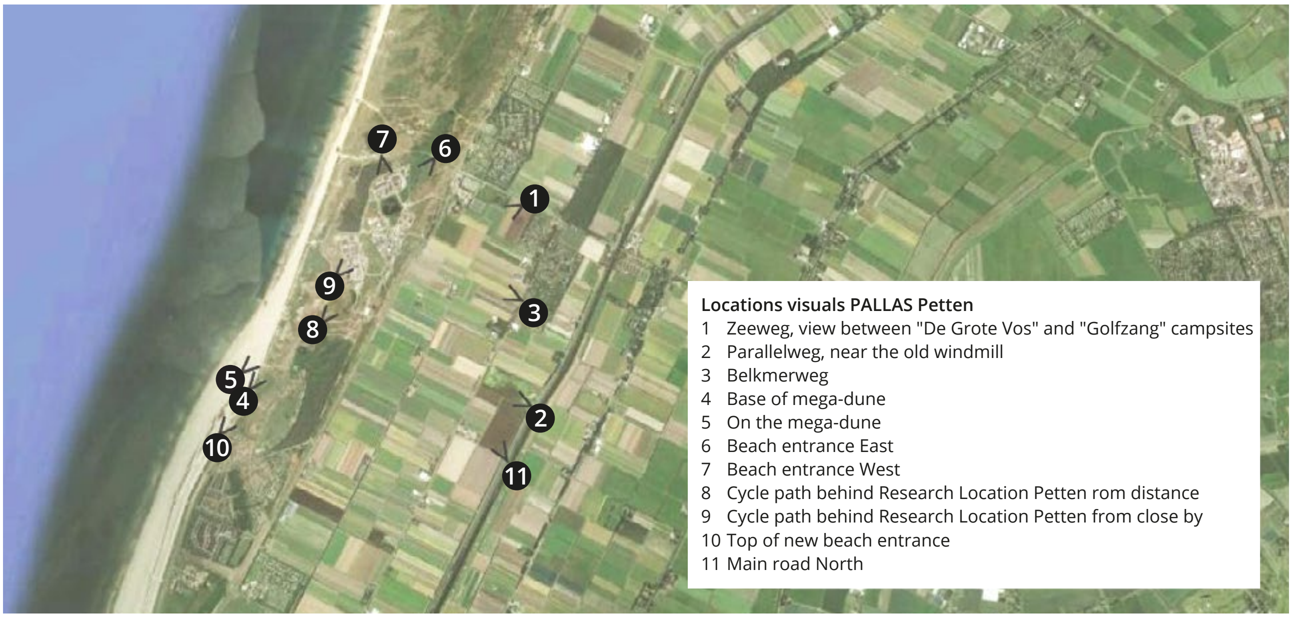

Figure 46 Locations for visualization of PALLAS Petten

Table 89 Assessment framework for Landscape and Cultural history

Assessment criteria	Description
Physical degradation to landscape characteristics/values	Influencing of valuable landscape elements and patterns (points, lines, planes)
Physical degradation to historic geographical elements	Influencing of historical and geographical valuable elements and patterns (points, lines, planes)
Physical degradation to historic (urban) architecture	Influencing of objects and ensembles with historic (urban) architecture values
Experiential value	Influencing of the visual-spatial characteristics of landscape and cultural history
Usage value	Influencing of the use or suitability for activities in the landscape
Future value	Influencing of the sustainability of the landscape (adaptive capacity)

assessed on the basis of expert judgment. It was chosen not to quantitatively assess any physical degradation, due to the damage to a number of trees providing no information on the value of those trees and the degree to which this signifies a positive or negative degradation of the character or values of the landscape, for example.

Physical degradation
Physical degradation is taken to mean the influencing of landscape and cultural historically valuable elements and patterns: what is the extent of influence on those physical elements which are characteristic of a landscape (topography, tree-lined lanes, hedgerows, parcels of land and such)? The following factors are individually assessed:

- Landscape characteristics/values.
- Historic geography.
- Historic (urban) development.

Table 90 describes the assessment score for the physical degradation criterion.

Experiential value
The experiential value concerns the visible characteristics

Table 90 Scoring of assessment for Landscape and Cultural history, physical degradation

Score	Meaning	Explanation
++	Extremely positive impact	Great and/or permanent and/or regional addition/reinforcement of (relevant) landscape/ cultural history elements and patterns.
+	Positive impact	Addition/reinforcement of andscape/ cultural history elements and patterns.
0	No impact	Extremely limited or no degradation or addition/improvement of landscape/ cultural history elements and patterns.
-	Negative impact	Degradation of landscape/ cultural history elements and patterns.
- -	Extremely negative impact	Great and/or permanent and/or regional degradation of (relevant) landscape/ cultural history elements and patterns.

of/in the landscape, as experienced by users of the area. A distinction is made between visibility and a sense of experience. Visibility only relates to the degree to which something is visible (over what distance, for example). This need not be disturbing and therefore negative, however. The sense of experience relates quite simply to how the visible characteristic is experienced. The experiential value is defined as the influencing of visual-spatial characteristics of the landscape: what is the extent of influence on the spatial experience or experiential value and consequently on the experience of the landscape?
In the case of PALLAS, Research Location Petten and the PALLAS development on the site can be experienced in various ways:

- From outside:
  - From the polder.
  - From the dune area.
  - From the beach.
  - From the sea.
- Within the site.

In terms of scale, the greater the number of people for whom developments are experienceable, the more significant they become. The list above therefore applies from top to bottom, most strongly from the polder and least strongly within the site. Accessibility also plays a role. If an area or parts of an area have limited accessibility or limited usage, people's experience will be relatively limited, despite great visibility.
Table 91 describes the assessment score for the experiential value criterion.

Table 91 Scoring of assessment for Landscape and Cultural history, experiential value

Score	Meaning	Explanation
++	Extremely positive impact	Great and/or permanent and/or area-wide and/or relevant improvement/reinforcement of the experiential value.
+	Positive impact	Improvement/reinforcement of the experiential value.
0	No impact	Very little or no degradation or improvement/reinforcement of the experiential value.

Score	Meaning	Explanation
-	Negative impact	Degradation/reduction of the experiential value.
- -	Extremely negative impact	Great and/or permanent and/or area-wide and/or relevant degradation/reduction of the experiential value.

Usage value
The usage value criterion describes the influencing of or suitability for activities in the landscape: what is the extent of influence with regard to spatial usage forms such as recreation and agriculture? This SEA assesses recreation separately. In assessing the usage value as a component of spatial quality, recreation will therefore not be included as an activity in the landscape, so that the criterion will largely concentrate on the agriculture activity.
Table 92 describes the assessment score for the usage value criterion

Table 92 Scoring of assessment for Landscape and Cultural history, usage value

Score	Meaning	Explanation
++	Extremely positive impact	Great and/or permanent and/or area-wide and/or relevant improvement/reinforcement of the usage value.
+	Positive impact	Improvement/reinforcement of the future value.
0	No impact	Very little or no degradation, or improvement/reinforcement of the usage value.
-	Negative impact	Degradation/reduction of the usage value.
- -	Extremely negative impact	Great and/or permanent and/or area-wide and/or relevant degradation/reduction of the usage value.

Future value
The future value criterion describes the influencing of the future resilience of the landscape (adaptive capacity): to what extent does the landscape become more or less robust or adaptive for the accommodation of developments, such as changes in agriculture and/or climate change, for example? To what degree are land shaping processes or landscape dynamics influenced?
Table 93 describes the assessment score for the future value criterion.

Relevant phases
Any impact on the Landscape and Cultural history aspect will take place during the construction phase. This will concern a (temporary) impact occurring as a result of the construction process. Buildings under construction will become increasingly visible during the construction phase, for example. Such an impact relates to the end situation of the development and is therefore regarded to be an impact of the transition and operational phases rather than the construction phase. However, impacts resulting from the construction phase can last until after the construction phase, if the surrounding area needs to be permanently adapted for the purpose of the LDA, for example. The transition and operational phases have no differentiating impact in terms of the Landscape and Cultural history aspect and are therefore not separately described.

Table 93 Scoring of assessment for Landscape and Cultural history, future value

Score	Meaning	Explanation
++	Extremely positive impact	Great and/or permanent and/or area-wide and/or relevant improvement/reinforcement of the future value.
+	Positive impact	Improvement/reinforcement of the future value.
0	No impact	Very little or no degradation, or improvement/reinforcement of the future value.
-	Negative impact	Degradation/reduction of the future value.
- -	Extremely negative impact	Great and/or permanent and/or area-wide and/or relevant degradation/reduction of the future value.

SEA assessment scale
Assessment of the impact takes account of (see Table 94):
- Duration of the impact: is the impact temporary or permanent? The longer the duration, the heavier it is weighted in the assessment.
- Scope of the impact in relation to the value: is the entire value influenced or parts of the value? The greater the scope, the heavier it is weighted in the assessment.
- Scale of the impact: is a limited area influenced, or is the impact extremely far reaching (whole area)? The greater the scale, the heavier it is weighted in the assessment.
- Quality of the current situation: an impact on a current situation which has great value (unique, well-preserved, etc.) will be more heavily weighted in the assessment, than if the current situation is of lesser value. The context and combined value then also become important. There is however a tipping point: if the final fragmented remnants of cultural history were to disappear in an affected area, they will suddenly have great value.

A measure will seldom be equally negative or positive in terms of the duration, scope, scale and quality/relevance. A quantitative consideration will then need to be made, whereby for example the severity of one component (scope, quality, etc.) can at most be scored negatively. Generally speaking, the (most) negative components will weigh most heavily.

Table 94 General assessment system for Landscape and Cultural history

Score	Meaning	Duration of impact	Scope of impact versus the value	Scale of impact	Quality/ relevance of the value (well-preserved, uniqueness, etc.)
++	Extremely positive impact	Permanent improvement	Great improvement	Whole area	Reinforcement of unique values
+	Positive impact	Long-lasting improvement	Limited improvement	Part of the area	Reinforcement of important values
0	No impact	Brief/ extremely temporary or no impro-vement/ degradation	Little or no improvement or degradation	Not present or extre-mely local	No special/ general value.
-	Negative impact	Long-lasting degradation	Limited degradation	Part of the area	Degradation of important values
- -	Extremely negative impact	Permanent degradation	Great degradation	Whole area	Degradation of unique values

15.2 Current situation and autonomous development

15.2.1 Current situation

Origination and development history

Dynamic natural processes as the basis for the landscape

During the Pleistocene era, large parts of Noord-Holland were made up of mudflats intercepted by gullies. Early in the Holocene era, a beach was formed at the location of the Hondsbossche and Pettemer coastal defenses. Clay was then deposited on this sandy plain and its peat hinterland, via a tidal inlet to the south of Bergen. Sand barriers were formed in the period from 3000 to 1500 BC, which served as the basis for the development of dunes. And so the Noord-Holland dune areas developed. By 9 AD, they had become part of a largely continuous coastline, which ranged from Zeelandic Flanders to Vlieland. This coastline was made up of long sand barriers and dune belts, parallel to the coast with a number of interruptions in the form of river outlets and estuaries, including the Zijpe.

Subsidence in the peat and clay regions resulted in a process of coastal erosion, and the sea regularly started to break through the dunes in the period from 1000 AD on. In the Middle Ages, the Petten coastline was a kilometer more westerly than it is nowadays.

Occupation and engagement with the water

The dunes formed the basis for the earliest occupation of this area, though this did not occur permanently until the 7th century. From the 10th century on, the peat plains to the east of the sand barriers were excavated. Breaching of the coast by the sea transformed the original stretches of coastline into irregular shaped blocks. Excavation of the peat during the Middle Ages caused subsidence. In combination with the rising sea levels and various storm floods (in 1163, 1170 and 1196, for example), this gradually changed the areas around the Zijpe into vast coastal marshlands or mudflats.

Dikes were erected along the many stretches of land from the 10th century on, in order to protect settlements from the floods. Later in the 13th century, the individual dikes were interconnected, leading to the West Friesian ring dike being completed around 1300. A sheltered environment was formed between the row of dunes and the West Friesian ring dike, in which sedimentation took place very quickly. This was the basis for Zijpe polder.

In the end, the dunes at what is nowadays the Hondsbossche and Pettemer coastal defenses became so narrow that a (sand) dike needed to be constructed behind them. This was breached during the St. Elizabeth Flood of 1421, in which a large section of the area re-flooded. A second coastal defense structure was built in 1432, a so-called sleeper dike, which was soon to function as the primary coastal defense structure. Despite further reinforcements in 1506 and 1548, with groynes and pole shields being added, this could not prevent another breach during the extremely strong storm surge of 1570 (All Saints' Flood). Until that flood, wooded dunes could be found at the location of the sea defenses. This Hondsbosch was the remnant of a larger coastal woodland area [40].

The Zijpe polder was drained in 1597, resulting in the West Friesian ring dike becoming an inner dike. Right from the start, the polder was set out as an efficient agricultural areas.

When the predecessor of the current Hondsbossche and Pettemer coastal defense structure was nearly breached in 1792, the coastal defenses were further reinforced. The current coastline has hardly shifted at all over the past 200 years, partly due to stabilization of the dunes. For many years, these dunes were a bare wasteland, until the Netherlands Forestry Commission initiated drastic changes in the landscape at the end of the 19th century, by planting coniferous woods in half of the dunes. The drifting dunes became stabilized and a varied and more stable dune area was formed, suitable for recreational purposes.

Origination and development of Research Location Petten

The current Research Location Petten was developed in 1955, by the Reactor Center Netherlands (RCN), after the Dutch government decided to build its own reactor midway through the 20th century. This High Flux Reactor (HFR) needed to be built on a site far from centers of population and in the vicinity of cooling water. The Petten site was found to be ideal [41]. Construction of the HFR was completed in 1962, after which

Figure 47 Historic map of the Noord-Holland coast from the 16th century [40]

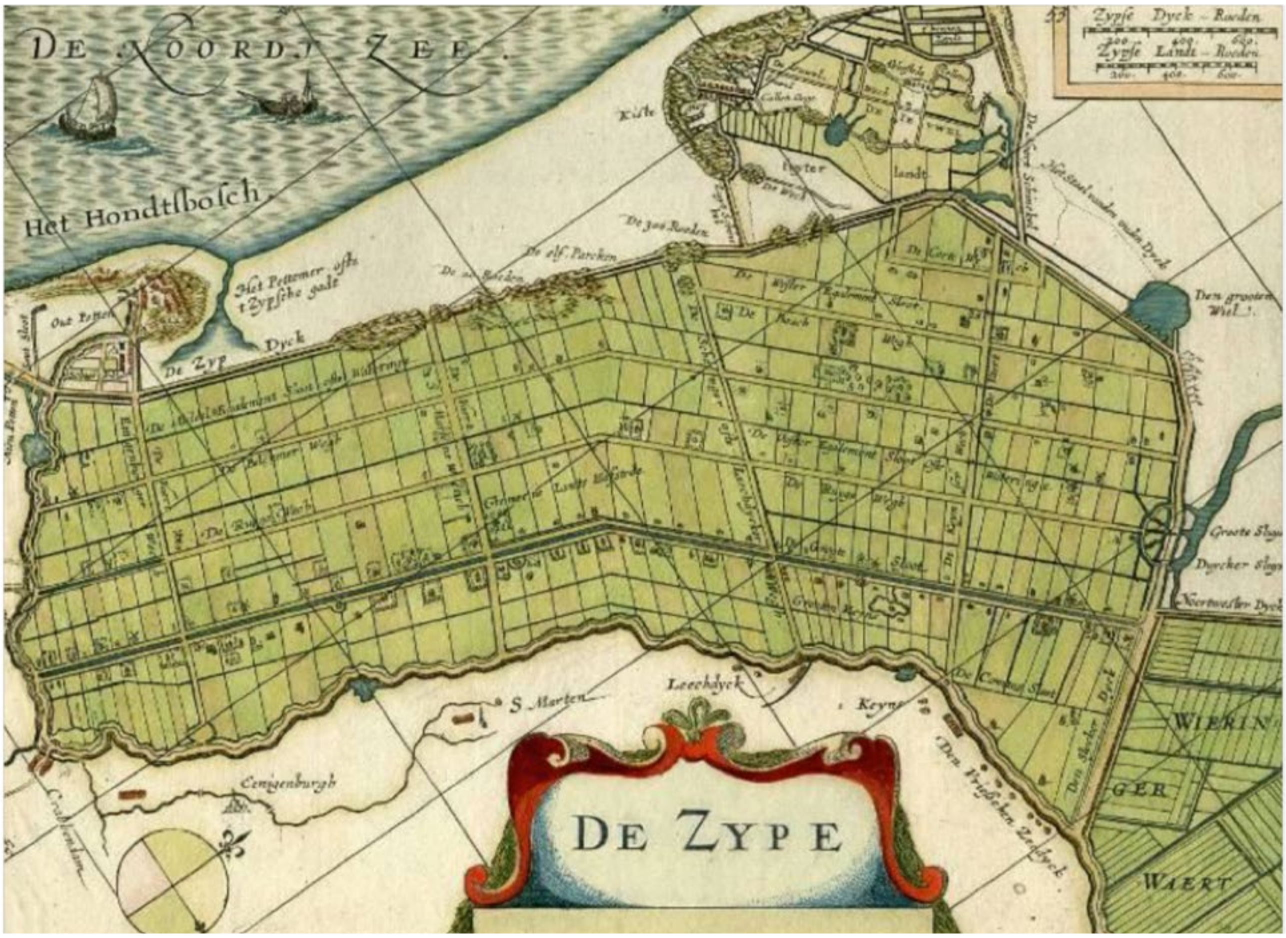

Figure 48 Historic map of the Zijpe (1631/1682)

40 Source of image: See [40], original Source: Hollandia from the atlas Theatrum Orbis Terrum.

it was sold to Euratom but under the management of RCN, which in turn was renamed ECN in 1976. 1998 saw the merger of the nuclear activities of ECN and KEMA in the new organization, NRG. The Euratom organization as part of the European Community, is now known as EC-JRC.
The site has continued to develop since the construction of the HFR, with numerous parties (including Euratom) moving to the site. The production of isotopes for medical purposes was soon to become an important development, initially by Philips subsidiary Duphar, but subsequently by Covidien, now known as Curium, following sale of the activities in 1977. The molybdenum production facility was built in 1996, for this purpose. The COVRA (Central Organization for Radioactive Waste) could also be found on the site for quite some time, until it moved to Borssele in 1993 [42]. Another development is the research into alternative (sustainable) forms of energy.

This was further reinforced once ECN hived off its nuclear activities, in order to fully concentrate on other forms of energy research. From 1977 on, extensive research was conducted into wind energy, for example. This now no longer takes place on the site itself, though the base of the first wind turbine atop a lofty dune is still prominently visible in the site, as a reminder of this research.
Access to the site was more central in the past, whereas there are two entrances nowadays. The most commonly used (main) entrance to the south and a northern entrance to the EC-JRC complex and the current HFR installation.

Landscape structure and characteristics
As indicated on the Landscape and Cultural history information map, three landscape units (culture landscapes or types of landscapes) can be distinguished (from west to east):
1. Young dune landscape.
2. Damming of landscape.
3. Old sea clay landscape.

These three types are mainly based on the geomorphological situation of the area.

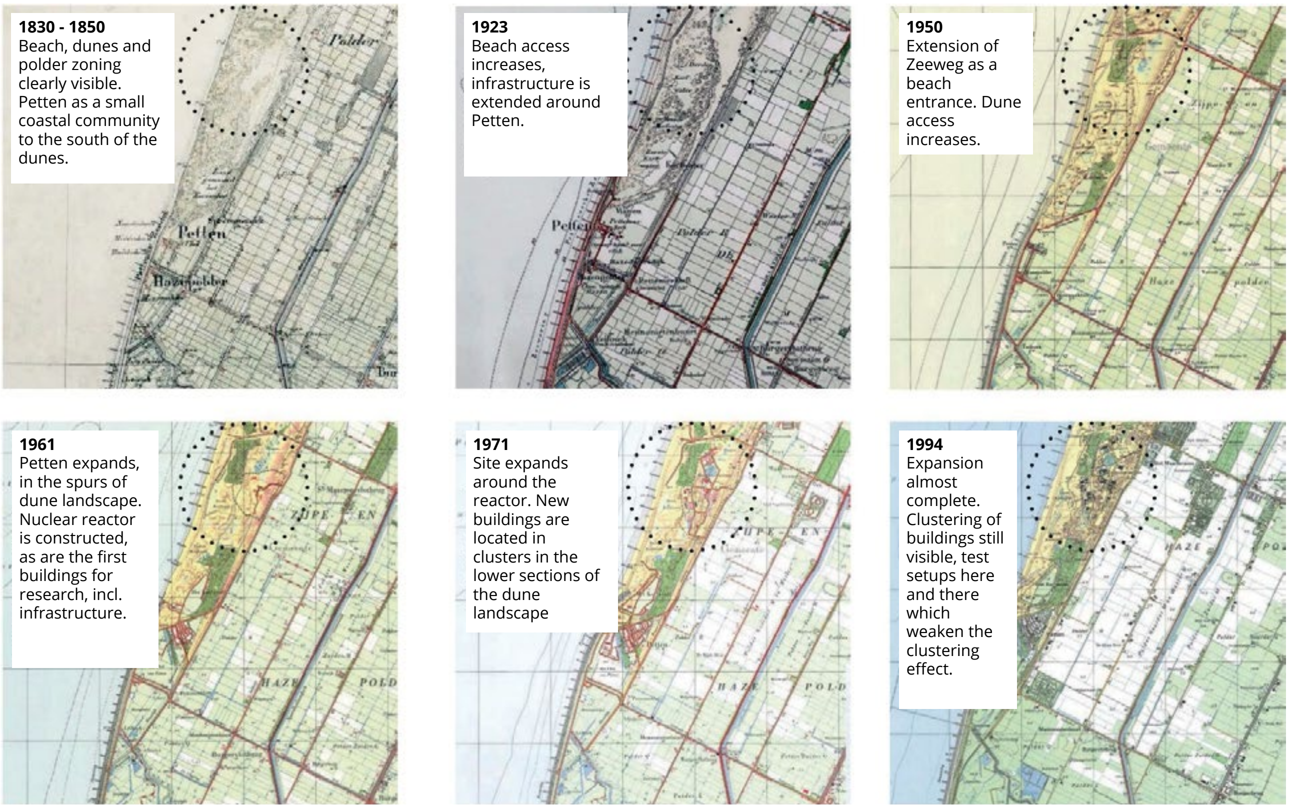

Figure 49 Recent history of Research Location Petten and the surrounding area, in map images

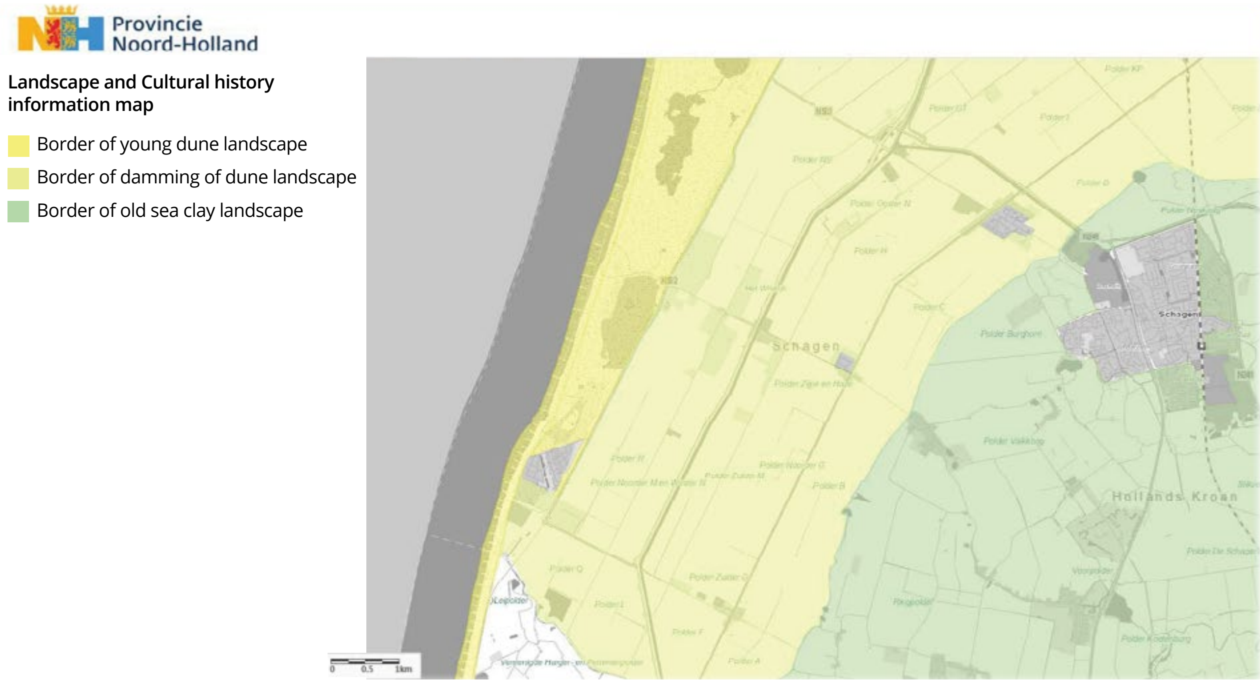

Figure 50 Landscape structure [40]

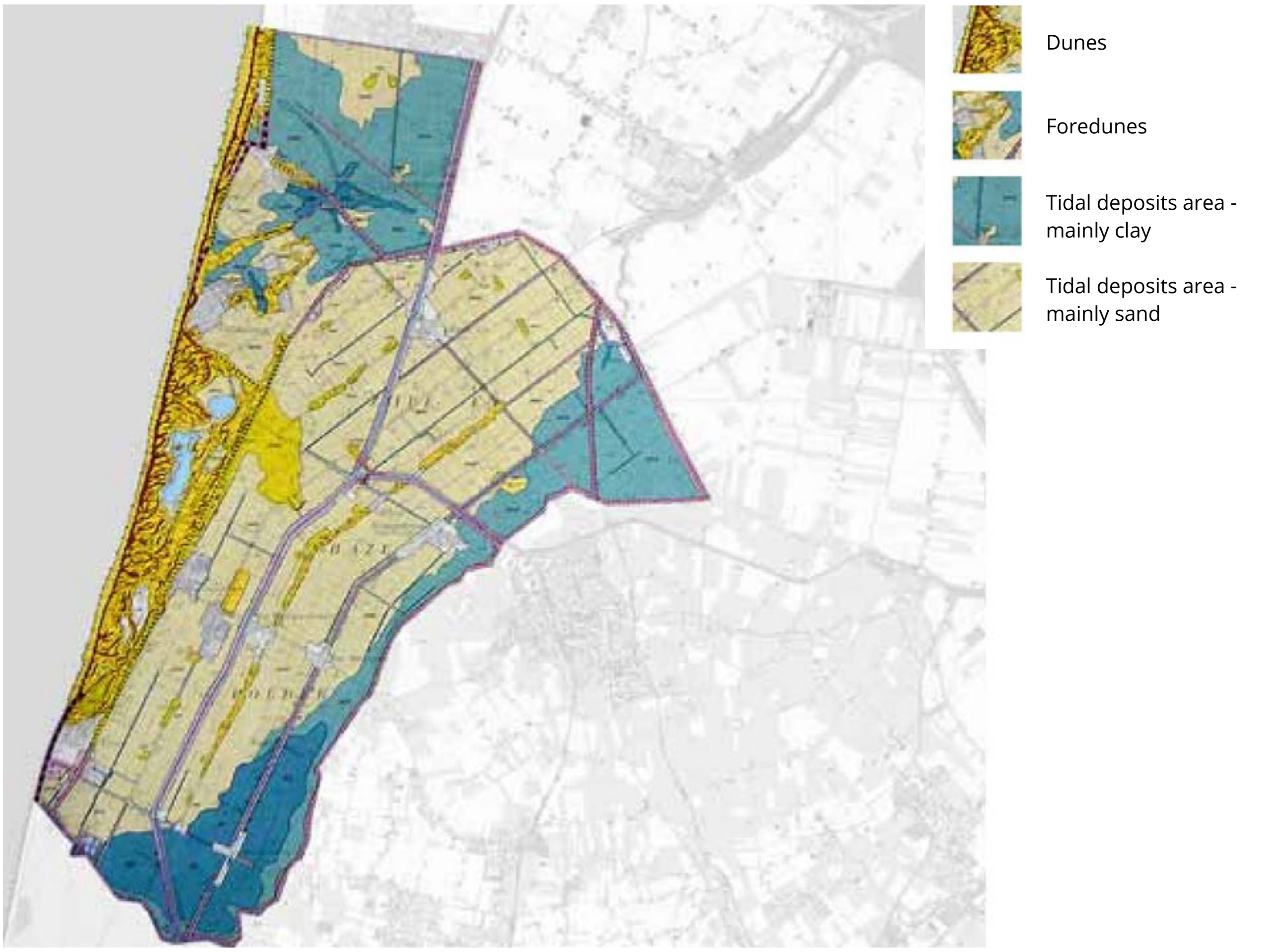

Figure 51 Geomorphology [41]

Soil and water structures

Mass Area
(Green structures and occupation)

Infrastructure

Figure 52 Landscape composition

Each of the three types of landscape has its own characteristics. The characteristics of the old sea clay landscape – which starts at the West Friesian ring dike – will not be discussed here, as it is way beyond the sphere of influence of the planning area.

Young dune landscape
Research Location Petten is part of the Pettemer dunes, which in turn are part of a continuous complex of (former) sandbars and drifting dikes from Petten to Callantsoog, which jointly form a narrow dune belt. It is a varied and small-scale area with great contrast, due to the alternation of valleys and narrow dunes, some of which have been windswept into parabolic dunes. The inner slopes of the dunes are often steep(er). Ponds can be found at various locations in the valleys, including the Research Location Petten. The dunes generally have low vegetation, with woodlands here and there.

Damming of landscape
The open and large-scale, rational flat landscape of Zijpe is in strong contrast to the variegated and small-scale topography of the dunes. Farms with limited greenery are located along a development line within a sparse and regular grid. The main structure is defined by three parallel main axes along which the farms lie. The Noordhollandsch Kanaal was excavated between the central and western axes in the period from 1819 – 1824, and this intersects the polder, whose main function is bulb cultivation. A relatively recent development is the large blocks of recreational accommodation complexes in Sint Maartenszee and Sint Maartensvlotbrug.

Figure 53 Geological values and monuments [43]

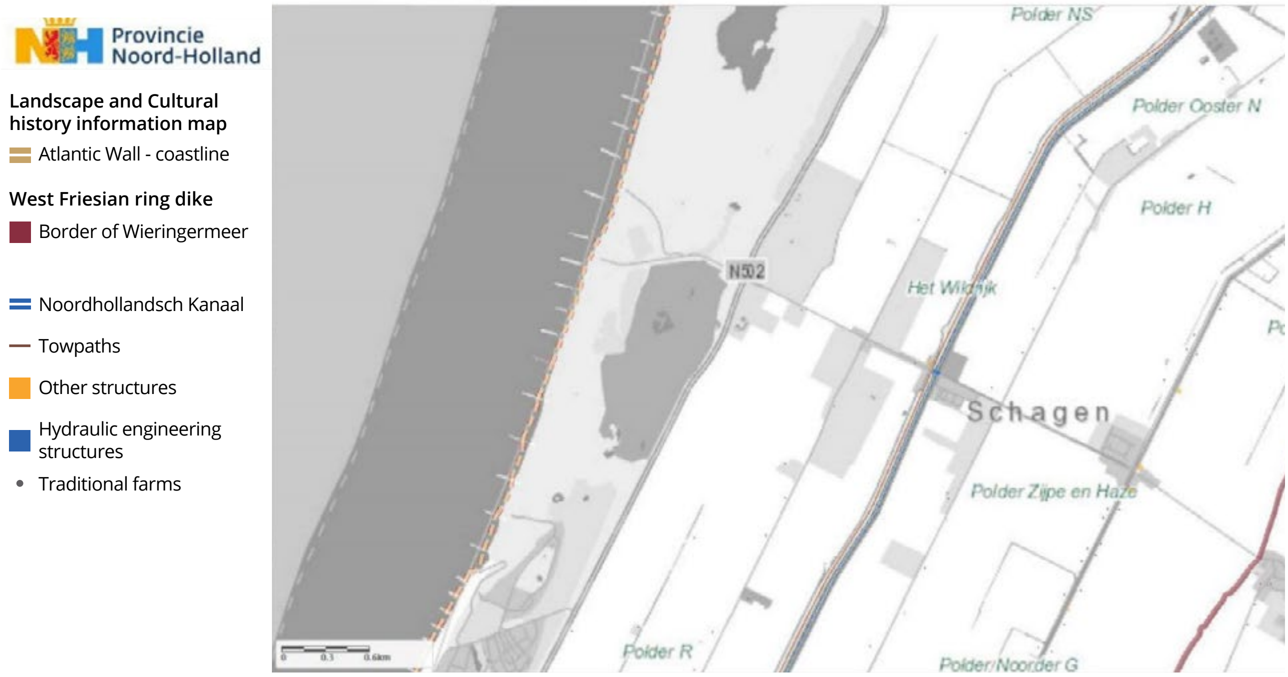

Figure 54 Cultural history values

Values

Landscape and cultural history values

The Province of Noord-Holland has designated large sections of the dunes from Den Helder to Zuid-Holland as a geological monument. Research Location Petten is not part of this geological monument [43], but is surrounded by these dunes. The site itself has been designated geologically valuable, as a result of the dunes and the processes by which dunes are formed. The geological values on and around the site are a so-called extra value zone in the zoning plan.

According to the Landscape and Cultural history information map of the province of Noord-Holland, Research Location Petten does not house any relevant landscape, historic geographical values or historic urban development values. In the surrounding area, the map only shows a number of small objects such as traditional farmhouses alongside the Noordhollandsch Kanaal. Along the coastline, the Atlantic Wall is a large cultural historic defense structure comprising a number of objects. There are no relevant elements found on or directly around the planning area [44].

The fact that there are no relevant values for the planning area on these maps, does not mean that there are no landscape values. The geologically valuable dune system with its diverse topography, vegetation, etc. can after all be defined as a valuable landscape. The system is constantly evolving and can therefore keep changing its appearance over time. This must be seen as a quality of the historic, current and future dune landscape. The rational patterns of land parcels, roads, etc. in the polder landscape are also a significant landscape and cultural history value. In the following map featuring the cultural history in the Landscape plan of the municipality of Zijpe, the transition line from dune to polder (sand dike) is indicated to be a relevant value.

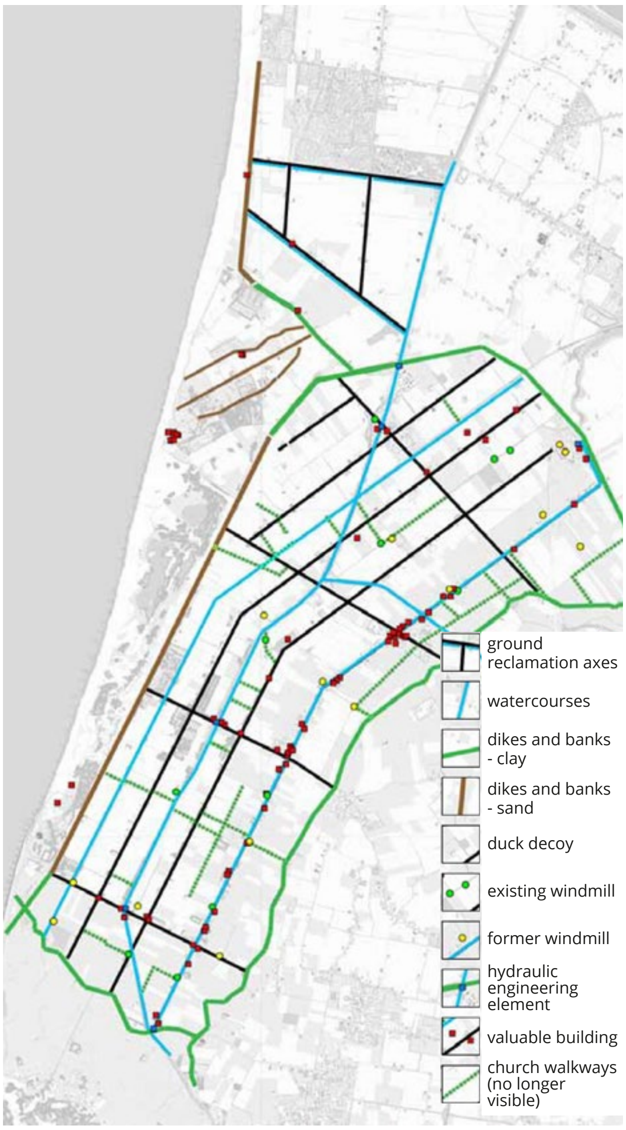

Figure 55 Cultural history values [41]

Experiential value
The visual spatial characteristics are very much in keeping with the types of landscape named above. However, the young dune landscape has two separate spatial elements. The beach is clearly very different, spatially, from the dunes themselves. And so the following spatial zoning can be made:

- North Sea and beach: open area, where land meets water. It is (apparently) limitless, namely in the length of the coastline and even further over sea. The dunes are the only real limit to the space. The separating line between the beach and dunes is not always entirely clear. The perception of the beach space is also strongly influenced by its seasonal use. A busy beach does not have the same feeling of limitless space.
- Dunes: naturally varied contrasting area. On top of a dune, you can have panoramic views, or a vista between two dunes, but a dune valley can suddenly become much less spacious. As it is obviously not intended that the general public has free access to the entire dune area, the perception is mainly linked to the experience from the paths in the area.
- (De Zijpe) polder area: open, large-scale agricultural landscape with long sight lines. The polder features extremely long infrastructure lines with accessory buildings. There are also large spatial elements such as recreational parks and villages. Wind turbines are clearly visible as individual spatial objects in the polder. The undulating edge of the dunes is often also very visible in contrast with the flat and austere polder lines. A visually very characteristic form of agriculture in this polder is flower bulb cultivation, which has great experiential value in the flowering season but is explicitly less attractive at other times of the year.

Figure 56 Visual spatial zoning

The site can be experienced in several ways:

- From outside:
  - From the polder.
  - From the dune area.
  - From the beach.
  - From the sea.
- Within the site.

Important aspects for visibility are the heights of the buildings and the surrounding dunes. The higher dune crests are 9 to 14 m above NAP on average, with the highest being 17 m. Most of the buildings are around the same height as the higher dune crests, while a number of buildings are actually higher than these crests. The concrete base of the wind turbine is unique in that it is located on top of a dune, making it extremely visible (see also Figure 43, section 14).
The dunes are not all the same height, with two rows of relatively lower dunes on the coastal side. The row of dunes along the polder is slightly higher, while the highest dunes of all are in the center of the site. The dune complex on the northwestern side is the only dune complex to be wooded, with all other dunes having low (rough) vegetation (bushes, marram grass, etc.). The dunes form two distinct areas on the site: the section on the coast and the other area.

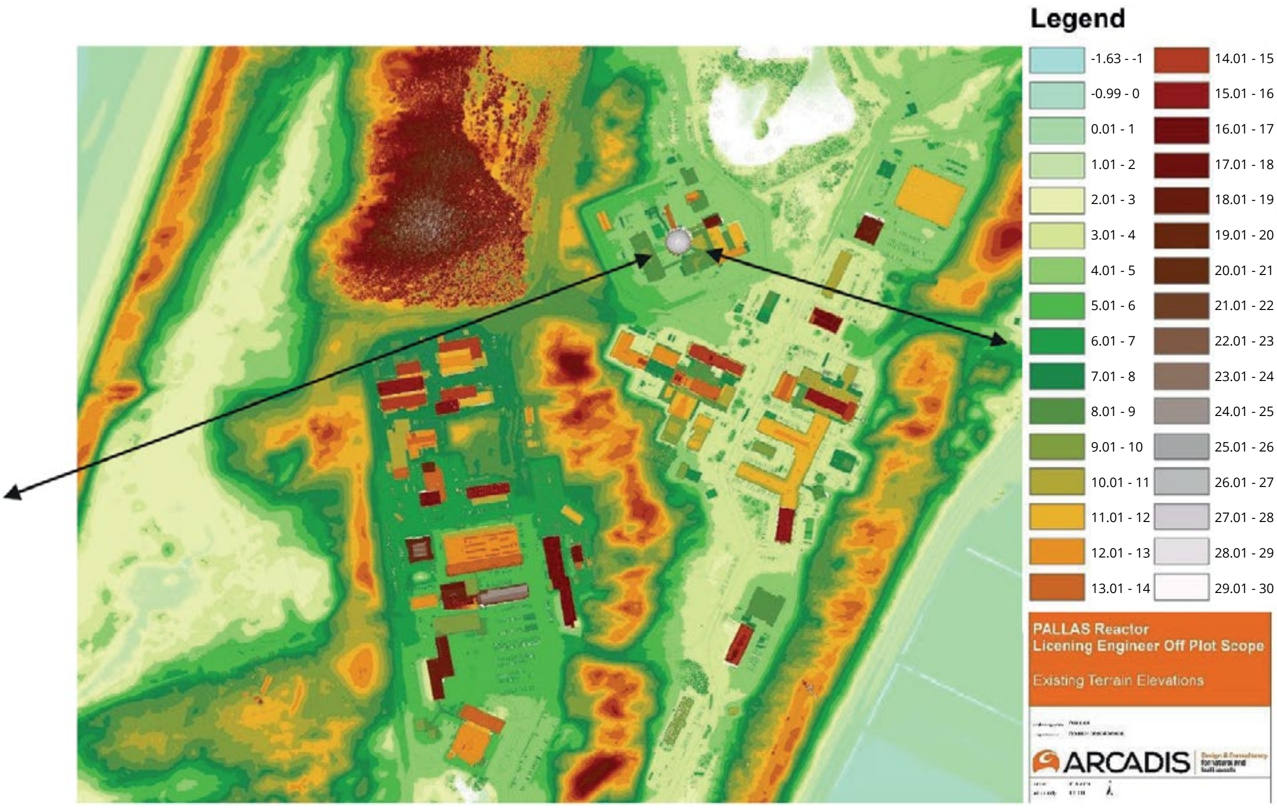

Figure 57 Altitude map of current site situation with views (arrows)

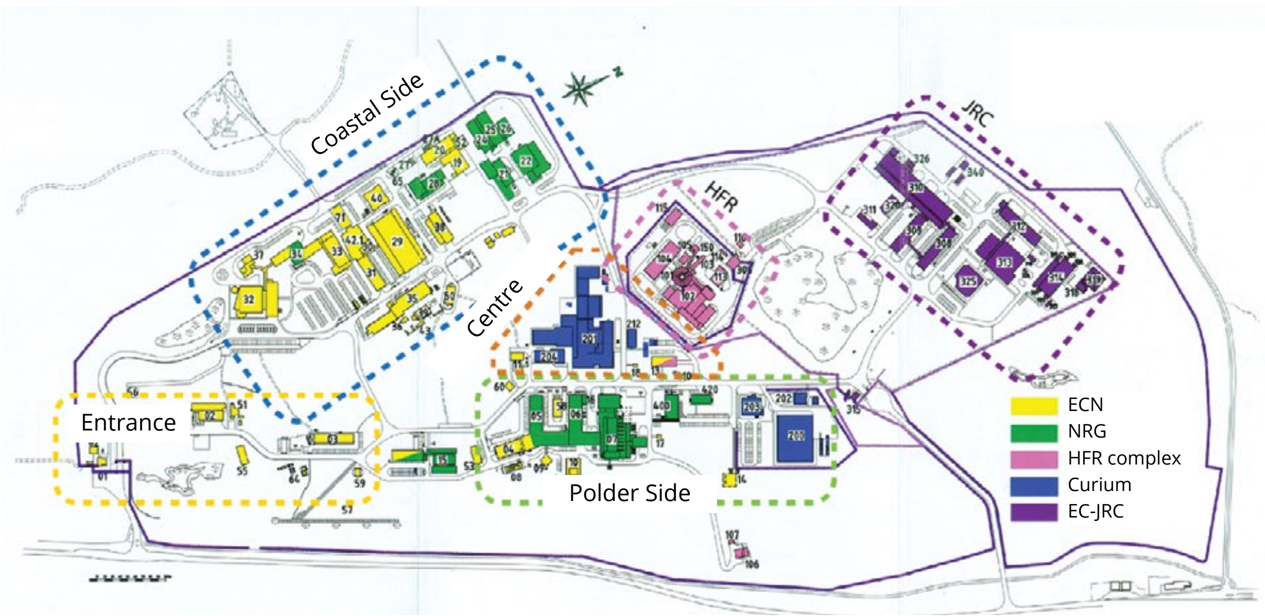

Figure 58 Current site layout showing building numbers and organizational and spatial clusters

Table 95 Height of buildings at Research Location Petten (to the left based on organizational clusters, to the right on spatial clusters[41]

Cluster	Building	Max. (roof) height (NAP)	Average (roof) height (NAP)
	Wind turbine base on dune	19	19
Covidien	200	12	12
Covidien	201	13	11
Covidien	202	8	8
Covidien	203	18	18
Covidien	204	12	12
ECN	2	14	11
ECN	3	10	10
ECN	19	14	14
ECN	20	11	11
ECN	29	14	13
ECN	31	26	26
ECN	32	14	12
ECN	33	21	21
ECN	34	18	18
ECN	35	17	17
ECN	37	9	9
ECN	38	17	16
ECN	40	19	19
ECN	42	21	21
ECN	50	12	12
ECN	55	14	14
ECN	71	13	13
ECN / HFR	13	9	9
HFR	102	20	16
HFR	104	9	9
HFR	113	13	11
HFR	115	13	13
HFR	309	10	10
HFR	dome	28	28
HFR	chimney	49	49
JRC	308	12	12
JRC	309	12	12
JRC	311	12	12
JRC	312	12	12
JRC	313	12	12
JRC	314	12	12
JRC	319	12	12
JRC	325	12	12
JRC	326	12	12
NRG	7	16	11
NRG	21	16	14
NRG	22	16	14
NRG	24	15	15
NRG	25	17	17
NRG	26	18	18
NRG	28	18	16
NRG	400	17	17
NRG	420	11	11

Cluster	Building	Max. (roof) height (NAP)	Average (roof) height (NAP)
	Wind turbine base on dune	19	19
Entrance	2	14	11
Entrance	3	10	10
Entrance	55	14	14
HFR	102	20	16
HFR	104	9	9
HFR	113	13	11
HFR	115	13	13
HFR	309	10	10
HFR	dome	28	28
HFR	chimney	49	49
JRC	308	12	12
JRC	309	12	12
JRC	311	12	12
JRC	312	12	12
JRC	313	12	12
JRC	314	12	12
JRC	319	12	12
JRC	325	12	12
JRC	326	12	12
Coastal side	7	16	11
Coastal side	19	14	14
Coastal side	20	11	11
Coastal side	21	16	14
Coastal side	22	16	14
Coastal side	24	15	15
Coastal side	25	17	17
Coastal side	26	18	18
Coastal side	28	18	16
Coastal side	29	14	13
Coastal side	31	26	26
Coastal side	32	14	12
Coastal side	33	21	21
Coastal side	34	18	18
Coastal side	35	17	17
Coastal side	37	9	9
Coastal side	38	17	16
Coastal side	40	19	19
Coastal side	42	21	21
Coastal side	50	12	12
Coastal side	71	13	13
Centre	13	9	9
Centre	201	13	11
Centre	204	12	12
Polder side	200	12	12
Polder side	202	8	8
Polder side	203	18	18
Polder side	400	17	17
Polder side	420	11	11

41 The heights have been determined on the basis of measurements in the 3-D site model. Efforts have not been made to achieve absolute accuracy, as the purpose is to indicate the relationship between the heights at Research Location Petten. The chimney of the Jaap Goedkoop laboratory has not been included separately in the list, and has a height comparable with the HFR chimney.

Table 96 Heights of buildings from smallest to tallest, in relation to the dune heights

Average height of dune crests (dashed black box: Centre 13 to Entrance 55)

Heights greater than highest dune crests (dashed red box: Coastal side 26 to HFR chimney)

Cluster	Building	Max. (roof) height (NAP)
Polder side	202	8
Centre	13	9
Coastal side	37	9
HFR	104	9
Entrance	3	10
HFR	309	10
Coastal side	20	11
Polder side	420	11
Centre	204	12
Coastal side	50	12
Polder side	200	12
JRC	308	12
JRC	309	12
JRC	311	12
JRC	312	12
JRC	313	12
JRC	314	12
JRC	319	12
JRC	325	12
JRC	326	12
Coastal side	71	13
HFR	113	13
HFR	115	13
Centre	201	13
Entrance	2	14
Coastal side	19	14
Coastal side	29	14
Coastal side	32	14
Entrance	55	14
Coastal side	24	15
Coastal side	21	16
Coastal side	7	16
Coastal side	22	16
Coastal side	25	17
Coastal side	35	17
Coastal side	38	17
Polder side	400	17
Coastal side	26	18
Coastal side	34	18
Polder side	203	18
Coastal side	28	18
Coastal side	40	19
	Wind turbine base on dune	19
HFR	102	20
Coastal side	33	21
Coastal side	42	21
Coastal side	31	26
HFR	dome	28
HFR	chimney	49

Average height of dune crests (dashed black box: Centre 13 to Entrance 55)

Heights greater than highest dune crests (dashed red box: Coastal side 26 to HFR chimney)

Cluster	Building	Average (roof) height (NAP)
Polder side	202	8
Centre	13	9
Coastal side	37	9
HFR	104	9
Entree	3	10
HFR	309	10
Entrance	2	11
Centre	201	11
Coastal side	20	11
HFR	113	11
Polder side	420	11
Coastal side	7	11
Centre	204	12
Coastal side	32	12
Coastal side	50	12
Polder side	200	12
JRC	308	12
JRC	309	12
JRC	311	12
JRC	312	12
JRC	313	12
JRC	314	12
JRC	319	12
JRC	325	12
JRC	326	12
Coastal side	29	13
Coastal side	71	13
HFR	115	13
Coastal side	21	14
Coastal side	19	14
Coastal side	22	14
Entrance	55	14
Coastal side	24	15
Coastal side	38	16
HFR	102	16
Coastal side	28	16
Coastal side	25	17
Coastal side	35	17
Polder side	400	17
Coastal side	26	18
Coastal side	34	18
Polder side	203	18
Coastal side	40	19
	Wind turbine base on dune	19
Coastal side	33	21
Coastal side	42	21
Coastal side	31	26
HFR	dome	28
HFR	chimney	49

Figure 59 Compiled photo showing the view of the surrounding area from Research Location Petten (by Arcadis 2016)

The height of the HFR and the various chimneys makes them easily visible from various viewpoints in the surrounding area. The sight lines given in the following photos show that the HFR is more visible from one or two viewpoints than from elsewhere, due to it being less shielded as a result of low-lying areas in the dunes. In the polder, the wind turbines are sometimes more spatially dominant than the HFR.
The area on the coastal side is (very slightly) visible from the coastline, due to it sometimes just protruding over the dune. The other zones are hardly or not at all visible from the coastline due to the first row of dunes and the role of dunes through the center of Research Location Petten. Vice versa, the area on the coastal side is hardly or not at all visible from the polder. The visibility of the buildings on the polder side depends very much on the combination of building height, dune height and viewpoint.

Figure 60 Photos showing views of Research Location Petten from the Westerduinweg (by Arcadis 2016)

Closer to the site, the view of many of the buildings, including the HFR, is often limited, as it becomes difficult to "look over the dune". The viewing angle is different at a greater distance, allowing a better look. When viewed from a great distance, it merges as an object with the other objects on the horizon. This effect is more or less likely to occur depending on the weather / clarity. The openness of the polder landscape gives views of the HFR in an extremely large area.

Industrial sites are experienced to be relatively disturbing elements in the landscape [37], as you certainly do not expect to discover an industrial site in a natural environment such as a dune area. In the case of Research Location Petten, the nuclear dimension is an added factor, of which many people are fearful. Despite the site varying in terms of its visibility, each component is then more likely to be perceived to be disturbing and therefore negative.
The current industrial site has a number of clusters of buildings, and their quality and the image given of the site as a whole is relatively disorganized. There is great variety in the shape, design and quality of the buildings, as well as the site layout, and this perception is reinforced by the many individual buildings and elements. The site looks like one large laboratory or experimental area. The greatest quality of this area is that it is embedded in the dunes without encroaching on them. The constant dynamics of the dunes and of the spatial development on the site actually accord well together in a certain sense.
The somewhat disorganized design therefore becomes less disturbing here than a standard industrial site would. The area absorbs new spatial developments relatively easily.
The current HFR does not play a prominent role in the area, and is often not even visible because of the dune structures and the other buildings. There is a more or less isolated cluster of buildings close to the HFR, around the iconic dome structure. Users of the site experience it differently to outsiders, due to their relationship with the buildings and their functions. Nuclear activities therefore do not (as quickly) have a negative connotation for the users. The quality of the combination of buildings within the unique context of the dunes is more important to them.
With the exception of the beach pavilions, the stretch of coast between Sint Maartenszee and Petten is empty, though it is full of visitors in summer months. Many of them experience the vastness and natural forces of the sea as sublime.

Figure 61 Compiled photo from the Sint Maartenszee beach entrance towards Petten (by Arcadis 2016)

The dunes at Petten are not a protected landscape, and have no formal status as a national landscape, for example. They are however greatly appreciated as a component of the North Sea coast. On presenting the National Coast Vision in 2013, the president of the Delta program Coast steering group, Ms. Geldhof, spoke as follows: "The Dutch coastline is an iconic and attractive landmark". She described the coastline as "our golden edge" [45]. Recent discussions have made it even more explicitly clear that development, building activities on the coastline – whatever their form – can count on great resistance [46] [47]. Various organizations have united in order to keep a close eye on all developments in the coastal zone, in order that it is not further degraded [48]. Openness, naturalness and the unspoiled character are the core qualities which must not be further degraded. They have also indicated that the spatial quality of the coastline must not be regarded as a segmental level but rather as an integral system. The entire North Sea coast is valuable and any encroachment on it will influence it as a whole [49].

Usage value

The polder area is primarily of significance for agriculture and particularly for bulb cultivation. This agricultural function can take place efficiently within the large-scale, rational structure of the polder.

A number of individual wind turbines can be found in the area, often connected to buildings in the polder, while line structures of wind turbines are also present in the distance.

Future value

The future value concerns the processes which shape the landscape, among others. This particularly applies to the coastal system as a landscape, which is continually shaped by water and wind. There has often been human intervention however, and this is ongoing. Relevant activities for the area include the stabilization of the dunes due to the Netherlands Forestry Commission planting woodland, and the recent interventions in the Hondsbossche and Pettemer coastal defenses. As far as the industrial site is concerned, it is favorable for the dune system to be stable. In a dynamic dune system, the dunes might (be able) to shift to sites where there is currently industrial activity and/or where industrial activity may take place in the future. For the purpose of the coastal defenses, it is important that the process is not undermined to the extent that the dune system could be weakened, particularly in relation to the need for a robust structure with a view to the forecast effects of climate change. In nature however, a certain degree of dynamism makes it very interesting.

The current Research Location Petten has an extremely flexible setup, in which a wide range of developments can be relatively simply embedded within the industrial zone.

In the broader context, the presence of a nuclear reactor influences the development possibilities in the surrounding area. The reactor was originally built here due to this region being relatively sparsely populated. If the nuclear activity were to disappear from the site in time, there would be further opportunities for development of the area, which would be positive in many senses. However, that need not be positive from a landscape point of view, as extra development can negatively influence the quality of an open polder, for example.

15.2.2 Autonomous developments

The following autonomous developments have been identified:

- Petten beach huts: Fifty seasonal beach constructions (beach huts) are to be built on the North Sea beach at Petten. The municipality of Schagen has entered into an agreement with three parties for the management rights for a period of 10 years.
- Petten sports pavilion: The south beach in Petten will have a pavilion aimed at (water) sports. This pavilion is part of the total tourist impulse offered by the new beach for Petten. The sports pavilion will offer various sports,
- Bohemian Estate Sint Maartenszee: The prestigious Bohemien Estate project is to be built approximately 200 m from the base of the dunes in Sint Maartenszee. This project comprises a hotel offering 121 rooms, 71 holiday apartments, a parking basement and a large patio area. The Bohemian Estate is situated on the Zeeweg, between Petten and Callantsoog in the municipality of Schagen. The Bohemien Estate is part of a project which is also known as De Vier Hectaren (the four hectares).
- Former hotel opposite De Goudvis theme park: The vacant, former Sint Maartenszee hotel opposite De Goudvis is to make room for holiday apartments. Fourteen apartments and five penthouses are planned here.
- Hondsbossche and Pettemer coastal defense structure: There was no insight into the autonomous developments such as increased tourism or daytime recreation as a result of completion of the Hondsbossche and Pettermer coastal

defense structure, in 2015.

- Wind at sea: Permits have already been granted and zones designated for wind energy along the coastline. Depending on the design details, this may influence the degree of unspoiled views of the sea. The impact may be relatively limited for the planning area, as the zones close to shore are somewhat more southerly while the zones opposite the planning area are further offshore.

15.3 Environmental impact

15.3.1 Impact description

15.3.1.1 Construction phase

Physical degradation of landscape characteristics/values

During the construction phase, the impact is limited to the LDA outside of Research Location Petten. Agricultural land will be temporarily converted to form the LDA in the polder. However, the polder has no protected value, so that the impact during the construction phase is extremely limited. If existing ditches need to be filled or intersected for the LDA, this is in violation of the spatial policy of the municipality. Should this prove necessary, it is expected to be a temporary measure and have an extremely limited impact.

The openness of the area is a landscape characteristic which will be (slightly) degraded due to temporary realization of the LDA. However, this is not included in the present criterion, but rather in the experiential value criterion. All impacts will be temporary, due to the LDA being converted back into agricultural land, as already indicated.

There will be little to no degradation of the surrounding dunes for the purpose of construction of the buildings. A minimum or negligible surface of dunes will be lost. There are no protected landscape values, even though the dunes are valuable from a landscape and geological perspective. The dunes form a dynamic system, and slight changes or adjustments have little to no influence on the quality of the landscape characteristics as a whole.

Cooling variant K1 has a pipeline which is installed via an open excavation process. This requires a broad working site, though the actual trench is relatively narrow. The search area is also large, within which the optimum route can be sought, while the excavation itself is only temporary. The greatest risk is that a tree line could be degraded, though it is improbable that there will be any significant degradation of trees and/or tree structures due to the limited width of the trench and the freedom within the search area.

A pipeline route will need to be realized through the dunes for cooling variants K1 and K2. This could potentially result in degradation of protected geological values. However, the dune system has a dynamic character and the impact is therefore never expected to be great.

The cooling variant using cooling units (K3) is subject to the same conditions named earlier for the construction of buildings, so that no impact is expected.

Physical degradation of historic geography and historic (urban) architecture

There are no designated historic geographic and/or historic (urban) architecture values at Research Location Petten or in the direct vicinity. The PALLAS-reactor is therefore not expected to have any impact. The same applies to the cooling variants. Only when connecting to the Noordhollandsch Kanaal (variant K1), must account be taken of the cultural historic significance of this element. A pumping station is planned, measuring 12x10x5 m (l*w*h). However the impact will be extremely limited in relation to the dimension and scale of the landscape and the canal as a landscape element, and due to it being located on the other side of the N9 road, so that the canal cannot be said to be significantly degraded as a cultural historically important element.

Experiential value

During the construction phase, the visibility of the LDA in the open polder will have an impact. In terms of scale, the LDA is approximately 4 to 15 times larger than the farmyards in the surrounding area. It will be visible at a greater distance, due to the relative openness of the polder landscape. However, the impact on experience will be limited, also due to the presence of other disturbing elements such as wind turbines, and the dimension and scale of the site in relation to the scale of the polder. The disturbance caused by the LDA will thereby depend very much on the location, design, orientation and layout of this site, but will be limited to the period of construction. Illumination of the temporary LDA located outside Research Location Petten is also an important aspect, which will render the site visible from a great distance during the hours of darkness. This will however remain limited to the working hours, rather than day and night.

Usage value

During the construction phase, the LDA in the polder will have impact on the usage value of the area if it results in agricultural land becoming fragmented and/or less accessible.

Future value

The dynamic processes in the dunes will not be significantly influenced, either positively or negatively, during the construction phase. There are also no landscape processes in the polder which are influenced by the temporary realization of the LDA.

15.3.1.2 Transition phase and operating phase

Physical degradation of landscape characteristics/values

The Noordhollandsch Kanaal pumping station in variant K1 and the inlet platform at sea in variant K2 will not result in significant physical degradation of landscape characteristics and values.

While the canal is a relevant landscape element, its cultural historical significance is greater than its landscape significance. Due to the position on the other side of the N9 road, together with the extremely limited impact, it cannot be said that there is any significant physical impact. There are no physical values which can be degraded in the sea due to variant K2.

Experiential value

During the transition and operational phases, the new PALLAS-reactor buildings will be more or less visible from the surrounding area. The impact of the transition phase will thereby be comparable with that of the operational phase. Industrial sites and subsequently industrial buildings are found to be relatively more disturbing than many other objects [37]. An increase in their number will result in deterioration of the experiential value. Three components can be distinguished for assessment purposes:

- The nuclear island. This building is the strongest determining factor with regard to experiential value, due to this element being the most sensitive, psychologically speaking. After all, the volume is associated with radiation and therefore with hazard. The sense of experience strongly depends on the height of the building, while the design is also important. The more it resembles a standard industrial volume, in keeping with surrounding industrial volumes rather than the archetypal dome which is associated with nuclear energy, the less the building will have a negative connotation.
- The chimney. Due to its great height, this element will always be visible at a great distance, regardless of the choice of variant. However, a number of comparable chimneys are already located at Research Location Petten, which are not directly associated with the nuclear activities.
- The other PALLAS industrial buildings. These are comparable with other industrial buildings present at Research Location Petten, in terms of dimension and volume. They are often hardly visible at all in relation to the dunes.

Construction height variants

Visualizations of the various construction height variants are given in the background report on Landscape, Cultural history and Spatial quality (Appendix F10). Variant B3 has an extremely dominant and large volume from virtually all viewpoints, and will be explicitly more conspicuous than the current HFR. B3 also exceeds the maximum construction height as stated in the current zoning plan. The construction height of variant B2 is the maximum possible height according to the zoning plan, based on an amendment by the authoritative body. The building volume of B2 is much less dominant than that of B3. From most viewpoints, the new construction of variant B2 is in line with the current building. However, B2 is more visible than the current HFR from a number of important viewpoints in the polder. This is mainly due to the scope (height in combination with width) of the new construction volume. The construction height of variant B1 is the maximum standard construction height according to the current zoning plan. This brings the building volume into line with existing building volumes, making it even smaller than a number of the existing company buildings at Research Location Petten. B1 is therefore much less visible, and regularly not at all, from the viewpoints under consideration.

Cooling variants

Two impacts are important for the variant which uses cooling units based on water evaporation (cooling variant K3):

- The visibility/perception of the installation itself.
- The visibility/perception of condensation (visible water vapor as a result of evaporation).

The height of the installation (14.5 m + NAP[42]) is comparable with the average height of the row of dunes between the installation and the polder (approximately 11 – 14 m + NAP). It is therefore hard to see it "over the dune" from close by, while the limited height difference versus the dunes also makes the cooling units indistinctive from a greater distance. The cooling units are explicitly lower than many of the surrounding buildings.

In terms of disturbance, the cooling installation is not expected to be regarded any differently to the standard buildings. The same does not apply to the condensation formed, which evokes an association with smoke, which in turn has a negative tone because it gives a sense of harmful substances being emitted. This will be particularly negative in the case of a nuclear installation, despite this only concerning water vapor in reality.

Within the current design framework, condensation may be formed at exterior air temperatures below 11°C (see Figure 63 as an illustration). The conditions for formation of condensation are almost exclusively dependent on the temperature, due to the water evaporation process. However, the dryer the air, the more quickly condensation will dissolve and therefore be less voluminous. A precise indication cannot be given of the degree to which this will occur. Figure 62 shows the average number of hours during which the temperature drops below 11°C, for a 10-year period.

Over a complete year, the conditions under which condensation may be formed apply more than 50% of the time, though the conditions for condensation formation are not equal throughout the year. Figure 62 distinguishes between summer & winter and day & night[43]. The difference in summer and winter time is relevant, as many more people, mainly recreational visitors and tourists, frequent the area in the summer period rather than in the winter period. The impact is therefore greater in the summer period than in the winter

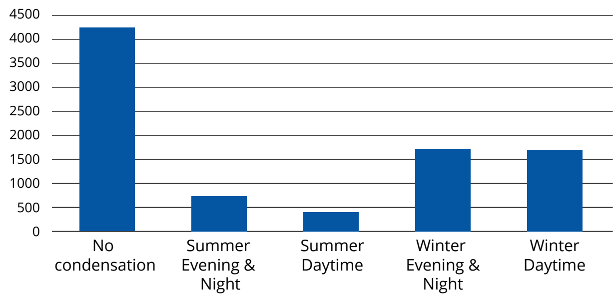

Figure 62 Average number of hours per year that the exterior air temperature drops below 11 degrees Celsius (KNMI weather station in de Kooy, 2006 - 2015 period)

42 According to the Design framework, the maximum height of a cooling unit is 11 m. The cooling units are at 3.5 m + NAP.

43 With a view to the varying starting dates of summer time and winter time, we have opted to round this off to complete months. Summer time: April-October; winter time: November-March. Daytime period: 06:00-17:59; evening and nighttime: 18:00-05:59.

period. Relatively little condensation is formed in the summer period, and substantially more in the winter period. With regard to the total number of hours during which condensation formation conditions apply, approximately 75% fall within the winter period. The difference between day and night is relevant, as the perception of condensation is expected to differ in darkness or light. In daytime, the condensation will be proportionate to its direct surroundings. In darkness, the visibility will depend on the degree of reflection of ground light, which may result in a visible contrast in a darker context. This is extremely difficult to estimate beforehand however. During the winter period, there is relatively little difference between the number of hours in daytime and nighttime during which condensation may form. During the summer period, there is a clear difference, with very limited occurrence in daytime.

The condensation will be less visible during misty weather. Condensation occurs under conditions whereby visibility is less than 900 m, during an average 2.2% of the time on an annual basis. The condensation is then no longer visible from Sint-Maartenszee, for example. Another factor is the wind speed, as the condensation will disperse more quickly at higher wind speeds. The degree to which this will occur is difficult to indicate, in much the same way as the humidity conditions. The percentage/hours given is therefore based on a worst-case scenario. In practice, clearly visible condensation will actually occur during a lesser number of hours.
Parallel to the row of dunes, the condensation will be as wide as the installation itself (approximately 50 m)[44] . In height, it will be approximately 10 m to 15 m and therefore 25 m to 30 m + NAP. It is difficult to predict a precise maximum or average height, as this depends greatly on local weather conditions. Figure 63 gives an impression of the average formation of condensation.

For variants using cooling water, the new pipelines required in the dunes for variants K1 and K2 will not be problematic, when considering the dynamic character of the dune system. A pipeline route for K1 through the polder will also not have any major spatial impact.
Variant K2, which uses water from the North Sea, will have a strong impact on the experiential value, due to the platform of the inlet point being visible close to the beach. This has a considerable negative impact on the greatly appreciated natural and unspoiled image of the area. People at the seaside are confronted with Research Location Petten and PALLAS, which are otherwise largely concealed behind the dunes.

Figure 63 Reference condensation formation of cooling installation

Usage value
With regard to cooling variant K1, only the land use above the pipeline routes in the polder is relevant. However, there is a 1.50 m ground margin above the pipeline(s), which will hardly pose a limitation for the land use in practice. The only potential limitation is for extreme forms of deep plowing and the installation of the deeper-lying drainage. Neither activity is probable here and can, if necessary, be conducted in a manner without conflict with the pipeline. Any other agricultural activities which might be problematic (greenhouse horticulture, etc.) are prohibited by the zoning plan.

Future value
The dynamic processes in the dunes will not be significantly influenced, either positively or negatively, during the transition and operational phases. There are also no landscape processes in the polder which are influenced by the temporary realization of the LDA.

15.3.2 Impact assessment

Construction phase
Table 97 presents the impact assessment for the construction phase of the PALLAS-reactor. An explanation of the assessment criteria is then given per criterion.

Physical degradation
No significant effects are to be expected in terms of physical degradation of landscape characteristics/values, historic geographical elements or historic (urban) architecture, due to either the construction height variants or the cooling variants. These are therefore all assessed as neutral (0).

Experiential value
The impact with regard to the experiential value is limited to the presence of the LDA in the polder. This is a temporary impact of limited scope in an area of relatively limited value, partly because the area is already negatively influenced by the presence of wind turbines and the visible Research Location Petten. There is however some degree of impact, which results in a negative score (-) for the construction height variants. There is no differentiating impact between the variants.

Usage value
With regard to the usage value, the LDA will have a negative impact in the form of fragmentation and poorer accessibility of agricultural land. However, this impact is extremely local, temporary, of a very limited scope and also easily preventable within the search area. The impact score is therefore neutral (0) for the construction height and cooling variants.

44 According to the Design framework, a single cooling unit is 12.5 m wide. There are four of these units at a short distance from each other.

Table 97 Impact assessment for Landscape and Cultural history, construction phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Physical degradation to landscape characteristics/values	0	0	0	0	0	0
Physical degradation to historic geographical elements	0	0	0	0	0	0
Physical degradation to historic (urban) architecture	0	0	0	0	0	0
Experiential value	-	-	-	0	0	0
Usage value	0	0	0	0	0	0
Future value		0	0	0	0	0

Future value
There is no impact on the future value during this phase. The impact score is therefore neutral (0) for the construction height and cooling variants.

Transition and operational phases
The operational phase is identical to the transition phase for the landscape, cultural history and spatial quality aspect, due to the spatial situation being the same. The impact scores are therefore also identical. Table 98 presents the impact assessment for the construction phase of the PALLAS-reactor. An explanation of the assessment criteria is then given per criterion.

Physical degradation
Cooling variants K1 and K2 can potentially have an impact on the landscape characteristics and values. The installation of new pipelines in the dunes can result in degradation of protected geological values. However, the dune system is naturally dynamic, and slight topographical changes are therefore not disturbing, as long as there is no degradation of the topography and topographical cohesion.
The expectation is that there will only be disturbance of the ground composition rather than degradation of the topography. As there is limited scope and impact on the landscape characteristics and values, but degradation cannot be excluded and because of the monument status, the impact is scored as negative (-).
No significant impact is to be expected in terms of physical degradation of historic geographical elements or historic (urban) architecture, due to either the construction height variants or the cooling variants. These are therefore all assessed as neutral (0).

Experiential value
With regard to the experiential value, there is a clear difference in impact between the construction height variants. There is no significant difference between construction height variant B1 and the reference situation. The impact score is therefore neutral (0). Construction height variant B3 results in a large and dominant volume which will have a strongly negative experiential value even at a great distance, also due to it being associated with nuclear activities. When considering this volume, the color or design will have little or no effect on a more or less positive perception. Due to the great impact, this is scored as extremely negative (- -). Variant B2 is between these two variants. It is certainly more visible than variant B1 and therefore more negative, but certainly not to the same degree as variant B3, in that it is visible but not dominant. Variant B2 is therefore scored as negative (-).

Table 98 Impact assessment on Landscape and Cultural history, transition and operational phases

Assessment criterion	B1	B2	B3	K1	K2	K3
Transition phase and operating phase						
Physical degradation to landscape characteristics/values	0	0	0	-	-	0
Physical degradation to historic geographical elements	0	0	0	0	0	0
Physical degradation to historic (urban) architecture	0	0	0	0	0	0
Experiential value	0	-	- -	0	- -	-
Usage value	0	0	0	0	0	0
Future value		0	0	0	0	0

Cooling variant K1 is not expected to have any significant impact with regard to the experiential value. It is therefore scored as neutral (0). Variant K2 will have a strongly negative effect on the experiential value, due to the platform being extremely visible in an open, virtually unspoilt natural landscape in front of the inlet point, clearly referring to the nuclear activities, which are otherwise concealed behind the dunes. Despite the fact that the horizon will not remain unspoiled in the future due to the autonomous development of wind farms at sea, this installation located so close to the coast is much more visible and dominant. It can only be scored as extremely negative (- -), especially considering the great value attributed to the unspoiled, empty, vast, natural coastline in the various policy documents, whereby violation of part of the coastline is also regarded to be violation of unity of the entire coastline.
The formation of condensation in cooling variant K3 will be discernible for most of the year, though mainly in the winter period. This is precisely the period in which the least number of people frequent the area (few recreational visitors and tourists), so that the impact is limited. The scope of condensation formed is comparable with the impact of construction height variant B2. Unlike the building, this is a dynamic situation which depends very much on the weather conditions. It will therefore have less impact than the construction height variant B2, though it is of such a scope and frequency that it must however be scored as negative (-).
The combination of construction height variants and this cooling variant is relevant. In B1, the formation of condensation will be the representative element for PALLAS in the surrounding area. The formation of condensation is therefore extremely relevant and its impact weighed more strongly. B2 will result in a visibly wide "block" on the horizon. Its length makes it less of a point-based element and more of a line-based element, therefore more in keeping with the line of the dunes located between the installation and the polder. B3 will always be more conspicuous than the condensation formed. The impact of the formation of condensation itself is therefore extremely insignificant versus the considerable negative impact of B3. The impact of condensation formed in K3 remains negative in all cases.

Usage value and future value
There is no significant impact on the usage value and future value during this phase. The impact score is therefore neutral (0).

15.4 Mitigating measures

Hardly any negative impacts are identified in the impact assessment. However, there are still possibilities for optimization in terms of detailing and incorporation of the proposed activity.
The following mitigating measures apply for this purpose, subdivided into LDA, nuclear island and cooling variants:

LDA

- Incorporate the LDA, outside of Research Location Petten, in the polder in such a manner that no (or as few as possible) ditches need to be filled or intersected. Also respect the existing land parcel structures where possible and avoid fragmentation of agricultural land.
- When designing the LDA located outside of Research Location Petten, measures can be taken to limit the negative image of the site, for example by treating the site as a (farm) yard and using (temporary) landscape planting around the boundary. Storage facilities and buildings should be kept as low as possible. Measures can also be taken to limit lighting radiation wherever possible. If the LDA can be optimally incorporated so that it is no longer recognizable as a working site, the impact score may even become neutral.

The nuclear island

- When detailing the design of the nuclear island and other buildings, the lower and more compact the buildings are, the better they will score in terms of experiential value. The architectonic detailing strongly determines the result. The more inconspicuous (in color and shape), the better. The new construction will also be more readily accepted if it is not immediately associated with a nuclear installation. There must also be attention for the organizational design of the buildings. Together with the site layout, this must be designed in such a manner that the current dunes are minimally degraded and the natural surroundings respected where possible. An optimal architectonic design will certainly result in a great improvement, but not to the extent that this will change the impact scores for experiential value, due to these being mainly linked to the visibility of the building mass.
- Besides optimization of the buildings, the surrounding area can also be adapted in order to keep the buildings out of sight wherever possible, for example by raising the dunes at strategic spots and possibly even adding natural vegetation. This adaptation may result in the B2 score for the experiential value improving to neutral, due to the nuclear island even being largely hidden from view. However, this is not necessarily an actual solution, because of the natural values involved. Possibilities could be examined in consultation with organizations such as the Netherlands Forestry Commission. The transition from the surrounding area to Research Location Petten can be improved in accordance with the wishes of the municipality of Schagen, through better incorporation of the site fencing along the Westerduinweg in particular, for example. Possibilities include raising the dunes and planting vegetation in order to hide the fencing from view. While this will result in an improvement, it will not be sufficient to change impact scores.

Cooling variants

- Although installation of the pipelines for cooling variants K1 and K2 in the dunes towards the North Sea will have little impact, the preference will always be to follow existing pipeline routes in order to minimize disturbance

to the existing topography and therefore also the geological values occurring here. If an optimum combination is achieved, the assessment of physical degradation of the landscape character may change to neutral during the operational phase, as there will be no significant further disturbance on top of the disturbance caused by the previous pipeline.
- A drilled pipeline with gravity flow for cooling variant K1 is greatly preferable to a relatively superficially excavated route. Firstly, it only requires a relatively simple inlet construction rather than a pumping station on the Noordhollandsch Kanaal. This will have less impact on the canal and be easier to incorporate. Although the usage value is hardly affected by the superficial route (neutral impact score), a gravity flow route will be drilled deeper and therefore have even less impact on the usage value. The ground will also not be disturbed, and degradation of agricultural land quality is therefore excluded. Pipeline routes through the polder must be connected parallel to existing structures (ditches, roads, etc.) wherever possible. While this will not result in a change in impact score, it will improve the situation. A zigzag, diagonal, freely lying route must be avoided wherever possible. In this way, patterns and usage can be minimally influenced. Should a pumping station be required on the Noordhollandsch Kanaal, it will need to be optimally incorporated in terms of architecture and landscape, with respect for the landscape and historic context. Once again, while this will not result in a change in impact score, it will improve the situation.
- If an inlet platform is required at sea, a great deal of attention must be paid to its location (distance to the coastline, etc.) and the architectonic design. The object must be as inconspicuous as possible. The impact score could become neutral if it is constructed underwater or at a great distance from the coast, as there will then be no visible experience from the beach. While optimal architectonic design, limitation of the visibility of the platform, also by limiting the illumination of the platform, and other such measures represent important improvements, they cannot deter from the fact that a (virtually) unspoiled situation is negatively influenced in an undesirable manner. The impact score therefore remains extremely negative.
- When opting for a cooling variant with cooling units (K3), the installation could be optimized to such an extent that the condensation formed is as small as possible (lower than the dunes) and as infrequent as possible. In the optimum situation, there would be no condensation. A dry cooling system would then need to be used, instead of the current wet cooling system. However, a dry cooling system does not work if the outdoor air temperature is too high. A hybrid cooling system which combines the two, will never result in compensation being formed, as the temperatures at which wet cooling is applied, exceed the target value of 11 ºC. If no condensation is formed, the experiential value score will improve to neutral.

15.5 Gaps in knowledge

There are no relative knowledge gaps in this phase. Extra details are required on the circumstances and duration of condensation formed on the basis of various weather conditions (temperature, humidity, wind, light/dark, etc.) for the further design and detailing of PALLAS in combination with the permit process, accessory study and SEA project. The exact conditions and scope of condensation formed is unclear.

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16 Archaeology

The following description of the Archaeology aspect is based on the Archaeology background report (see Appendix F11).

16.1 Assessment framework

16.1.1 Policy framework

Table 99 summarizes the relevant policy and relevant legislation and regulations for the Archaeology aspect, along with an indication of their relevance for the project. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Archaeology.

Table 99 Policy, legislation and regulations on Archaeology

Policy plan, law, regulation	Description/ Relevance for PALLAS
Valletta Treaty, European treaty, 1992	The Valletta Treaty states that archaeological material in the ground is irreplaceable and that it should only be excavated if preservation in situ is not (longer) possible. The party disturbing the ground must pay for the archaeological survey. It also states that measures must be taken for the protection, conservation and preservation of the archaeological heritage.
Heritage Act, Dutch government, 2016	The Dutch Heritage Act harmonizes existing legislation and regulations to form a single Heritage Act for the management and conservation of cultural heritage. Until the Dutch Environmental Planning Act comes into force, those articles of the Dutch Monuments Act 1988 which are not included in the Heritage Act (such as rules regarding environmental permits and zoning plans) will continue to apply.
Archaeological Heritage Management Act (WAMz), Dutch government, 2007	The Archaeological Heritage Management Act is a revision of the Monuments Act 1988, among others, and addresses the protection of both man-made and archaeological monuments and the protection of archaeological heritage. Where possible, preservation in-situ in the ground is preferable. If this is not possible, an archaeological survey must be conducted, and the initiator/ disturber of the ground is responsible for costs incurred in the survey.
Monuments Act, Dutch government, 1988	The Monuments Act regulates the protection of buildings (national or municipal monuments), of heritage towns or villages and of objects / combinations listed on the (provisional) UNESCO World Heritage list. Archaeological monuments can also be designated at the national level. Finally, municipal authorities are entitled by law to formulate a monuments regulation as the basis for designation of municipal archaeological monuments.
Archaeological Heritage Management Decree (BAMz), Dutch government, 2007	This decree represents further detailing of the Monuments Act 1988, revised on the basis of the Archaeological Heritage Management Act, which includes regulations pertaining to the archaeological excavation permit, for example.
Quality norm for Netherlands Archaeology (KNA, version 4.0), Central Board of Experts, 2005	The KNA contains minimum requirements with which archaeological surveys and the management of archaeological finds and documentation must comply. The KNA also establishes requirements for those actors conducting the archaeological survey, including a description of the minimum combination of actions to be conducted in order to comply with the basic quality requirement. The process steps (and any relevant specifications) given in the norm are a minimum requirement.
Archaeology policy, municipality of Schagen	The valuation and designation of valuable archaeological areas and policy regulations regarding their management and preservation, is given in the municipality of Schagen archaeology policy (see Figure 64) [76]. This valuation and designation of valuable archaeological areas is registered by the municipality in a municipal archaeological policy advisory map. Such maps are largely determined on the basis of the location of the valuable archaeological areas in the landscape. Further, the municipal potential maps include existing archaeological sites and patterns of use and habitation.

16.1.2 Assessment framework and methodology

The assessment criteria for the Archaeology aspect are given in the following table (Table 100). Table 103 gives the assessment scoring for known archaeological values. Generally speaking, there will be no positive impact in terms of archaeology.

Study area

A distinction is made between the various study areas for the Archaeology aspect. These concern the PALLAS study area, the area where the nuclear reactor will be built, the search area for the LDA and the study area for the zones where cooling pipelines will be installed. This is shown in Table 100 and Figure 66.

Assessment framework

The tables are followed by an explanation of each assessment criterion, and details of the method applied. A quantitative/ qualitative method has been used for each criterion. This means that an assessment is made according to a qualitative assessment scale, on the basis of quantitative basic data, such as number of hectares of an area with an expected archaeological value.

Degradation of areas with expected archaeological value
Construction height variants
In order to reach an impact assessment and comparison, it has been determined whether and if so, which of the

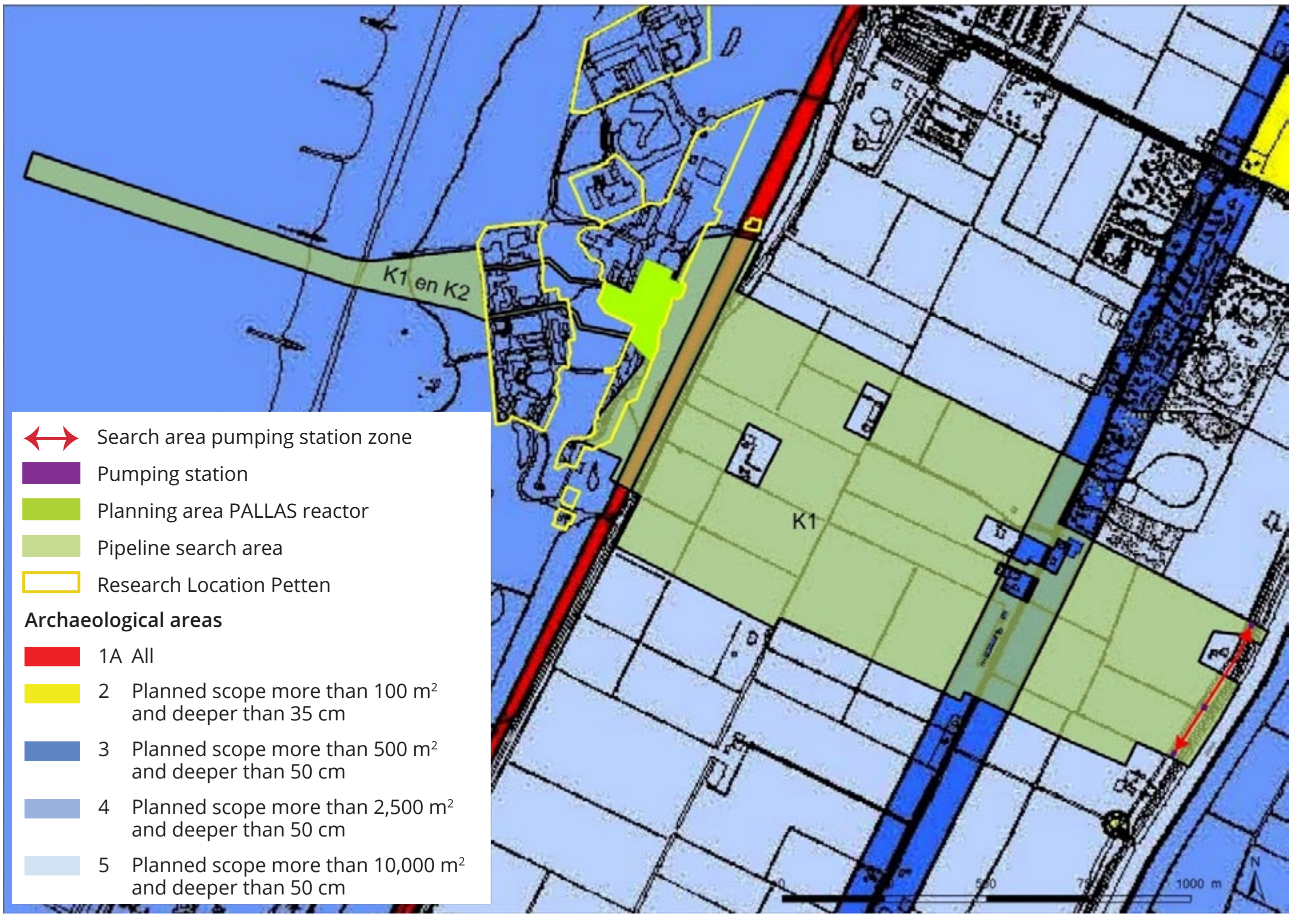

Figure 64 Archaeological areas with legend [50]

Table 100 Assessment framework for Archaeology aspect

Assessment criteria	Explanation
Damage to areas with expected-archaeological value	Quantitative assessment takes place if the impact can be defined through quantification (for example the number of hectares or square meters) and/or if there are other generally accepted quantitative methods for determining the impact.
Physical or indirect damage to archaeological evidence (known archaeological value)	Quantitative number of known values, including assessment (qualitative).

construction height variants may disturb the layer of possible archaeological value at approximately 10 m depth [51]. The greater and deeper the disturbance, the more negative the variant is scored. This is due to the fact that the depth of the archaeological layer may fluctuate, so that the archaeological values are possibly located even deeper in the ground. Deeper disturbances therefore carry a greater risk that a valuable archaeological layer will be disturbed.

Cooling variants

In order to reach an impact assessment and comparison, the intersection surface area of the various cooling variants through the municipal archaeological areas was calculated in square meters (m^2) (see Figure 64). The archaeological areas 1A, 1B, 2 and 3 were considered as a coherent area with a (medium) high expected value. This limits the number of classifications and simplifies comparison of the variants. Moreover, this is a worst-case approach. Intersections in the 1A, 1B, 2 and 3 areas have therefore been added together and given as a total impact per variant.

The archaeological areas 4 and 5 are defined as areas with a low expected value. The intersection surface area of the archaeology areas 4 and 5 have therefore been added together, though the large potential disturbance surface may bring them above the permit-free limit for archaeological survey, and they have therefore been included in the impact assessment.

In order to reach an impact assessment, the study considered the intersection surface area of the two cooling variants through the areas with expected archaeological value (areas 1A, 1B, 2 and 3 and areas 4 and 5). Two cooling variants were studied, as these were relevant for the assessment (K1 and K2)[45]:

- The design for cooling variant K1 distinguishes between a

45 The percentage division of the intersection surface area in the impact assessment is an arbitrary breakdown required in order to reach a comparison.

cooling pipeline system using 1 or 2 pipelines [52]. In the case of 2 cooling pipelines, the disturbance will concern a trench, 8.5 m wide and 2.60 m deep. In the case of 1 cooling pipeline, the disturbance will concern a trench, 7.5 m wide and 2.90 m deep. This impact assessment is based on the most harmful method for the Archaeology aspect, and will therefore consider the impact of 2 cooling pipelines installed by means of open excavation from the pumping station to the PALLAS-reactor.
The surface area disturbance due to excavation of the trench for supply pipelines is 14,373.5 m². An extra 35 m² extra surface area disturbance is added for the construction of the pumping station.

- Although the pipelines will not be dug in over the entire length of the route in cooling variant K2, there may be disturbance of archaeological remnants in the top of the seabed over the entire route. The entire length of the cooling pipeline is therefore included in the impact assessment.

Degradation of areas with known archaeological value
For each construction height and cooling variant, it was determined how many known archaeological values were present in or adjacent to the variants, with disturbance of the ground (50 m). If 0 to 10 archaeological values are located in this zone, the variant is scored as negative. If 10 or more archaeological values are located here, the variant is scored as extremely negative.

Percentage surface areas for the impact assessment
The total surface area of the two cooling variants with cooling pipelines (K1 and K2) was then subdivided into percentages to allow interpretation according to the qualitative assessment scale (0, - or - -).

- In variant K1, 0 – 14,245 m² is in the < 50% disturbance category and 14,243 – 28,485 m² is in the category of 50% disturbance.
- In variant K2, 0 – 12,806 m² is in the < 50% disturbance category and 12,807 – 25,612 m² is in the category of 50% disturbance.

The division is based on the total surface area of disturbance on each side of the nuclear island, per pipeline variant. As the location of cooling variants K1 and K2 has yet to be determined but they are clearly distinctive from one another, this impact assessment is based on disturbance of the archaeological values within the search areas for these variants.
The table below (Table 101) gives the intersection in m² per cooling variant for each area of archaeological value (according to the policy advisory map, see Figure 64). The square meters for archaeology areas 1A to 3 were then added together, as were the square meters for archaeology areas 4 and 5 in order to reduce the classifications and to arrive at an impact score of neutral, negative and extremely negative. This was based on the principle that the intake and outlet pipelines of variant K2 are installed in a single trench. There is no ground disturbance for realization of variant K3.
The number of m² disturbance for cooling variant K1 also includes the area required for construction of the pumping station. This translates into a disturbance of 12 x 10 m. These extra square meters of disturbed ground have been added to the total disturbance for cooling variant K1.
The disturbance surface area of 40 x 60 m for the sea platform has been included for cooling variant K2, as well as the surface area of the cooling pipeline on the seabed.

Table 101 Intersections in policy zones within search areas of cooling variants (in square meters)

Variant	W 1a	W 3	W 4	W 5	Total intersection 1a+3	Total intersection 4+5
K1	357	1411	15,002	11,714	1768	26,716
K2	-	-	25,615	-	-	25,615
K3	-	-	-	-	-	-

Relevant phases
Only the construction phase is relevant for the Archaeology aspect, as there can only be an impact on known and expected archaeological values during this phase.

SEA assessment scale
Expected archaeological values
Table 102 gives the scoring method for expected archaeological values. The scoring is based on the total (quantitative) m² intersection of the various archaeological policy classifications on the municipal policy map.
The table distinguishes between areas with a (medium) high

Table 102 Scoring of assessment for Archaeology, expected archaeological values

Score	Meaning	Explanation of (medium) high expected archaeological value (1A – 3)	Explanation of low expected archaeological value (4 – 5)
++	Extremely positive impact	-	-
+	Positive impact	-	-
0	No impact	No m² intersection in areas of expected archaeological value	Little or no m² intersection in areas of expected archaeological value 0-50%
-	Negative impact	Limited m² intersection in areas of expected archaeological value 0-50%	Large m² intersection in areas of expected archaeological value > 50%
- -	Extremely negative impact	Large m² intersection in areas of expected archaeological value > 50%	

expected archaeological value and those with a low expected archaeological value. The impact on archaeology is determined on the basis of these criteria. If there is disturbance of both high and low archaeological values, these are added together and considered a compounding impact, resulting in an extremely negative (- -) score.

The only way to determine whether there are actually archaeological values at these locations is via a field survey. It should be noted that a low probability zone simply means that archaeological values are less likely to be present than in higher probability zones. There is always the possibility of archaeological values being present.
Interventions in the ground will always score negatively for archaeology, as mandatory reporting always applies, even in a low probability zone or if a ground intervention falls under the surface area requiring a survey. In the unlikely case that archaeological remains are encountered, this mandatory reporting requirement results in work being halted until these remains have been examined. This is a risk in terms of the planning and costs for the executing party.

Known archaeological values
Table 103 gives the assessment framework for known archaeological values, as well as translation of the qualitative assessment into a quantitative classification. The relevance of the known values has therefore been assessed. There are locations of finds registered purely for administrative purposes, for example, because their origin is unclear. Such known values are therefore not included in the quantitative assessment.
The greater the number of known values, the more negative the score (this is an arbitrary breakdown required in order to reach an impact score and to indicate any distinction between alternatives).

Table 103 Scoring of assessment for Archaeology, known archaeological values

Score	Meaning	Explanation
++	Extremely positive impact	-
+	Positive impact	-
0	No impact	No known archaeological values located at or near to an alternative.
-	Negative impact	0 – 10 known values at or near to an alternative*.
- -	Extremely negative impact	> 10 known values at or near to an alternative*.

* Archaeology cannot score positively because the condition of remains can never be improved. In-situ is therefore neutral and ex-situ negative.

16.2 Current situation and autonomous development

16.2.1 Current situation

When assessing the impact on archaeology, a distinction is made between two different study areas:
- The first concerns the PALLAS study area, i.e. the area where the nuclear reactor will be built.
- Secondly, there is a 'larger' study area concerning the zones in which the cooling pipelines may be installed. This larger study area is marked green in the various figures.

There is little information on the situation in the study areas prior to the Middle Ages. The current dune area was formed during the late Middle Ages and has a strongly accentuated topography with crests sometimes reaching tens of meters above sea level.
We have no idea how much of the old landscape dating from the prehistoric era and the early Medieval peat excavations has been preserved under the layers of sand. The sea may well not only have deposited a large volume of sand, but also eroded the older deposits such as peat.
The village of Petten itself has been flooded and moved on various occasions. A significant factor for the study areas is that Petten disappeared one last time during the 20th century, but this had nothing to do with the sea. The German occupying forces demolished the village in 1943 in order to construct the Atlantic Wall coastal defenses. This Atlantic Wall was built in the dunes along the entire coast, and comprises bunkers and fortifications with empty spaces in-between. A bunker was constructed in Petten. It is unclear whether anything was actually built in the PALLAS study area itself [53] [54].

PALLAS study area
Analysis of historic maps is an effective approach in order to gain insight into the land use in the PALLAS study area in the Modern era. None of the historic maps consulted show any development of buildings in the study areas [55] [56] [57]. The ECN Energy Center Netherlands site became developed from the 1960s on [57].
The PALLAS study area has a high archaeological expectation for archaeological remains from the Late Paleolithic to Mesolithic periods covered by sand deposits [51].
There is a medium archaeological expectation for archaeological remains from the Neolithic period to the Bronze Age and from the Late Middle Ages to the 11th century, and a low archaeological expectation for remains from the Mesolithic period, the Bronze Age to the Late Middle Ages and from the 11th century to the Modern era.
A field survey [51] showed the ground in the study area to have been disturbed down to 0.8 to 1.9 m-gl. Below that,

the expected ground composition was indeed discovered: dune deposits on salt marsh deposits on peat deposits on salt marsh deposits on peat deposits on cover sand deposits. Based on the results of this survey, it is concluded that there is one level at which archaeological remains may be found: the top of the cover sand (from 10.3 to 11.8 m-gl; 6.7 to 8.6 m - NAP). A fragment of burnt hazelnut shell was found at this level, and may be proof of the occurrence of an archaeological site in the top of the cover sand.

Study area for pipelines
A flint sickle was discovered on the beach at 950 m north-west of the PALLAS study area (Archis identification number 18502). The sickle has been dated to the Late Bronze Age to Middle Iron Age. This discovery (now known as the find location) is in the pipelines study area. A stone ax was discovered at 1200 m north-east of the PALLAS study area (Archis identification number 228100). The ax was found on a field and has been dated to the Late Neolithic to Middle Neolithic period. This discovery (now known as the find location) is north of the search area for pipelines.
An earlier bore hole survey (Archis number: 53987) conducted by Hollandia on Petten and Camperduin beach in 2012 did not discover any archaeological layers or finds in the first 1.20 m-gl. The advice was therefore not to conduct further surveys [58].

Grontmij conducted an exploratory bore hole survey in 2011, within the study area for pipelines (Archis number: 46746). This survey showed that the area under study mainly comprises sea and mud flat deposits. The top of the subsoil has been disturbed within the entire area surveyed, as a result of construction activities and infrastructure work. The bore hole survey did not discover any archaeological indicators[46]. The advice was therefore not to conduct further archaeological surveys [59].

Find locations
The find location marked yellow (420255) concerns the archaeological indicators discovered during the RAAP survey [51].
There is a find location numbered 228100 to the north-east of the search area, which concerns a flint ax found in 1993 (type: Fels-Oval ax) dating from the Middle or Late Neolithic period. The ax was an individual find on a field and has not been named as part of any type of complex.
There are no Archaeological monuments (AM mapped sites) or other known values in the vicinity of the cooling variants (see Figure 65).

Six earlier surveys in and around the study area have been registered in ARCHIS III. This concerns the following survey notifications (see Figure 66):

Figure 65 Find locations [60]

46 An archaeological indicator, such as for example charcoal, can indicate an archaeological site, it is no real proof of a find location. A find location is a location recorded in ARCHIS III, where an actual find has been made, of an artifact or a shard.

- 10919: A survey by RAAP in 1999. Archis has no further information on this survey.
- 36261: Within the scope of the plans to reinforce the Noord-Holland dunes, ARCADIS Nederland B.V. was commissioned by the Water Authority for Northern Holland and the Province of Noord-Holland to conduct archaeological desktop research (together with Oranjewoud; Archis number 45537) in 2009 and 2011. This survey showed that a number of archaeological zones of a diverse nature and scope and a variety of expectation values can be designated within the planning area. A supplementary bore hole survey was therefore advised.
- 46746: Based on an earlier desktop survey (OMG 45537 Oranjewoud), the municipality and the Water Authority for Northern Holland agreed to survey a number of zones in more detail by means of an exploratory bore hole survey. This survey was conducted by Grontmij in 2011. Following the survey, the advice was to not conduct further archaeological surveys.
- 51697: RAAP [51] conducted a desktop survey and inventory field research (exploratory phase) in 2014, the results of which are described in this document.
- 53987: Hollandia conducted a type of bore hole survey in 2012, which drilled to a depth of 1.20 m-gl. No archaeological layers or finds were discovered in doing so. The advice was therefore not to conduct further archaeological surveys.

16.2.2 Autonomous developments

There are no autonomous developments in the archaeological situation, in the sense of new archaeological values developing during the brief time period to 2026. It is however possible that developments other than the construction of the PALLAS-reactor, result in degradation of archaeological values during this period. At the time of formulating this SEA, no other developments are planned in the study area which might influence the archaeological values in the area.

Figure 66 Survey notifications [60]

16.3 Environmental impact

16.3.1 Impact description

This paragraph visualizes the environmental impact of the various construction height and cooling variants for the Archaeology aspect, based on the assessment framework. The assessment framework, as explained in paragraph 16.1, is used to assess the impact, and a description is given of the environmental impact per assessment criterion (see paragraph 16.1.2). Only the construction phase is relevant for the Archaeology aspect.

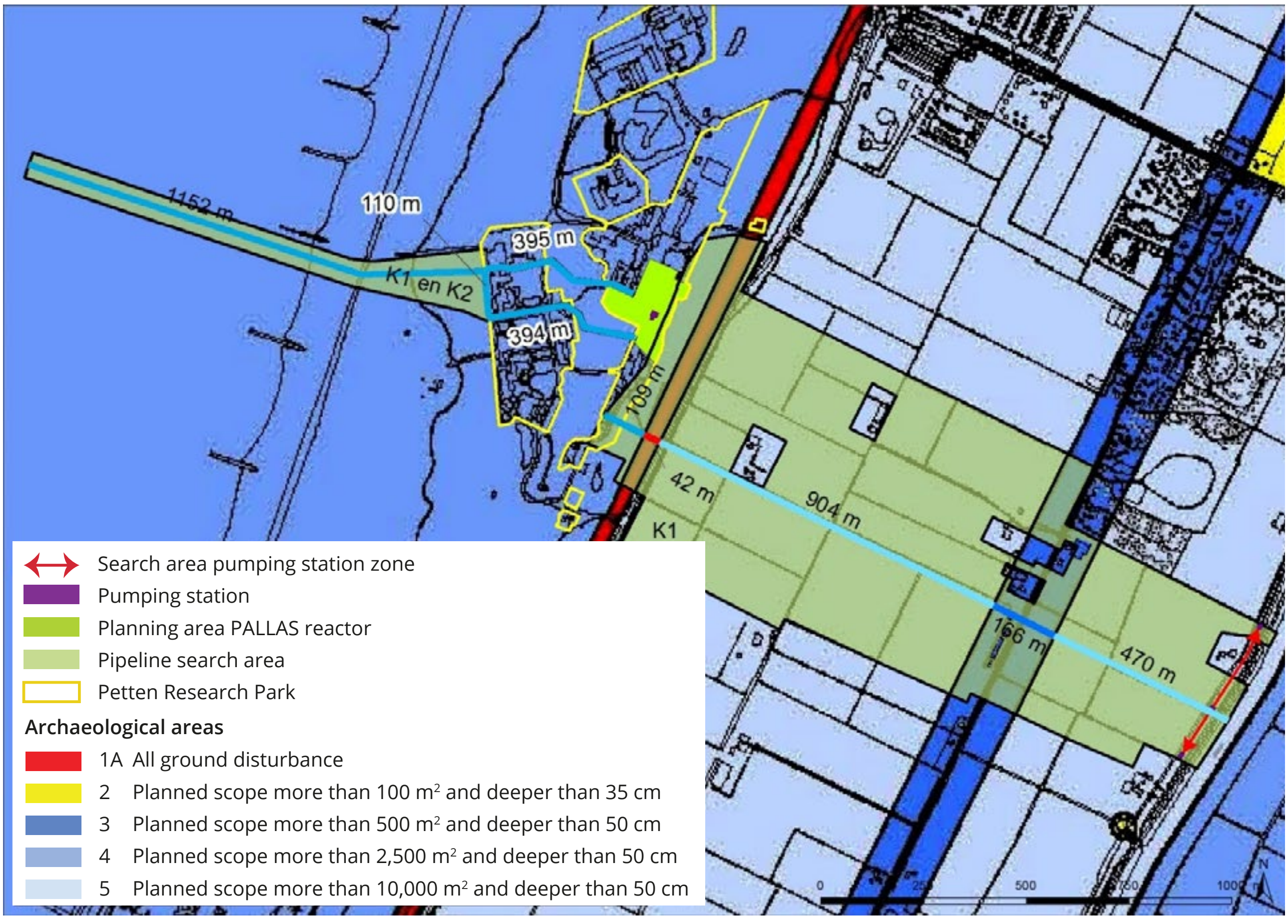

Figure 67 Lengths of the intersections of the installation trench for the cooling water pipelines. The light blue line indicates the location and length of the cooling water pipelines

16.3.1.1 Construction phase

Expected archaeological values

Figure 67 gives the various archaeological policy classifications on the municipal policy advisory map. The width of the disturbance surface used to calculate the total disturbance surface area, is derived from the report on the technical design of the PALLAS-reactor [52] (consulted on 11 November 2016). The length of the installation trench for the cooling water pipelines used to calculate the disturbance surface area, is given in Figure 67.

Cooling variants

The discharge pipeline of cooling variant K1 is to the west of the PALLAS-reactor. There are three different route options for this cooling water pipeline to run into the sea [52]. The impact assessment assumes the longest and widest design, in this case the design which features a double discharge pipeline. The surface disturbance of this design for discharge of the cooling water is 14,076 m².

The total surface area disturbed by cooling variant K1 is 28,484.5 m².

The supply pipeline of cooling variant K2 starts 700 m from the coastline and is a double supply pipeline for which the trench is 11 m wide. The discharge pipeline runs to 300 m from the coastline. The trench for the discharge pipeline is 8.5 m wide. The total surface area disturbed by cooling variant K2 is 25,258 m².

The platform at sea (cooling variant K2) takes up 40 x 60 m space with a cooling water pipeline over the seabed and 6 foundation piles with 800 mm diameter, 15 m into the seabed, 800 m from the coastline. The surface intersected by foundation piles is 3 m². 4 foundation piles temporarily on the seabed result in a surface area disturbance of 2 m².

Percentage surface areas for the impact assessment

The surface area disturbance is identical for all construction height variants (60 m x 60 m). There is however a difference between the three construction height variants, regarding the way in which the ground is disturbed, though this makes no difference for the degree to which archaeological remains can be preserved. Despite construction height variants B2 and B3 not requiring total excavation for the construction of the nuclear island (unlike construction height variant B1), the underlying archaeological layer is completely disturbed due to the installation of piles. Preservation in situ is therefore no longer possible.

A trial excavation must be conducted prior to installation of the piles, in order to survey any archaeological remains. This results in disturbance comparable to excavation for the construction of the nuclear island according to construction height variant B1. All construction height variants are therefore scored extremely negatively, and no differentiating table has been made.

With a view to the archaeological expectation given for this

area, the location of the pipelines for cooling variants K1 and K2 within the search area makes no difference for the impact on the Archaeology aspect. The intersection of the archaeological values is identical throughout the search area from the Noordhollandsch Kanaal to the nuclear installation, as the defined archaeological expectation zones are completely perpendicular to the pipelines. The score for the assessed cooling variants therefore applies to the entire search area, and also for the search area towards the sea. The archaeological expectation is identical throughout this area, and therefore so too is the impact score for the entire search area.
As an alternative for excavation for the purpose of installation of cooling water pipelines, another option is to drill the cooling water pipelines. The pipelines are then drilled at a depth of between 4 and 8 m-gl. In that case, no open excavation is required, making this method less detrimental for any archaeological remains occurring here. However, when considering the architectural layer at a depth of approximately 10 m-gl, which may possibly fluctuate, there may also be archaeological remains above this layer which may be disturbed as a result of drilling. This method may therefore also have a detrimental impact on the Archaeology aspect. The assessment therefore does not assume a total reduction of impact, so that the score remains negative.

Known archaeological values

The construction height variants of the PALLAS-reactor have no differentiating impact with regard to known archaeological values. In all three construction height variants, the location of the PALLAS-reactor affects a known archaeological find location. This find location will be disturbed during the construction phase.
Policy zone 1a concerns the historic sand dike in this area, which will be disturbed by variants K1 and K2.

16.3.2 Impact assessment

The known and expected archaeological values are used in order to arrive at the impact assessment in Table 104. Only the construction phase and cooling variants are relative for the Archaeology aspect, see paragraph 16.1.2. This assessment is explained in more detail after the table.

16.3.2.1 Construction phase

Expected archaeological values

Construction height variants

Seeing as all construction height variants foresee a depth of 30 to 35 m under ground level for the foundation piles and/or the nuclear island itself, it is unavoidable that the valuable archaeological layer found 10 m under ground level, will be disturbed. All construction height variants for the nuclear island (B1 – B3) are therefore scored as extremely negative.

Cooling variants

Variant K3 scores most favorably in terms of cooling variants. The construction of cooling units (K3) removes the need for possible intersection of archaeological values by cooling water pipelines (score: 0).
Variant K1 and variant K2 both score negatively in terms of maritime archaeological remnants, as the realization of either variant can result in disturbance of shipwrecks and/or flooded villages. As these archaeological remnants can be expected to be located on the seabed, such remnants may be under threat upon installation of the cooling water pipelines and the platform in the sea. Variant K2 scores negatively (-) due to the ground disturbance being well above the permit-free limit of areas with a low expected archaeological value zone.
Variant K1 has an extremely negative score (--) as this entails the greatest intersection in an area with a relatively high archaeological expectation, as well as disturbing a large area with a low archaeological expectation value.

Known archaeological values

Construction height variants

The find locations will be disturbed as a result of construction of the PALLAS-reactor and/or installation of piles. All construction height variants are therefore scored as negative (-).

Cooling variants

Variants K1 and K2 will both disturb the historic sand dike. These two variants are therefore assessed as negative (-). Variant K3 does not have a cooling water pipeline and is therefore scored as neutral (0).

Table 104 Impact score table for Archaeology aspect, construction phase of PALLAS-reactor

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Expected archaeological values Degradation of areas with (medium) high and/or low expected value	- -	- -	- -	- -	-	0
Known archaeological values Physical or indirect degradation of known archaeological values	-	-	-	-	-	0

16.4 Mitigating measures

Mitigating measures may be the result of legislation, policy or wishes expressed by (parties in) the surrounding area. They can be applied whenever there is a negative impact, and there are opportunities for mitigation in this project.
There is no possibility for compensatory measures, in the sense of creating or adding archaeological values elsewhere (either ground traces or artifacts).
Archaeological values can be protected by leaving the ground in which the values are located undisturbed (preservation in situ). Disturbance of any archaeological values due to groundbreaking interventions can be prevented by means of adaptations to the plan. When the plan can be adapted prior to the permit being granted, any impact will be avoided and the impact score will be neutral.
Variant K3 does not require any mitigating measures in relation to the Archaeology aspect. In terms of the cooling variants, the choice for variant K3 is a mitigating measure, as it results in less ground disturbance than K1 and K2. As far as variants K1 and K2 are concerned:

- If the cooling water pipelines are installed above ground, a large section of the ground can remain undisturbed, which is favorable for the preservation of any archaeological remnants and the sand dike.
- The installation of the cooling water pipelines by means of directional drilling instead of an open excavation will strongly reduce the surface area to be disturbed, and reduce the damage to archaeological find locations.
- If the plan cannot be adapted, an option is to merely document the values which will be destroyed (preservation ex situ). This can be achieved by means of an archaeological excavation.

16.5 Gaps in knowledge

This SEA makes use of an earlier desktop and inventory survey by RAAP [51], ARCHIS III and the municipal policy of Schagen/Zijpe. One gap in knowledge concerns the lack of information on one of the survey notifications from ARCHIS III (Archis number no. 10919).
An inherent problem for archaeology is that it is partially based on limited information and assumptions. The desktop survey and probability/policy maps therefore refer to expectations.
This even applies to a certain extent to known values, as shown in the inventory survey of the exploratory phase: the survey has no knowledge of the scope of the actual find locations and the state of conservation of these values. It is in fact impossible to determine whether archaeological values are present, and their precise dating, scope, etc., until the ground is actually opened
Further archaeological studies will be required for construction of the B1, B2 and B3 construction height variants, in terms of the further detailing, integration and the permits required for that purpose (according to the policy advice by the municipality of Schagen). It is as yet unknown what form this research will take. An Archaeological study plan is being conducted for the PALLAS-reactor, in order to determine what options are possible and suitable for further archaeological survey.
If opting for cooling variants K1 or K2, no form of archaeological survey has yet been conducted for the pipeline route. Further research will be necessary should the surface area under assessment be exceeded (according to the policy advice of the municipality of Schagen) in the form of an archaeological desktop survey to begin with. This will determine whether further research is required. However, such research goes beyond the scope of this SEA, which only concerns amendment of the zoning plan for the purpose of the PALLAS-reactor. This research will in any case need to be conducted for the SEA project for the PALLAS-reactor and for the permits for installation of the cooling water pipelines.

17 Traffic

The following description of the Traffic aspect is based on the Traffic background report (see Appendix F12).

17.1 Assessment framework

17.1.1 Policy framework

Table 105 summarizes the relevant policy and relevant legislation and regulations for the Traffic aspect, along with an indication of their relevance for the project. There is also attention for vibrations within the Traffic aspect. While there is no statutory framework for vibrations, guidelines are applied. The relevant guidelines are given in the table hereafter. For a full explanation of the policy plans and relevance for PALLAS, please refer to the background report on Traffic.

Table 105 Policy, legislation and regulations on Traffic

Policy plan, law, regulation	Description/ Relevance for PALLAS
Sustainably Safe Road design (CROW technology platform publication 315 [61])	The ambition of Sustainably Safe Road design is to create a sustainable and safe road traffic system in which the risk of accidents is automatically already drastically limited due to the design of the infrastructure. Insofar as accidents still occur, the process which determines the severity of accidents is conditioned to such an extent that serious injury is more or less excluded. Traffic safety is assessed according to this framework.
SBR (foundation for building research) Measurement and assessment guideline for Vibrations	The SBR guideline pays great attention to measurement of vibrations, and is therefore generally the reference guideline when a vibration survey is prescribed and conducted. Besides attention for the measurement of vibrations, the guideline also includes an assessment system. The guideline applies only to vibrations occurring outside the building to be assessed, i.e. only those vibrations which reach the building via the ground and foundations.

17.1.2 Assessment framework and methodology

Het aspect Verkeer wordt beoordeeld conform het beoorThe Traffic aspect is assessed according to the assessment framework given in Table 106. An explanation of the assessment criteria is given below the table. worden de beoordelingscriteria toegelicht.

Study area

The study area for Traffic concerns the access roads which connect Research Location Petten and the LDA to the N9 road, see Figure 68.

Table 106 Assessment framework for Traffic

Assessment criteria	Description
Traffic safety	Road design complies with the Sustainable Safety principles
Traffic movements	Increased traffic (perceptual and absolute) versus maximum (desirable) intensity
Vibration hinder due to traffic	Increase in vibration hinder

Assessment framework

Traffic safety

Heavy goods transport (trucks) will be necessary to transport goods/sand/concrete to and from the site during the construction phase. Goods will be transported by ship via the Noordhollandsch Kanaal for this purpose, and a transfer location will be created near the Sint Maartensvlotbrug bridge, for transfer from ships to trucks. An LDA will also be created on the other side of the N502 road.

When examining the routes for construction traffic, the N9 and N502 past Petten will be used for the vast majority (75%) of the time. However, all the bulk material will be transported by ship to and from the transfer station near Sint Maartensvlotbrug The most direct route for traffic from the construction location to the transfer station is via the N502 and the Zeeweg. There has been an examination of whether the N9, N502/N503 and the Zeeweg are suitable for the construction traffic:

- The N502 is a regional access road, outside of the built-up area, 2x1 lanes with a speed limit of 80 km/h. The lane width is approximately 6.5 m, which is the minimum lane width for a regional access road. An important aspect for heavy goods traffic is that the lane width offers sufficient visibility (the so-called vision distance) so that drivers can see through bends and anticipate quickly enough.
- The N503 has the same layout as the N502. It is a regional access road, outside of the built-up area, 2x1 lanes with a speed limit of 60 km/h. Overtaking is not allowed on the largest part of the route, with the exception of agricultural vehicles) and there are a number of speed humps which serve as traffic calming devices. The lane width of the N503 is also approximately 6.5 m, the minimum lane width for a regional access road. Here too, it is important that there is good vision distance.
- The Zeeweg is a residential access road. Between the N502 and the Belkmerweg, the Zeeweg is outside the built-up area and has a speed limit of 60 km/h. This section of the Zeeweg is managed by the Water Authority for Northern Holland.
  From the Belkmerweg towards the Sint Maartensvlotbrug bridge, the Zeeweg is inside the built-up area (30 km/h) and is managed by the municipality of Schagen.

The foreseen routes for construction traffic are assessed with the aid of the CROW publication 315. This examines whether the road meets the set guidelines but also whether the design and function of the road is in keeping with the expected increased traffic (mainly heavy goods traffic) as a result of construction of the PALLAS-reactor.

Using accident data derived from Viastat-online, insight has been gained into accidents occurring on the section of N9 between the crossroads with the N502 and the connection to the N503, during the 2012-2015 period. This period was chosen due to this section of the N9 being designed to be Sustainable Safety in 2012, and the N9/N502 crossroads being converted into an overpass.

Figure 68 Routes for supply and removal per road axis (red) and ship (green). The transfer station, construction location and LDA are denoted by the green, red and yellow circles, respectively.

Traffic movements

No specific assessment framework is available for the traffic flow. There are indicators (maximum volume of traffic) for various types of roads, used in order to indicate whether the flow is at risk. The increased traffic as a result of the construction or transition phases is calculated in relation to the current intensity, and assessed qualitatively.

There will be 57 heavy goods movements per day (back and forth, therefore 114 trips) over the road network. All materials will be supplied from the transfer station and must therefore be transported by heavy goods vehicle from this transfer station to the PALLAS-reactor. Although the route via the N9 and N502 south is the shortest (approximately 8 km), the northern route (N9, N503 and N502, approximately 11 km) is also under consideration to determine the impact of construction traffic. The complete volume of construction traffic will be added to the current traffic intensity.

Vibration hinder

The passage of buses and heavy goods vehicles as road traffic results in brief vibrations, which are mainly generated by irregularities in the road surface and then propagated through the road construction and ground. In a weakened form, the vibrations reach buildings in the surrounding area, where they may result in nuisance. Depending on the level of vibration, local residents may experience them to be admissible or a nuisance. Strong vibrations may even cause damage to buildings.

The degree to which vibrations cause nuisance, generally depends on:

- The road surface (un)evenness.
- The driving speeds.
- The traffic intensity and type of traffic.
- The ground profile.
- The distance between traffic and the building in which vibrations are felt.
- The structural state of the building.

The smoother the road surface, the smaller the dynamic load on the road. This means, for example, that there will be less vibration on an asphalt road laid on a sand bed without any further traffic devices, than in a situation with a cobbled road on a clay bed, with traffic calming devices. The greater the driving speed, the larger the vibrations caused by vehicle passage.

The degree to which vibrations are propagated up to a certain distance from the road depends very much on the subsoil. In the case of a sandy subsoil, vibrations will be dampened more effectively versus a clay or peat subsoil.

The distance from the building to the road strongly determines the actual risk of nuisance and damage caused by vibrations. The structural state of the building also plays an important role, as this determines the degree to which vibrations are passed from the subsoil to the building.

A building comprising a rigid, heavy construction will not be affected as much as a building of limited rigidity and mass. This means that the sensitivity to vibrations varies per building. Generally speaking, new concrete constructions (apartment complexes, offices) do not transmit vibrations as strongly as older masonry buildings with wooden floors.

The analysis of the impact of vibrations concerns the passage of construction traffic over the road network. The N9 is

not taken into account. On the one hand, because the traffic intensity on this road will not truly increase as a result of the construction traffic, while the load classification of the construction traffic is comparable with the regular heavy goods traffic on this road. On the other hand, because the buildings along the N9 are situated at distances greater than 20 m from the road.
The construction year and usage function of the buildings in question has been determined on the basis of the BAG (basic addresses and buildings) archives. All locations feature buildings constructed during the 1890-1930 period. Unless the buildings have been modified during renovation work, they can be expected to be masonry-built in combination with wooden floors. Such constructions are generally sensitive to vibrations.
Similarly to the Noise aspect, other locations where people spend any length of time will need to be considered for the Vibration aspect, in specific cases.
The impact assessment uses the SBR Measurement and assessment guidelines for Vibrations: Part B: Nuisance for persons in buildings with various usage functions (housing, healthcare, education, offices and gatherings). This guideline includes the following assessment values:

- The maximum level of vibration: this is the greatest vibration value measured within the building upon passage of traffic.
- The level of vibration over the assessment period (vper) calculated over the course of an assessment period (day, evening or night period).

Besides the nuisance experience, the SBR Measurement and assessment guidelines for Vibrations: Part A, Damage to buildings, gives the target values for the maximum value of vibration frequency for buildings. When vibration levels remain under the target value, there is an acceptably small risk of damage (< 1%).
The target value for damage is considerably higher than the assessment values at which nuisance is experienced. The impact on the nuisance experience has been qualitatively assessed on the basis of expert judgment.

Relevant phases

The impact on the Traffic aspect is described for the construction phase, as this phase will have the greatest impact by far. The transition and operational phases have not been separately assessed due to the activities resulting only in marginal traffic impact.
The construction height and cooling variants have no differentiating impact and are therefore not considered distinctive in the impact assessment.

SEA assessment scale

The assessment scale for the Traffic aspect complies with the assessment scores in previous sections. Target values have not been given, as the assessment is purely qualitative.

17.2 Current situation and autonomous development

17.2.1 Current situation

In the current situation, Research Location Petten has direct access to the N502. The N502 runs parallel to the N9 past the Petten and Sint Maartenszee communities. The N9 is the connection route to the south (Alkmaar) and becomes the A9. To the north, the N9 runs to Den Helder or can access the A7 Afsluitdijk causeway via the N249 and the N99. There are three possible traffic routes from Research Location Petten, namely:

- N502 towards Petten or the N9 to the south.
- N502 - Zeeweg to the east or to the N9.
- N502 towards Callantsoog or to the N503/N9/N248.

Figure 69 Traffic structure around Research Location Petten

Figure 70 shows the road managers for the roads located directly around Research Location Petten. The N502 and N503 are managed by the Province of Noord-Holland. The N9 is an important traffic artery and is managed by Rijkswaterstaat. The regional roads (blue) are managed by the Water Authority for Northern Holland (HHNK).
The roads within the built-up area are managed by the municipality of Schagen, though these are not directly part of the Research Location Petten access routes, with the exception of the Sint Maartensweg road).

17.2.2 Autonomous development

No great changes are expected in the traffic structure up to 2026, versus the current situation. Only limited autonomous traffic growth is expected, due to realization of the “Petten structural vision”, among other developments. This includes the development of a new beach (already complete) and the resultant tourist attractions, and the new village center (Plein 1945). The municipality of Zijpe traffic and transport plan of 2012 [62] refers to the possible future development of a new access road to ECN, between the Westerduinweg and the N9. However, this development is not yet concrete enough to be included as an autonomous development.

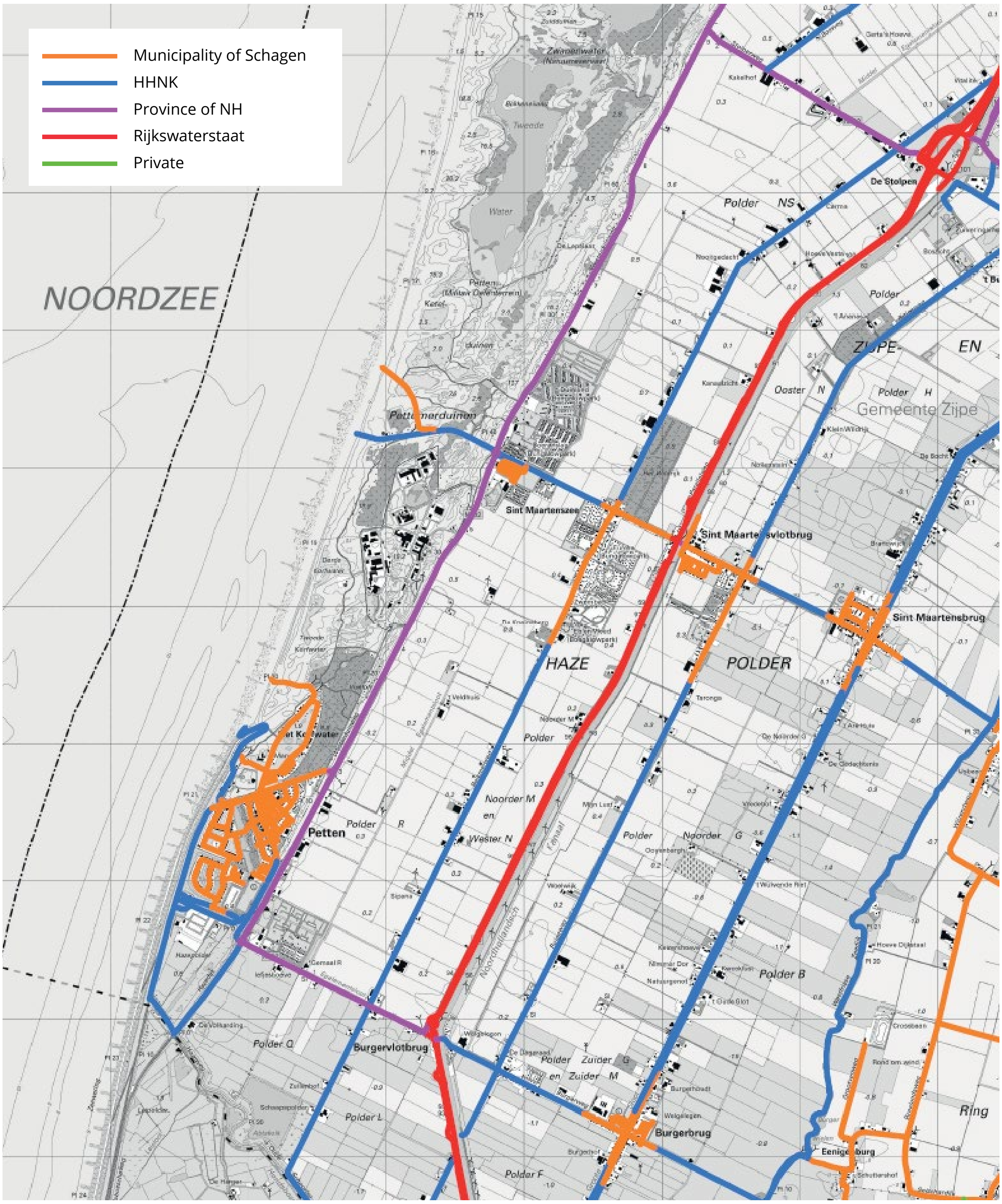

Figure 70 Road managers

17.3 Environmental impact

17.3.1 Impact description

17.3.1.1 Construction phase

Traffic safety

N9

The N9 is the main north-south connection between Alkmaar and Den Helder. It is a regional access road (which more or less has the function of a regional through-traffic road), mainly outside the built-up area, 2x1 lanes with a speed limit of 80 km/h, see Figure 71. The N9 has lanes approximately 7.5 m wide, and therefore easily complies with the requirements (minimum lane width is 6.5 m).

Agricultural traffic is prohibited on large sections of the N9 (including between Burgervlotbrug and Sint Maartensvlotbrug). As can be seen in Figure 71 N9 (Source: globespotter), the N9 is located in the open field directly adjacent to the Noordhollandsch Kanaal. A crash barrier is in place at locations where the road is close to the canal. There is a two-way cycle path on the west side, separated from the road by means of a grass verge. This provides the division between motorized and slow traffic, according to the Sustainable Safety principles.

Properties are not gated and are connected to a parallel road. Outside the built-up area, junctions (see Figure 72) take the form of roundabouts (junction with N502) or overpasses (junction with N503), with priority intersections within the built-up area (crossroads with Zeeweg). The roundabouts have been designed spaciously. They have a radius of approximately 20 m (minimum is 18 m) and therefore comply with the requirements and layout to also successfully process construction traffic.

The road layout complies with the minimum road layout according to the Sustainable Safety principle, with the exception of the broken center lane marking. Sustainable Safety recommends a solid center lane marking.

With a view to the road layout, the conclusion is that the N9 complies with the requirements and is suitable to function as an access road for the construction traffic.

Accident data N9

Table 107 shows the year, severity, location and nature of accidents occurring on the N9.

Figure 71 N9 (Source: globespotter)

Figure 72 N9 junctions with N502 – Zeeweg – N503, respectively (Source: globespotter)

Table 107 Accident data N9

Year	Severity	Location	Nature
2012	Personal injury	Junction Burgerweg/N9	Rear-end collision
2013	MD incident	N9 hm. 100.7 (exit lane to Schagerbrug)	Rear-end collision
2013	MD incident	Junction N248/Stolperbrug	Unknown
2014	MD incident	Junction N9/Zeeweg	Rear-end collision
2014	Personal injury	N9	Head-on collision
2015	MD incident	N9 - hm 100.8 (exit lane to Schagerbrug)	Unknown

As shown in Table 107, there have been six accidents on the N9 over a four-year period. Two of these involved personal injury, while four were MD incidents[47]. There is no discernible trend in the number of accidents per year. There are also no particular locations where accidents frequently occur, as the accidents are distributed over the entire route.

N502

There is good vision distance over the entire route of the N502, see also Figure 73. There are no objects (for example trees) which restrict visibility. Furthermore, the N503 has few bends, the road is almost entirely straight, which is favorable for heavy goods traffic.

Figure 73 N502 between Petten and the N9 (top and center) and between Petten and Sint Maartenszee (bottom, Source: globespotter)

47 UMS: Material Damage only.

The speed limit has been reduced to 60 km/h or 50 km/h (at Sint Maartenszee and the Mennonieten neighborhood, respectively) along sections of roads which feature connections to property. Speed humps have also been installed here as traffic calming devices, along with an overtaking prohibition. These are all measures designed to increase traffic safety on the route. Roadside parking is allowed on a small section of the N502, between Petten and Sint Maartenszee (for dune access). Agricultural traffic is permitted. There is no limitation for heavy goods traffic (maximum axle load) on the N502.

There is a two-way cycle path along the entire length of the N502, which is separated from the road by means of a grass verge. A crash barrier is in place at locations where the cycle path is directly adjacent to the road, in order to guarantee cyclist safety. Priority intersections without further traffic controls are in place within the built-up area and at locations where the speed limit has been reduced to 50 km/h.
Other intersections take the form of roundabouts or priority intersections in which traffic turning left has its own lane, in order to avoid traffic congestion on the road (Westerduinweg). Reference factors for the construction traffic are those bends and intersections where construction traffic must undertake maneuvers (Figure 74).

The roundabout suffices for processing of construction traffic. The bend has been widened and a truck apron added in order to give heavy goods traffic enough room to maneuver in the bend. The island in the road has been enlarged in order to optically narrow the bend, the bend is actually easily wide enough for heavy goods traffic. The N502 - Zijperweg roundabout has a radius of approximately 18 m and therefore complies with the minimum size of a roundabout outside the built-up area (the same applies to the N502 - Zeeweg roundabout). There is a wide rumble strip (made of concrete brick) over which heavy goods traffic can drive when using the roundabout.
The N502 deviates from the minimum road layout advice of Sustainable Safety on a number of points. There are a number of connections to properties (mainly between Petten and the N9) which should preferably be accessed by a secondary parallel road. The center lane marking is also not completely compliant (is broken and is only a single line in sections where a double broken line is advised).
This is due to the fact that the road has a low traffic intensity, and an important function for direct residents. The intersections, bends and road width all comply with the minimum requirements for the processing of heavy goods traffic. Despite the deviations versus the Sustainable Safety road design principles, the road design and function make it suitable for heavy goods traffic access during the construction phase.

Figure 74 Bend N502 Pettemerweg towards N9 (top) and roundabout N502 – Zijperweg (bottom, Source: globespotter)

Figure 75 N503 at the Belkmerweg (top) and between the N502 and Bosweg (bottom, Source: globespotter)

N503
The N503 has hardly any bends, and has no visibility restrictions with the exception of the buildings, see Figure 75
Just like the N502, the N503 also deviates from the minimum road design advice of Sustainable Safety on a number of points. There are number of connections to properties, and the center lane marking is also not completely compliant (is broken and is only a single line in sections where a double broken line is advised). This is due to the fact that the road has a low traffic intensity, and an important function for direct residents.
The intersections, bends and road width all comply with the minimum requirements for the processing of heavy goods traffic. There is no limitation for heavy goods traffic (maximum axle load) on the N503. Despite the deviations versus the Sustainable Safety road design principles, the road design and function make it suitable for heavy goods traffic access during the construction phase.

Accident data N502/N503
Using accident data derived from Viastat-online, insight has been gained into accidents occurring on the N502 between the N9 and the N503 and the N503 between the N502 and the N9, during the 2012-2015 period.
The same period was chosen, as for the N9 accident data. Table 108 shows the year, severity, location and nature of accidents occurring.

Table 108 Accident data N502 and N503

Year	Severity	Location	Nature
2013	Personal injury	Intersection N502/N503	Broadside collision
2013	MD incident	Roundabout N503/connection to N9	Immovable object
2013	MD incident	Intersection N503/Belkmerweg	Unknown
2014	MD incident	N502	Unknown
2014	Personal injury	Intersection Westerduinweg/Spreeuwendijk	Unknown
2014	MD incident	N502	Unknown
2014	Personal injury	N502	Unknown
2015	MD incident	Intersection Westerduinweg/Spreeuwendijk	Unknown
2015	Personal injury	N502	Unknown
2015	MD incident	N503	Unknown

As shown in Table 108, there have been ten accidents on the N502 and N503 over a four-year period. Four of these involved personal injury, while six were MD incidents. There is no discernible trend in the number of accidents per year. There are also no particular locations where accidents frequently occur, as the accidents are distributed over the entire route, see Figure 76

Zeeweg
The Zeeweg has a freely lying, two-way cycle path over the entire length between the N502 and the N9. This is not essential in the case of a residential access road. Within the built-up area where there is a speed limit of 30 km/h, cyclists may also cycle on the road in order to reach the adjacent housing/companies. This means that motorized traffic and (more vulnerable) bicycle traffic shares the road on this section of the Zeeweg. Bus traffic also stops on the road and the intersections are priority intersections.

Figure 76 Location of the accidents Red denotes the personal injury accidents and blue the MD accidents

Figure 77 Zeeweg between the N502 and Belkmerweg (top) and between the Belkmerweg and the N9 (bottom, Source: globespotter)

Conclusion regarding traffic safety
The Zeeweg complies with the Sustainably Safe road design guidelines. However, due to it being a residential access road, cyclists may also use the road within the built-up area (to reach housing/companies). Due to the limited width of the road, it is therefore not desirable that construction traffic uses the Zeeweg as the main access route to the transfer station. There is also a risk of accidents involving vulnerable road users. Due to there being good alternative routes such

as the N9, the N502 from the south or the N503 from the north (which has the same road profile as the N502), it is not advised to use the Zeeweg as an access route for construction traffic.
The N502 and the N503 do not entirely comply with the requirements of Sustainably Safe. This is due to the way in which the roads have been historically used. The roads are important access roads for adjacent properties which directly access the N502/N503 (connections to properties). In order to ensure traffic safety, the speed limit has been reduced to 50 or 60 km/h in these sections, and a number of speed humps installed. In principle, these measures have no negative impact on the construction traffic. Both roads comply with the minimum design requirements (in terms of width, layout of intersections/roundabouts and peripheral matters such as truck aprons and bend widening).
No limitations have been ascertained for heavy goods traffic (maximum axle load). There have also not been any concentrations of accidents which might indicate a potentially hazardous location.
It can therefore be concluded that construction traffic can make use of the N502 and N503 for the supply and removal of building materials and ground during the construction phase.

Traffic movements

The traffic counting points on the surrounding roads are given in Figure 78, and the intensities are shown in Table 109. Where possible, a distinction is made in terms of the peak and low seasons. During the peak season (summer period), there is more traffic in the area because of the beach (tourism). This has been taken into account by applying peak season data (summer period) where possible in order to estimate the traffic impact (worst case approach).

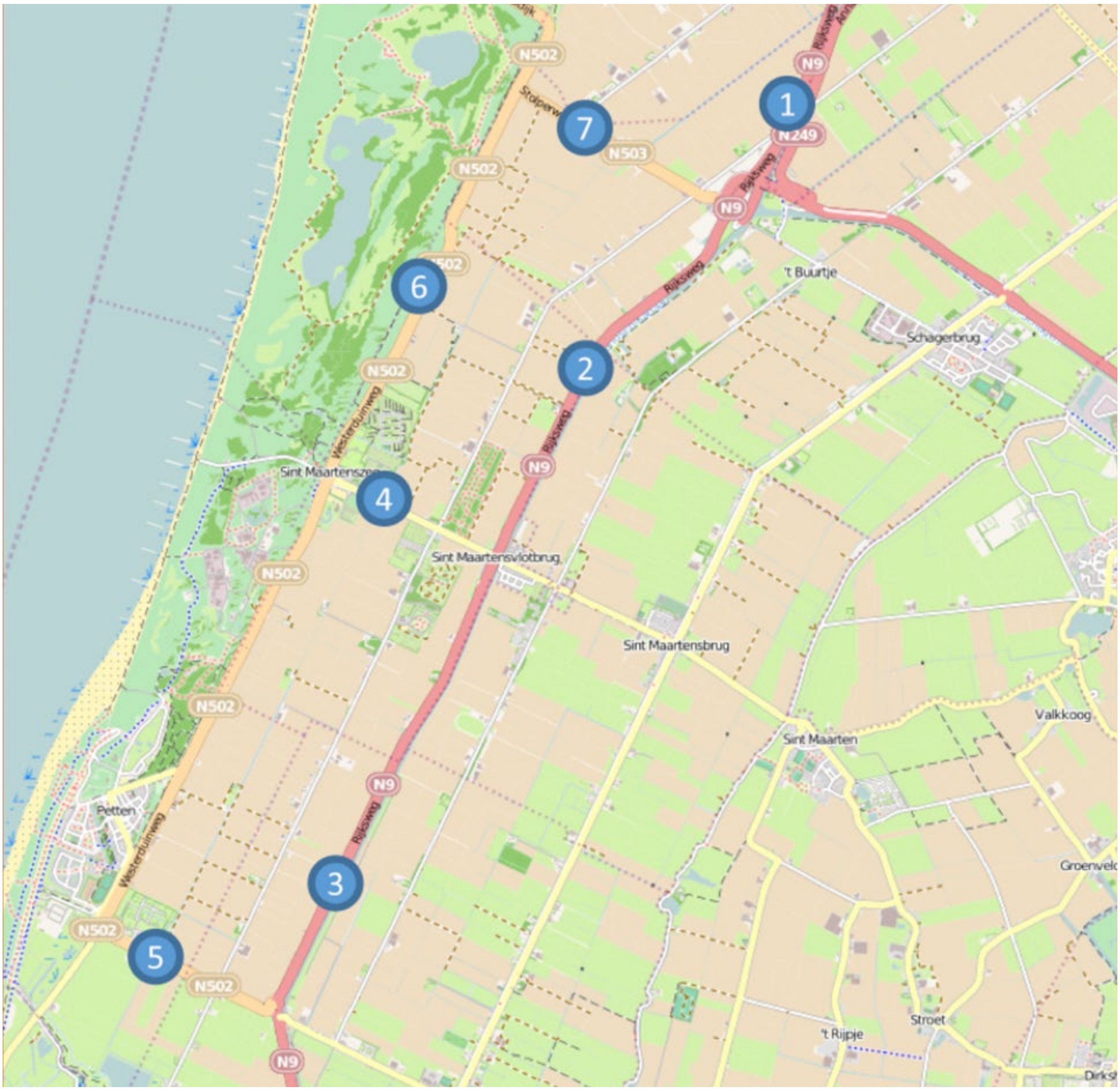

Figure 78 Counting points

Table 109 Intensities situation 2014 per road section and with construction traffic

Road section	24-hour intensity on working day	Increase due to construction traffic
N9	10,700	n/a
N9	15,100	+114 heavy goods movements (+0.75%)
N9	14,500	+114 heavy goods movements (+0.79%)
Zeeweg	2,500	-
N502 - peak season[48]	5,400	+114 heavy goods movements (+2.11%)
N502 – low season	4,500	+114 heavy goods movements (+2.53%)
N502	4,800	+114 heavy goods movements (+2.37%)
N503 - peak season	6,100	+114 heavy goods movements (+1.87%)
N503 – low season	4,300	+114 heavy goods movements (+2.65%)

The impact of 114 extra heavy goods movements on the total volume of traffic on the N9 is minimal (less than 0.8%). The impact is somewhat greater on the N502 or the N503, where an increase of maximum 2.4% can be expected during peak season and maximum 2.7% during low season. The proportion of heavy goods vehicles on the N502 and N503 is currently maximum 1.8% per day. While an increase of approximately 100 heavy goods vehicles translates into a (temporary) doubling of heavy goods traffic, the volume of heavy goods traffic is limited in absolute terms.
On a regional access road, 2x1 lanes, the maximum intensity is generally between 20,000 to 25,000 motor vehicles per 24 hours. The N502 and N503 are more likely to be subject to a required maximum intensity, as both roads run (partly) through the built-up area, and there are connections to properties and speed humps are in place. These roads can therefore be said to process a maximum intensity of 10,000 motor vehicles per 24 hours, if the livability factor is not to be overly influenced. The intensity will remain well below this, even during peak season) and including the construction traffic.

Hourly intensities N502 and N503
Due to the possibility of traffic processing being under pressure particularly in the rush hour period (reference period), Figure 79 gives the hourly intensities for counting points 5 and 7 per direction during the peak and low seasons. The peak season is the average of the working days from 12 to 26 August 2016 and in the low season from 1 to 30 September 2016.
There is no great difference between the peak and low seasons on the N502, with the exception of afternoons being busier in the direction of the N9 during peak season. Great-

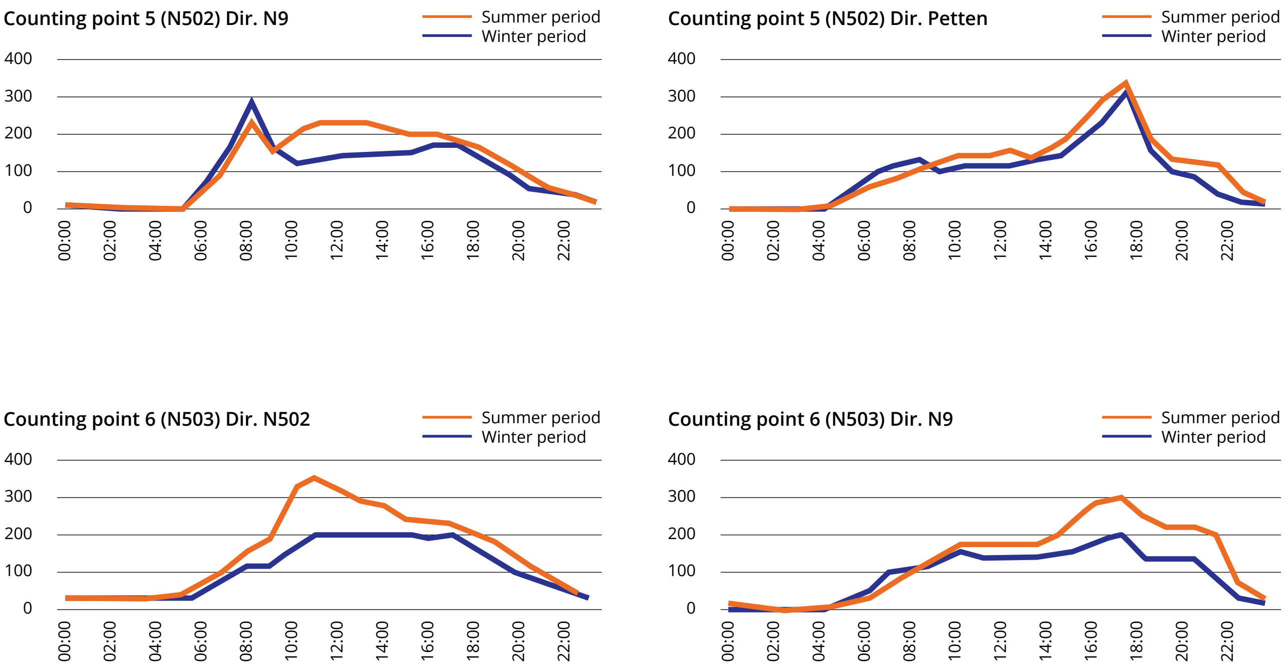

Figure 79 Hourly intensities at counting points 5 and 7 per direction for both the peak and low seasons

48 Data is available from counting point 5 (N502) and counting point 7 (N503) for the intensities during peak season (August 2016, summer period) and low season (September 2016). The other counting points have only provided data from the peak season (summer period) 2014.

er differences can be seen on the N503. The intensities are higher for a longer period during peak season than during low season. There is a clear rush hour direction from 10.00 hours towards the intersection with the N502 and from 16.00 hours towards the N9. This is due to visitors heading for Petten beach late in the morning and returning home again in the afternoon/evening.
A regional access road with 2x1 lanes has an average capacity of 1500 motor vehicle movements/hour. In this case, the required maximum hourly intensity will be lower, for the same reasons given above (maximum around 1000 motor vehicle movements per hour). The intensities do not exceed 350 motor vehicle movements/hour during the morning and evening rush hours, on both road sections during both periods.
The conclusion is therefore that there will be no congestion or deterioration of the traffic flow during peak moments, even with the increased construction traffic.

Vibration hinder

The traffic intensity on the road network will increase by maximum 114 heavy goods vehicle movements per day during the construction phase. These extra traffic movements will take place during a consecutive period of 12 hours per day, and this period is assumed to take place during the daytime period from 7 hours to 19 hours.
The project location is located on the edge of Petten Dunes, where the subsoil is mainly sandy. This means that the N502 can be expected to be situated entirely on a sandy subsoil. The area between the Noordhollandsch Kanaal and the N502 is a transition area between the polder and the dunes, and comprises silty and sandy clay. This situation applies to the connections from the N502 to the N9 (Pettemerweg), Zeeweg and N503.
The subsoil situation means that the roads are not sensitive to subsidence on the one hand, and that there is therefore no great risk of vibration hinder as the result of subsidence. On the other hand, the subsoil situation ensures that the impact of traffic vibrations quickly diminishes. All roads have an asphalt pavement, which limits the production of vibrations caused by traffic movements. There are speed tables at three locations in the roads. These can be found at the intersections of the N502, the Zeeweg and the N503 with the Belkmerweg. The speed limit at these intersections is 60 km/hour. The purpose of the speed tables is to reduce the driving speed of passing vehicles. The design of the tables is such that, in combination with lower passage speeds, they are not expected to result in greater traffic vibrations at these locations.
There are buildings all along the given roads. The distance from the road to the buildings varies from a few meters to a few tens of meters. The closest distance to buildings is found at the intersections of the roads with the Belkmerweg and in the "De Stolpen" community. At these locations, one or two buildings are less than 2 m away from the road.

Description of effect of vibrations

During the construction phase, heavy goods traffic will use the road network for the supply of building materials to the LDA. As there are no restrictions for the use of the road network by heavy goods traffic in the current situation, the reference point is that the roads are now already used by vehicles with axle loads comparable to those of the construction traffic. This means that the maximum vibration levels of the reference situation will not increase during the construction phase.
As far as the Zeeweg is concerned, certain sections of the road profile are too narrow for heavy goods traffic to easily pass. A number of houses are also located extremely close to the road, resulting in increased noise and vibration hinder from heavy goods traffic.
The vibration level will increase slightly during the assessment period as a result of the more frequent road use during the construction process. Construction traffic will use the road during the daytime period (between 7.00 and 19.00 hours). It is assumed that in the reference situation, 70% of all traffic movements takes place during the daytime period. This

Figure 80 Speed table at intersection of N503 with Belkmerweg (Source: Globespotter)

means that the increase in movements in daytime will be around 3% during the construction phase, if the construction traffic is processed fully over the N502 or N503 routes. This increase will result in 1 to 2% higher vibration level during the assessment period, versus the reference period. Should all traffic be processed over the Zeeweg (which is not recommended), the relative increase in movements will be slightly higher, due to the lower traffic intensity in the current situation, resulting in 2 to 3% higher vibration level.
It is difficult to determine to what degree such an increase will result in target values being exceeded, without the traffic first having been monitored in the reference situation.
Target values may indeed already be exceeded at a number of locations in the current situation. This is expected at a number of locations where the distance between houses and the road is less than 5 m.
When houses are situated more than 15 m from the road, and based on the quality of the road and subsoil, targets are then not expected to be exceeded in the reference situation.
When considering the slightly raised vibration level during the daytime period, it is unlikely that a few percent increase will result in people experiencing more nuisance.
It should be noted that in existing situations whereby people are already exposed to vibrations, a limited increase in the vibration level is generally found to be less of a nuisance than in new situations (when a new road is constructed, for example). This is taken into account in the target values of part B of the SBR Vibrations guideline, which regards the acceptable vibration level to be twice as high in existing situations versus new situations.

17.3.1.2 Transition phase and operating phase

Traffic movements

During the transition phase, both the HFR and the PALLAS-reactor will be operational. The Design framework appendix to this SEA PALLAS [63] indicates that maximum 100 passenger vehicles and seven heavy goods vehicles will drive to and from PALLAS per workday (107 vehicles, 214 extra movements per day). This is extra traffic versus the current situation (traffic for the purpose of the HFR is already included in the vehicle counts). In accordance with the reference point, it is assumed that 75% of the traffic will come from the south (N9/N502) and 25% from the north (N9/Zeeweg for passenger traffic and the N9/N503/N502 for heavy goods traffic). This has been determined on the basis of the counting points given in Figure 78. However, unlike the construction traffic (which will mainly drive from the transfer station), this traffic from the N9 will originate from south of the Burgervlotbrug bridge. Unfortunately there is no useful counting point on the N9 to the south of the N502. The intensity to the north of the N9 (Sint Maartenszee) is approximately 15,000 vehicle movements per 24 hours, and it can be assumed that the intensity of the south of the N502 will be slightly increased but no more than 2000-3000 vehicle movements per 24 hours.
As in the situation with construction traffic, there will be a slight traffic increase versus the current intensity. The greatest increase is expected on the N502 at Petten (nearly 2%). However, the intensity on the N502 here in the current situation is so low in relation to the desirable maximum intensity of a regional access road (approximately 10,000 motor vehicles per 24 hours) that this increase will not result in deterioration of the traffic flow. This also applies to the other sections of roads.

17.3.2 Impact assessment

Construction phase

Traffic safety

In terms of traffic safety during the construction phase, the N502, N503 and N9 (being provincial or national roads) generally comply with the Sustainable Safety design guidelines. The form and function of the roads are appropriate and suitable for the flow of heavy goods traffic during the construction phases of PALLAS. This does not apply to the Zeeweg, of which the section within the built-up area of Sint Maartensvlotbrug is particularly unsuitable for heavy goods traffic. The road is so narrow there that trucks cannot pass. There are also cyclists on the road, as well as bus stops, which will result in bottlenecks in terms of traffic safety. There are also houses facing directly onto the road, making the use of the Zeeweg undesirable for construction traffic, from the livability point of view. Good alternatives are available in the form of the N9 and the N502/N503. If the Zeeweg is avoided by heavy goods

Table 110 Intensities situation 2014 per road section and with transition phase traffic

Road section	24-hour intensity on working day	Traffic increase in transition phase
N9	10,700	+50 passenger vehicles and 4 HGV (+0.50%)
N9	15,100	+50 passenger vehicles (+0.33%)
N9	14,500	-
Zeeweg	2,500	+50 passenger vehicles (+2.0%)
N502 - peak season[49]	5,400	+150 passenger vehicles and 10 HGV (+2.96%)
N502 - low season	4,500	+150 passenger vehicles and 10 HGV (+3.56%)
N502	4,800	+ 4 HGV (+0.08%)
N503 - peak season	6,100	+ 4 HGV (+0.07%)
N503 – low season	4,300	+ 4 HGV (+0.09%)

49 Counting point 5 (N502) and counting point 7 (N503) give the intensities during the summer period (August 2016) and winter period (September 2016). The other counting points have only provided data from 2014.

Table 111 Impact assessment on Traffic safety, construction phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Road design according to the Sustainable Safety principles – if the Zeeweg is avoided.	0	0	0	0	0	0
Road design according to the Dutch Sustainable Safety principles – if the Zeeweg is used.	-	-	-	0	0	0

Table 112 Impact assessment on Traffic movements, construction phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Traffic movements	0	0	0	0	0	0

Table 113 Impact assessment on vibration hinder, construction phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Construction phase						
Vibration hinder	0	0	0	n/a	n/a	n/a

traffic, there will be no impact (0), whereas if the Zeeweg is used by construction traffic, there will be a negative (-) impact on traffic safety.

Traffic movements
The number of traffic movements per 24 hours will be limited during the construction phases, and will not result in greatly increased intensity. In the current situation, the roads in the planning area (N502, N503 and N9) have an intensity well under the maximum (guideline) of 20,000-25,000 motor vehicle movements per 24 hours (N9) or the desirable maximum intensity of approximately 10,000 motor vehicle movements per 24 hours (N502 and N503). These roads therefore have sufficient residual capacity to facilitate a slight increase in (construction) traffic without negative consequences for the traffic flow; they are therefore scored as neutral (0).

Vibration hinder
The number of extra traffic movements per period, with daytime as the reference period, will be limited during the construction phase. This will not result in a higher vibration level on the N502 and N503. The vibration level will however increase by a few percent during the daytime period. However, this increase will be so limited that it is not expected to result in a greater experience of nuisance by residents of houses along the road.

Impact assessment on vibration hinder, construction phase
The impact during the transition and operational phases is negligible versus the impact during the construction phase, and has therefore not been separately considered.

17.4 Mitigating measures

The Zeeweg is not a suitable route for construction traffic (heavy goods vehicles). The proposal is therefore to forbid the use of the Zeeweg for construction traffic. With a view to the location of the goods transfer facility, we propose that construction traffic be diverted via the N9 and the N502 (via Petten). The N503 and N502 can be used when approaching from the north. The N502 would already be the most logical choice when coming from Alkmaar via the N9, see also Figure 81. Another option is to move the goods transfer station, to the N502/N9 connection for example, in order to minimize the driving distance for heavy goods traffic.

The design framework assumes that heavy goods traffic will not use the Zeeweg during the construction phase. This mitigating measure therefore results in an impact assessment of neutral (0).

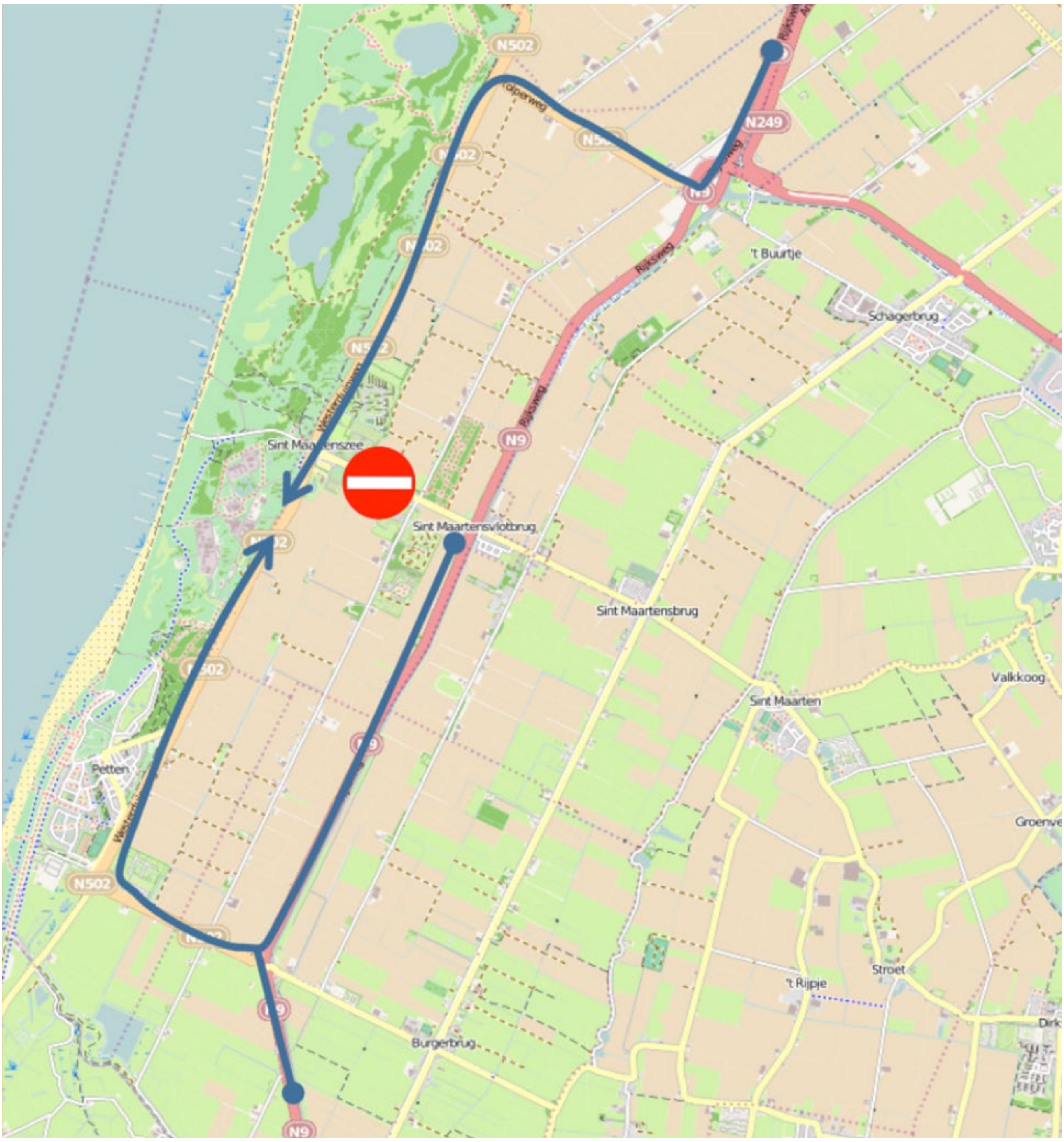

Figure 81 Access routes for construction traffic

17.5 Gaps in knowledge

Two knowledge gaps have been identified:

- There is no counting point on the N9 to the south of Burgervlotbrug, resulting in incomplete insight into the impact of increased traffic at this point during the transition phase. A substantiated assumption has been made however, with no difference being expected in the impact assessment.
- The assumptions applied were based on information from the Design framework for this SEA PALLAS [63] and the Principles Memorandum for the PAS nitrogen control program application [64]. These are currently the best available assumptions. With a view to the conclusions, the impact assessments are unlikely to change, should these assumptions be revised.

18 Sensitivity analysis

18.1 Reference situation 1 and 2

Background
Paragraph 3.2 of the communication memorandum of the SEA PALLAS describes the assessment framework for the environmental assessment of the PALLAS-reactor. The environmental assessment takes place versus the reference situation. The reference situation comprises the environmental values of the current situation and the foreseen autonomous developments occurring in the planning area. Autonomous developments concern other plans and projects which have been established and officially recognized. Following the advice of the NCEA for the EIA, closure of the HFR at some point in time may be assumed for the autonomous development.
The communication memorandum states that the timing for the closure of the HFR is still uncertain, and that the SEA therefore refers to two reference situations:

- **Reference situation 1:** HFR is operational during the construction phase and the initial years of the operational phase of the PALLAS-reactor, until the point at which the PALLAS-reactor has taken over complete production from the HFR. For this situation, there is a visualization of the environmental impact of the variants in the construction phase and in the operational phase, as well as the transition phase in which both reactors are operational. This provides insight into the cumulative impact of the HFR and the PALLAS-reactor (see Figure 82).
- **Reference situation 2:** HFR is decommissioned prior to construction of the PALLAS-reactor taking place. For this situation, there is a visualization of the environmental impact of the variants in the construction phase and the operational phase. This only provides insight into the absolute impact of the PALLAS-reactor (see Figure 83).

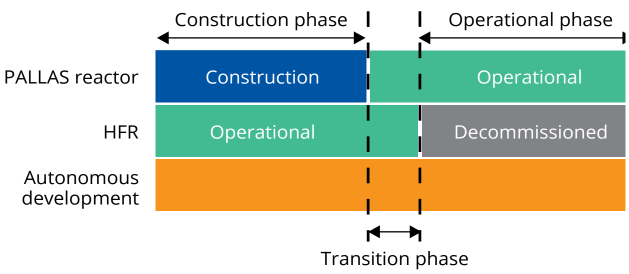

Figure 82 Relevant phases in reference situation 1

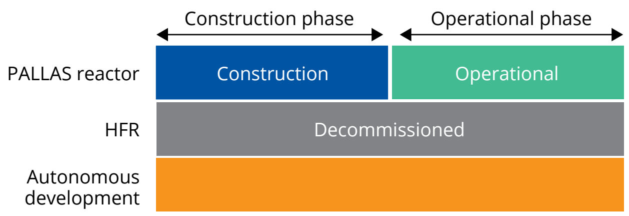

Figure 83 Relevant phases in reference situation 2

The PALLAS aim is that the HFR not be decommissioned until after the PALLAS-reactor becomes operational. This is necessary in order to guarantee the supply of isotopes. The reason why this second reference situation is visualized, is that the HFR is coming to the end of its technical and economic life cycle. It could therefore occur that the HFR must be decommissioned before the PALLAS-reactor is ready for use. This has therefore also been included in the SEA, in order to gain an idea of the possible environmental impact should this situation occur.

Reference situation 2 is not relevant for all environmental aspects
Reference situation 2 is an extremely undesirable situation however, and therefore not particularly realistic, with the exception of unforeseen circumstances. The HFR is the world's second-largest supplier of medical isotopes and is responsible for nearly 30% of the global production capacity. If the HFR were to be decommissioned before the PALLAS-reactor is operational, this would result in a "global problem for the supply of medical radio-isotopes and a void in the nuclear knowledge infrastructure" (letter by Minister of Economic Affairs dated 20 January 2012, House of representatives letter no. 32 646 no. 33).
Over the course of the SEA, it has become apparent that the two reference situations have a differentiating impact for only a limited number of aspects. Reference situation 2 is therefore only relevant for a limited number of aspects. In the unlikely event that the HFR is decommissioned prior to the PALLAS-reactor becoming operational, changes will apply to the impact for a number of aspects.
A comprehensive impact assessment has only been conducted for those aspects for which it is relevant to visualize the impact in reference situation 2. The inclusion of a second reference in all assessments would only result in unnecessary ballast in the SEA documents. This means:

- The choice was taken to describe the impact assessment of reference situation 2 separately in this SEA, for the purpose of readability. This concerns a separate sensitivity analysis rather than a component within the impact assessment for each aspect. This section is the result of that choice.
- In the other sections of this SEA, we refer to a "reference situation" which is taken to mean "reference situation 1".

Reading guide to this section
Paragraph 18.2 gives a brief overview of the environmental aspects and whether the application of reference situation 2 (premature closure of the HFR) would result in a different assessment. A brief explanation is given per aspect.
In the case of those environmental aspects to which this reference situation 2 is relevant, paragraph 18.3 examines what types of impact might occur and how they are assessed.

18.2 Does the application of reference situation 2 alter the impact?

Table 114 gives an overview of all environmental aspects for which the impact of reference situation 2 does not result in any differentiation. The right-hand column gives a brief explanation of the basis for this conclusion.

Table 114 Overview of environmental aspects in relation to reference situation 2

Environmental aspect	Will the impact of the proposal and the variants be different if the HFR is decommissioned earlier?
Radiation protection & Nuclear safety	**Yes.** If the HFR is no longer operational, there will no longer be radiation from this installation, therefore not cumulative with that of the PALLAS-reactor. These criteria are discussed in more detail in paragraph 18.3.
Soil and water	**Hardly at all.** Whether or not the HFR is operational has no differentiating impact on soil and water, as the HFR building will not be dismantled and the cooling water facility has no relation with the groundwater. There is also no differentiating situation for discharge of cooling water to the surface water, due to the extremely limited mixing zone in the North Sea (see paragraph 8.3.2.3) and the distance between the two discharge points. There is however a difference regarding extraction of cooling water, as the extraction of cooling water for the HFR from the Noordhollandsch Kanaal will cease earlier. The **Cooling water extraction** criterion is therefore paid attention in this section, in paragraph 18.3.
Water safety	**No.** There will be no differentiating impact on water safety if the HFR is prematurely decommissioned, as the HFR building will not be dismantled; this will take place via another procedure.
Air quality	**No.** The HFR has no (relevant) air emissions of NO_2, PM_{10} and $PM_{2.5}$. Whether or not the HFR is operational therefore has no (relevant) effect on air quality.
Noise	**No.** If the HFR is no longer operational, there will be no noise emission from the HFR. The reference level for noise will change. However, noise studies have shown that the HFR has a negligible contribution to the noise hinder of the housing (see paragraph 11.2.1) and that it is drowned out by far, by the noise of the N502 provincial road. The timing of closure of the HFR is irrelevant.
Light	**No.** There is relatively little light radiation in the planning area (see paragraph 12.2.1). If the HFR is no longer operational, only an extremely limited amount of light emission will be lost. The reference level for light will change slightly, but negligibly. The timing of closure of the HFR is irrelevant.
Nature	**Hardly at all.** There will be no differentiating impact on ecology if the HFR is prematurely decommissioned, The only difference is that there will be no period during which both installations require cooling. Reference situation 1/transition phase represents the worst case scenario for the impact on nature as a result of cooling. The **Suction of fish** and **Thermal changes in the surface water** will receive attention in this section. They are related to **Regional protection and Species protection according to the Dutch Nature Protection Act**. These criteria are discussed in more detail in paragraph 18.3. Paragraph 18.3 also specifically looks at the option of using the cooling water pipeline of the current HFR for cooling variants K1 and K2, as this would have a differentiating hydrological effect on **Regional protection and Species protection according to the Dutch Nature Protection Act** during the construction phase.
Recreation and tourism	**No.** There will be no differentiating impact on recreation and tourism if the HFR is prematurely decommissioned, as the HFR building will not be dismantled and will therefore remain visible. Dismantling will take place via another procedure.
Landscape, cultural history and spatial quality	**No.** There will be no differentiating impact on landscape, cultural history and spatial quality if the HFR is prematurely decommissioned, as the HFR building will not be dismantled; this will take place via another procedure.
Archaeology	**No.** In both situations, the ground disturbance at the construction location of the PALLAS-reactor and the cooling water pipelines remains the same.
Traffic	**No.** Passenger traffic to and from the HFR has a negligible share in the total traffic production. The timing of closure of the HFR is irrelevant.

18.3 Reference situation 2: relevant assessment criteria

The impact of realization of the PALLAS-reactor has been visualized for a number of relevant aspects, with regard to a situation in which the HFR is not operational (reference situation 2). This is presented hereafter. As there is no longer a transition phase (see Figure 83), only the construction phase and operational phase of the PALLAS-reactor are still relevant.

18.3.1 Radiation protection

In terms of the radiation protection aspect, the study looked at the impact on the effective dose as a result of direct radiation and indirect radiation. During the construction phase, as in reference situation 1, the PALLAS-reactor is irrelevant for radiation protection, as there will be no fissile materials or other radioactive substances present in the installation at that time. The variants therefore score neutral (0) versus the

Table 115 Impact of PALLAS variants for radiation protection versus reference situation 2 (premature decommissioning of HFR)

Assessment criteria	B1	B2	B3	K1	K2	K3
Construction phase						
Effective dose	0	0	0	0	0	0
Operational phase						
Effective dose	-	-	-	0	0	0

reference situation.
During the operational phase, the PALLAS-reactor will result in increased radiation exposure versus the situation whereby the HFR is not operational (reference situation 2). The PALLAS-reactor will certainly comply with the dose criteria given in the Dutch Radiation Protection Decree. Due to the limited increase, the environmental impact is scored as negative (-) versus reference situation 2. There is no differentiating impact between the various variants.
Table 115 gives the impact assessment for the radiation protection aspect versus reference situation 2 for the various variants.

18.3.2 Nuclear safety

In terms of the nuclear safety aspect, the study looked at the impact on radiological requirements for postulated incidents and the admissible risk as a result of incidents. The construction phase scores negatively (-) versus the reference situation 2 (and for that matter equal to reference situation 1) as a result of the influence of construction of the PALLAS-reactor on the directly adjacent nuclear facilities. The assumption was thereby made that these nuclear facilities are not necessarily out of operation as soon as the HFR is decommissioned. The risk for local residents as a result of the operational phase of the PALLAS-reactor will also at most be comparable with the risk posed by the HFR but will probably be lower. With regard to a situation without HFR therefore, the impact of the proposed activity is negative (-). There will be deterioration in terms of the safety versus a situation without the HFR, but there will also certainly be compliance with the statutory dose and risk criteria. There is no differentiating impact between the various variants.
Table 116 gives the impact assessment for the nuclear safety aspect versus reference situation 2 for the various variants.

18.3.3 Cooling water extraction

Premature decommissioning of the HFR means that cooling water will no longer be required for this installation, extraction of cooling water from the Noordhollandsch Kanaal will be non-existent. PALLAS does not require cooling water during the construction phase, and this phase is therefore not relevant. Once the PALLAS-reactor is commissioned, it will require cooling. The construction had variants are not relevant, but the cooling method is. During the operational phase, K1 requires an increase in the volume of extracted cooling water, from 0 to maximum 3150 m³ per hour. This increase is scored extremely negatively versus the reference situation. However, it must be noted that the scope of this extraction is less than 10% of the average 40,743 m³ discharge per hour of the Noordhollandsch Kanaal (see paragraph 8.2.1.3).
Variant K2 is assessed as neutral, as is variant K3 with air cooling.

Table 116 Impact of PALLAS variants for nuclear safety versus reference situation 2 (premature decommissioning of HFR)

Assessment criteria	B1	B2	B3	K1	K2	K3
Construction phase						
Radiological requirements for postulated incidents	-	-	-	0	0	0
Admissible risk as a result of incidents	-	-	-	0	0	0
Operational phase						
Radiological requirements for postulated incidents	-	-	-	0	0	0
Admissible risk as a result of incidents	-	-	-	0	0	0

Table 117 Impact of PALLAS variants for cooling water extraction versus reference situation 2 (premature decommissioning of HFR)

Assessment criteria	B1	B2	B3	K1	K2	K3
Operational phase						
Cooling water extraction	n/a	n/a	n/a	- -	0	0

18.3.4 Regional protection and Species protection according to the Dutch Nature Protection Act

Two types of impact are relevant if the HFR is prematurely decommissioned, namely suction of fish and thermal changes due to cooling water discharge. These are related to the cooling variants. The impacts become apparent in the Regional protection and Species protection according to the Dutch Nature Protection Act. PALLAS does not discharge cooling water during the construction phase, and this phase is therefore not relevant for this aspect. The construction height variants have no impact on nature.
If the HFR cooling water pipelines can be utilized for cooling water extraction and/or discharge, then this is certainly relevant during the construction phase. The installation of pipelines for the PALLAS-reactor then becomes (partially) unnecessary, hence there is less impact.

Suction of fish
In cooling variant K1, the HFR is cooled using water from the Noordhollandsch Kanaal. Extraction of cooling water entails a risk of fish becoming sucked in. If the HFR is decommissioned, there will be no cooling water extraction and therefore no suction of fish. Versus this situation (without HFR), operation of the PALLAS-reactor with cooling water extraction is scored negatively, because fish can become sucked in.

Thermal changes
In cooling variant K1, the HFR is cooled using water from the Noordhollandsch Kanaal. Cooling water discharge into the North Sea results in thermal pollution. For the PALLAS-reactor, it has been calculated that this discharge can be designed in such a manner that it largely meets the requirements, based on a conservative assumption (see appendix 6 of the background report on Soil and Water (Appendix F3)).
In the end, this results in the same assessment of the PALLAS cooling variants as for the reference situation, versus reference situation 2 (premature decommissioning of HFR).

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Appendices

PALLAS

Appendix

A Abbreviations and glossary

EIA	Environmental Impact Assessment
SEA	Strategic Environmental impact Assessment
AERIUS	Tool for calculating the nitrogen deposition within the scope of the PAS (Dutch Nitrogen Action Program)
ALARA	As low as reasonable achievable
ANVS	Autoriteit Nucleaire Veiligheid en Stralingsbescherming (Dutch Authority on Nuclear Safety and Radiation Protection)
BARRO	Besluit Algemene Regels Ruimtelijke Ordening (Dutch Spatial Planning Decree)
BAT	Best Available Technology
BKMW	Besluit Kwaliteitseisen en Monitoring Water (Dutch Water Quality and Monitoring Decree)
BREF	BAT Reference documents
BUS	Besluit Uniforme Saneringen (Dutch Uniform Remediation Decree)
dB	Decibel
EHS	Ecologische Hoofd Structuur (Dutch National Ecological Network)
AHW	Average highest water table
ALW	Average lowest water table
HFR	High Flux Reactor
HHNK	Water Authority for Northern Holland (HHNK)
IUCN	International Union for the Conservation of Nature
KeW	Kernenergiewet (Dutch Nuclear Energy Act)
WFD	Water Framework Directive
LAeq	Long-term average (relevant for calculation of noise contours)
LDA	Lay Down Area, the temporary working site
LDB	Landsdekkend Beeld Bodemverontreiniging (Netherlands soil pollution overview)
LDP	Landscape Development Plan
Ministry EZ	Dutch Ministry of Economic Affairs
N2000	Natura 2000
NCP	Netherlands Continental Shelf
NMP3	Netherlands Environmental Policy Plan 3
NNN	Netherlands Nature Network
NOx	Nitrogen
PAS	Programmatische Aanpak Stikstof (Dutch Nitrogen Action Program)
SVIR	Structuurvisie Infrastructuur & Ruimte (Dutch National Policy Strategy for Infrastructure and Spatial Planning)
WBB	Wet bodembescherming (Dutch Soil Protection Act)

Appendix B Countries informed

As indicated in paragraph 1.3, this project is not expected to have any important unfavorable, cross-border environmental consequences. However, due to the sensitivity of the project, the municipality of Schagen has decided to inform a large number of countries of the proposal. An English-language communication of the proposal and an English translation of the communication memorandum of the SEA has therefore be sent to these countries. The following table gives an overview of those countries who have been informed of this s.e.a. procedure.

Reactions

Five reactions have been received in total; from France, Romania, Lithuania, Belgium and Belarus. In their reactions, Belgium, Romania and Belarus indicated an interest in involvement in the further procedure. France and Lithuania indicated no further interest in the future.

Table 1 Countries informed

Countries		
Albania	Ireland	Portugal
Andorra	Iceland	Republic of Estonia
Armenia	Israel	Republic of Latvia
Azerbaijan	Italy	Republic of Macedonia
Belgium	Kazakhstan	Romania
Bosnia and Herzegovina	Kyrgyzstan	Russian Federation
Bulgaria	Liechtenstein	San Marino
Canada	Lithuania	Serbia
Croatia	Luxembourg	Slovenia
Cyprus	Malta	Slovakia
Denmark	Moldavia	Spain
Germany	Monaco	Sweden
European Union (EU)	Montenegro	Switzerland
Finland	The Netherlands	Tajikistan
France	Norway	Czech Republic
Georgia	Ukraine	Turkey
Greece	Uzbekistan	Turkmenistan
Hungary	Austria	United States
	Poland	Belarus

Appendix C

Design framework PALLAS

Table of content

1 Introduction

This design framework describes the main features of the PALLAS-reactor design. It provides a conservative yet realistic estimation of the proposed activity. It is based on the characteristics of the site at the Research Location Petten, on policy and legislative preconditions and on know-how gained at the current HFR.

1.1 Relation to SEA

The SEA and the background reports related to the SEA describe the impact of constructing and operating the PALLAS-reactor. Due to the precise design and technical detailing of the reactor and the reactor site not yet being known, the impact is assessed based on this design framework. The present design framework was formed for the benefit of the SEA and the zoning plan, and therefore has a corresponding level of abstraction (see Table 1) appropriate to the SEA and the zoning plan.

For example, the assumed potential maximum capacity of the reactor is used as the basis for the tender for the design of the reactor (55 MW[1]). The cooling capacity is then derived from this maximum capacity. However, obviously the actual capacity will be lower. The SEA therefore describes the maximum impact for the reactor capacity.

The exact location is as yet unknown for some components, such as the possible routes for cooling water pipelines or the temporary Lay Down Area (LDA). In such cases, the design framework works with a search area, for which the impact and possible obstacles are visualized in this SEA. These can then be taken into account wherever possible in further detailing of the design. This further detailing of the design is assessed within the scope of the EIA.

This annex includes the description of the design framework. Where relevant, alternatives and variants have also been described.

Table 1 Detail level

Detail level SEA	Detail level EIA
Search area	Concrete route of cooling water pipeline
Maximum capacity	Actual capacity
Possible layout of the site	Actual layout of the site

1.2 Document structure

A brief explanation is given hereafter for each section:

- Section 2: This describes the various project phases covered in the SEA.
- Section 3: The reactor is described here.
- Section 4: This section covers which preconditions the elements to be constructed must meet for the operational phase and what their maximum scope is. This includes a description of the variants for building height and depth and for cooling that are examined in the SEA.
- Section 5: This section covers which preconditions the constructed works must meet for the construction phase and what their maximum scope is

1 The 55 MW reactor capacity is based on 1) the current capacity of the HFR and 2) the initial discussions with experts in relation to the purpose of the PALLAS-reactor. As stated in the communication memo of the environmental impact assessment procedure, the capacity will be substantially lower than 55 MW.

2 Project phases

The realization and operation of the PALLAS-reactor can be divided into three project phases: the operating phase, the transition phase and the construction phase.

Operational phase

During this phase, the PALLAS-reactor will be commissioned. The reactor will be safely operated and maintained according to the specifications described in the section on the operational phase.

Transition phase

As soon as the PALLAS-reactor is ready for operation, it is likely that the HFR activities will be gradually discontinued. As it is still uncertain exactly when the HFR will be phased out, the description of the environmental impact in the SEA assumes a transition phase in which both reactors will be operational. The transition phase is not described in any further detail in the design framework, as this phase does not lead to unique design choices.

Construction phase

The PALLAS-reactor, the related systems and the related infrastructure modifications are realized during this phase, which will take approximately 4 years. Over these four years, in outline terms the following activities will be executed:

1. Preparing the site and the LDA.
2. Construction of the nuclear island.
3. Construction of the secondary cooling water system, at the same time as construction of the nuclear island.
4. Construction of the other buildings and facilities (sewer/car park, etc.) on the site. This takes place at the same time as construction of the nuclear island.

Within the scope of the SEA, particularly relevant factors are the excavation and ground moving for the purpose of the PALLAS-reactor and the realization of the secondary cooling water system. Also relevant is that a temporary LDA of approximately 50,000 m² must be formed. Excavated ground and construction materials will be transported in and out using trucks. The principle is that construction work must give the least possible hindrance for the surrounding area. Safety and accessibility are other important aspects, especially because the Research Location Petten has limited accessibility for security reasons. The activities in the construction phase are described in the section on the construction phase.

3 The reactor

The PALLAS-reactor will be located on a secure site. This site is surrounded by fencing and may only be accessed via monitored access points. Roughly speaking the site is divided into two parts: the nuclear island and the site directly surrounding the reactor where the supporting facilities are located.

3.1 The reactor

3.1.1 Type of reactor

Research reactors may be laid out in different ways in line with the reactor type. This distinction may be made based on:

- The design of the type of fissile elements used.
- The material used for neutron moderation.
- 'Pool-type' or 'tank-in-pool-type'.

The design and type of fissile elements

A distinction is made between research reactors based on the design and the type of fissile elements used. For instance:

- Research reactors in which the moderator is incorporated in the fissile element, so-called TRIGA reactors.
- Reactors in which the fissile elements are made up of thin plates (plate-type fuel), so-called Material Test Reactors (MTR), or
- Reactors in which the fissile material is used in liquid phase or is dissolved in a fluid.

Like the HFR, the PALLAS-reactor will use the 'plate-type' fissile elements. The choice is primarily based on the fact that there is a great deal of experience with this type of fissile element, which helps to promote the safe operation of the reactor.
A 'plate-type' fissile element comprises a number of plates with an attachment retainer on each side (thicker aluminum plates). The fissile plates contain low-enriched uranium in an aluminum matrix (together the fissile matrix). The matrix is covered with an aluminum cladding applied so that the uranium remains sealed in the fissile plate. Figure 1 shows an example of such a fissile element. The reactor core comprises a number (e.g. 16 or 20) of such fissile elements.

The material for neutron moderation

For the moderation of neutrons, typically water, heavy water, graphite or polyethylene are used. Like the HFR, the PALLAS-reactor is a water-moderated reactor (possibly combined with heavy water). The use of water as moderator in the PALLAS-reactor correlates with the choice of fissile elements to be used.

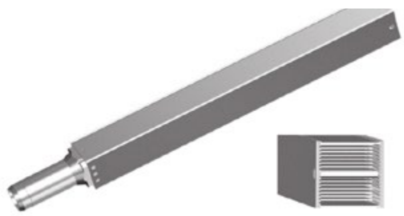

Figure 1 Example of fissile element from a research reactor (side view of the entire element and top view showing the fissile plates)

'Pool-type' or 'tank-in-pool-type'

Further, research reactors are classified on the basis of whether the reactor core is only placed in a basin ('pool'-type), or whether the reactor core is placed in a closed tank that is then placed in a basin (tank-in-pool-type). Like the HFR, the PALLAS-reactor will be a pool-type research reactor, but it has not yet been decided whether it will be a tank-in-pool reactor. In this design, the reactor core, which primarily comprises fissile elements and control rods, is placed in a large water basin (see Figure 2 and Figure3).
During normal operation, the reactor core produces a great deal of radiation. To work safely with the reactor, adequate protection is therefore required between the reactor core and the personnel. Also the personnel must be adequately protected from radiation emanating from experiments and isotopes. Water is extremely well suited for this because several meters of water provides sufficient protection to work safely. Furthermore, water is transparent, making it possible to maintain an overview at all times of the reactor core. The main benefit of a pool-type reactor is that the water basin provides adequate protection during normal operation for carrying out safe experiments and the safe production of medical isotopes, including discharging and charging.
A differentiation of the pool-type reactor is a tank-in-pool-type reactor. This is a reactor for which the reactor core is placed in a closed tank and this tank is located in a water basin (pool). The choice between a pool-type or tank-in-pool-type reactor is primarily driven by safety and operational considerations. Commonly, research reactors with a high power density use a closed tank to ensure sufficient cooling of the fissile elements. With a lower power density and total capacity of a reactor core, there is no longer a direct need to use a closed tank. If there is no direct need for using a closed tank, then a tank may be used with an open top. The makes it easier to access the reactor core during operation, which is favorable for carrying out experiments and producing medical isotopes. PALLAS has not yet made a decision in this regard.

Cooling the reactor (primary cooling system)

Figure 3 illustrates the principle of cooling in a 'tank-in-pool-type' reactor to show how the cooling process works (this principle is the same for all pool-types). Fission of the uranium atomic cores generates heat, which is dispersed by cooling the reactor core. The heat is transferred into cooling water which flows through the reactor basin. The cooling water is pumped around the so-called primary cycle, which transfers the heat absorbed from the cooling water to a secondary

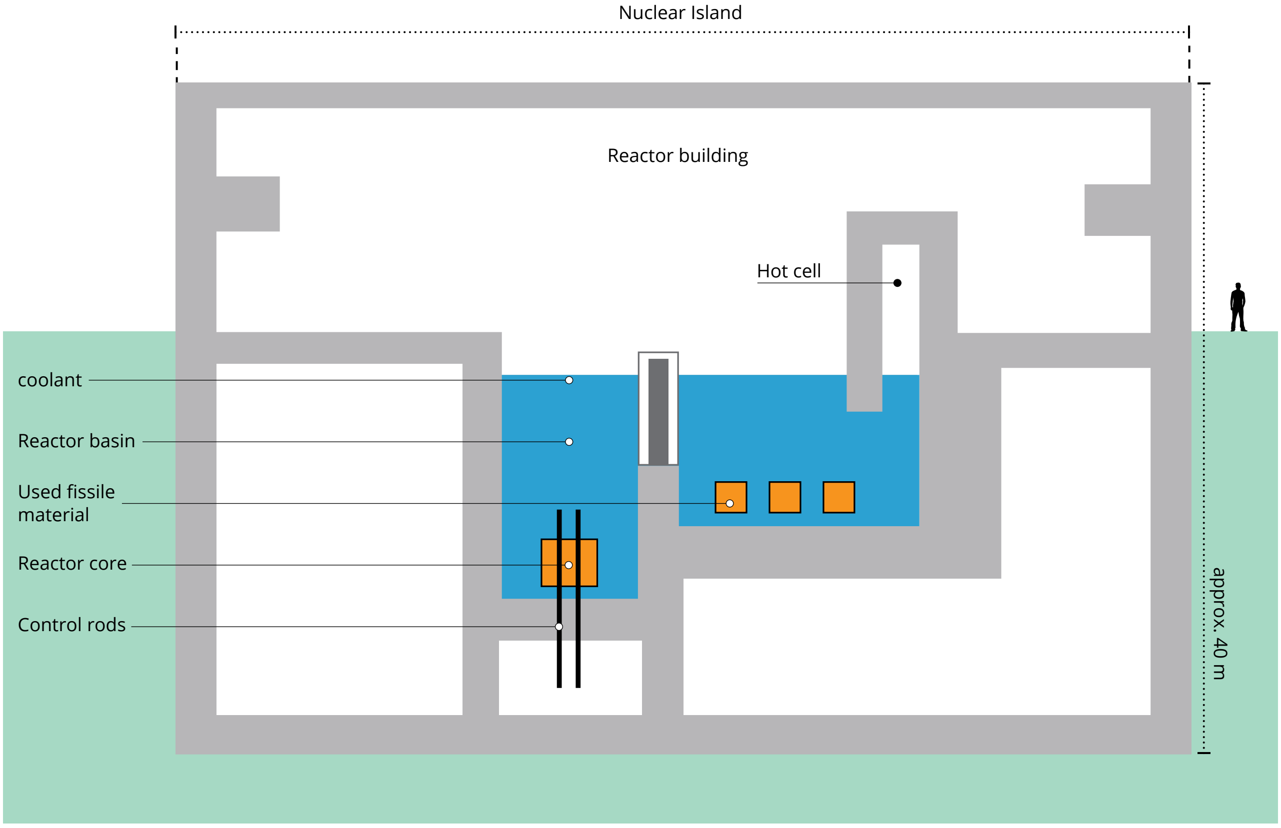

Figure 2 Schematic illustration of pool-type reactor

system, via a heat exchanger. The maximum capacity of the reactor is expected to be 55 MW. The cooling capacity needed is assumed to be 20% greater than the reactor capacity. The reactor core and the fissile material used also transfer heat to the reactor basin water. This reactor basin water is cooled in a similar manner to the cooling water, namely using a primary cycle which transfers heat to the secondary system via a heat exchanger. This primary water can then be cooled in various different ways, with one example given in Figure3, providing cooling through surface water.
The choice to cool the reactor core with water is a direct result of the choice for the type of fissile elements and the radiation conditions demanded of the reactor relative to the execution of experiments and the production of isotopes. This then

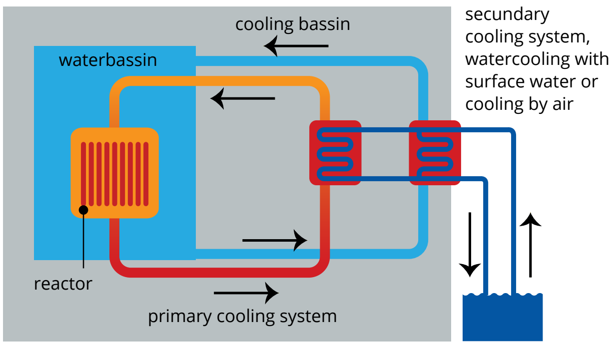

Figure 3 Schematic representation of the primary cooling cycle and secondary cooling cycle for a tank-in-pool reactor

precludes the use of a different coolant other than water in the primary cycle.

Hot cell
In or near the reactor, one or more hot cells may also be realized. A hot cell is a sealed-off treatment area in which robots are used to safely work with radioactive material. The hot cell thus protects the personnel working with radioactive material from radiation within the hot cell. In the hot cell, experiments are carried out and capsules or other radioactive objects are disassembled for the purpose of inspection, repair or transport. Also containers with experiments, nuclear waste and radio-isotope capsules can be charged here. Further, medium and high radioactive waste can be processed in the hot cells ready for transport for further processing or storage at COVRA (Central Organization for Radioactive Waste).

The nuclear island
The nuclear island comprises the building in which the reactor is located and functionalities directly linked to it. An important function of this building is that it provides a physical barrier, in order to seclude radioactive material and fissile material. The process of preventing or limiting the emission of radioactive material to the environment is also known as confinement[2].

Nuclear island dimensions
The assumed dimensions of the nuclear island are 40 m (Width) x 60 m (Lenght) x 40 m (Height). Table 2 shows the minimum height necessary for this. All individual section heights

2 Confinement: The prevention or limitation of the emission of radioactive materials to the environment during normal operations and during any incidents which may occur.

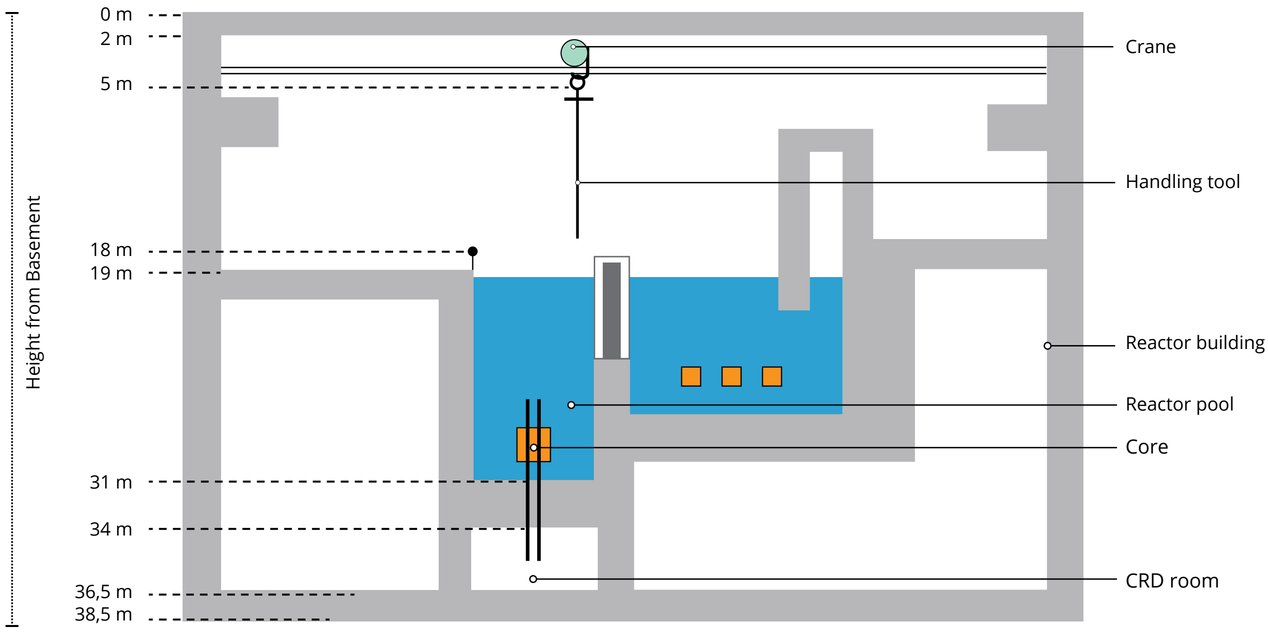

Figure 4 Factors determining the height of the reactor

together represent an aggregate height of 38.5 m. Factoring in unforeseen space, such as a domed roof, we arrive at a total height of 40 m for the nuclear island.
For the extraction of ventilation air and the discharge of gassy or airborne radioactive particles, the building features a ventilation shaft. Its height is about 45 m above ground (48.5 m + NAP, comparable with the ventilation shaft of the HFR), and is independent of the building height of the building.

Main features of the PALLAS-reactor
The following table gives a number of features of the PALLAS-reactor (compliant with the information supplied to Euratom).

Table 2 Height of nuclear island per section

Nuclear island height			
Description	Height		Position
	Per section	Total	
Roof	2	2	Construction necessary for plane crashes and containment
Roof - crane hook	3	5	Physical size of the equipment
Free height for using tools/molds	13	18	Equal to pool depth and pool barrier
Pool barrier	1	19	Operational protection
Pool depth	12	31	Radiological protection
Pool floor	3	34	Radiological protection and structure
CRD area	2.5	36.5	Lay Down Area
Shell of building (concrete)	2	38.5	Construction
Total	**38.5**		meters

3.1.2 Safety concept

Nuclear reactors must be operated safely. In other words, people and the environment will be sufficiently protected against the harmful influence of ionizing radiation throughout the life cycle of a nuclear reactor. Extensive international and national legislation and regulation exists to regulate this field, which is strictly monitored by the Authoritative body. The life cycle of a nuclear reactor concerns its design, construction, commissioning, operation and eventually decommissioning and dismantling.
A hazard is defined as an incident that could occur inside or outside the facility that has a potential or certain negative impact on reactor safety. Internal hazards are within the facility, while external hazards come from outside the facility. One example of an internal hazard is a fire within the facility. External hazards are either natural or caused by humans, such as lightening, earthquake or risks originating from a nearby industrial park.
A nuclear reactor must essentially comply with the three following safety functions:

1. Management of the reactivity (shutting down the reactor);
2. Cooling the fissile material;
3. Confinement of the radioactive or fissile materials.

These three safety functions apply to all phases of the life cycle of a nuclear reactor. If the safety functions are not met, a Nuclear Energy Act permit will not be granted (NEA permit). The safety functions are further underpinned in the application for the Dutch Nuclear Energy Act permit and the accessory EIA.
To guarantee the above-mentioned safety functions, a number of key recognized safety principles are employed, with the defense-in-depth concept and the barrier concept being the most important. These principles are described briefly hereafter.

The Defense-in-Depth safety concept
The nuclear safety of nuclear reactors is based on the concept

Table 3 Main features of the PALLAS-reactor

Parameter	Description
Reactor capacity (MWth)	As low as possible (<55 MW)
Thermal neutron flux (n/cm 2/s)	• Low flux zone - 1.0 X 1014
	• Medium flux zone - 2.0 X 1014
	• High flux zone - 3.0 X 1014
Rapid neutron flux	Not decisive for the reactor design
Reactor cooling principle	Cooling category 2 as per Dutch Safety Requirements – passive cooling in the event of external power supply outage
Cooling water flow direction through the core	Upward
Risk category	Risk category 3 as per Dutch Safety Requirements
Reactor availability	300 Full Power Days
Number of Hot Cells	Minimum two
Loading scheme	Redundant dry loading route and wet loading route as diverse method
Production	Mo-99, other isotopes for industrial and medical purposes
Research	• Support of research on medical isotopes
	• Irradiation of fissile material samples in capsules
	• Irradiation of material samples
Reservation for adjustments:	Additional space and infrastructure for:
	• future introduction of one complex fissile irradiation solution (e.g. Irradiation of fissile material in steady state, accident or ramp-up conditions);
	• or extension of irradiation of medical (such as Mo-99 etc.) or industrial isotopes.

of layers of safety, (known as 'Defense-in-Depth'). This safety concept is intended to prevent incidents or limit the consequences of incidents and is a combination of structural, technical and organizational measures. Multiple strategies are applied to guarantee the safety of the reactor under abnormal circumstances and incident conditions. This is achieved through several different levels of protective measures, each with its own strategy:

- A conservative design, quality assurance and high-quality operations prevent failures during normal operation of the nuclear reactor.
- Abnormal operations are monitored. This means that predictable operational incidents are manageable.
- Safety systems and incident procedures limit escalations that could lead to nuclear meltdown.
- In the event of extreme calamities in which significant amounts of radioactive substances are released, emergency measures are applied to limit the radiological impact on the locality.

Each strategy aims to prevent all possible forms of human error as well as the failure of equipment or to manage or mitigate any impacts as much as possible.

In compliance with the Dutch guidelines for the Safe Design and Operation of Nuclear Reactors (VOBK), the following types of incidents are considered for new reactors:

- Failure of an internal system, such as leakage of a cooling system or power outages.
- Internal hazards, such as fire.
- External hazards, such as flooding (taking account of climate change), an earthquake or an aircraft crashing into the installation.

According to Dutch regulations, the resilience of the system against these incidents must be demonstrable.

Barrier concept

The barrier concept is part of the Defense-in-Depth concept. The aim of the barrier concept is to confine radioactive substances and (irradiated) fissile material in the installation. This concept is based on the presence of multiple successive barriers and retention functions (see Figure 5). Upon functional failure of one barrier, the following barrier guarantees confinement.

The number of barriers and their form is determined by the type of nuclear reactor, its configuration and its capacity, among other factors. Barriers include the fissile matrix (1), the lining of the fissile plates (2) and the building (3). The radioactive fissile products that are formed during the nuclear reaction are retained by these barriers, with the fissile products remaining in the fissile plate in the normal situation. With a tank-in-pool type reactor, the reactor vessel is also a barrier.

Retention functions are measures or provisions taken to retain radioactive materials. These might include filtering the air, covering radioactive material with water, targeted (air) flows by maintaining underpressure, building seals, containers, etc. The basin water fulfills such a key retention function because fissile products, which would otherwise be released if the fissile plate is damaged, largely remain in the water.

For the sake of safety, it is important that the barriers function independently of each other. This means that in case of a hazard or an incident, a barrier may not fail just because another barrier failed. If one or more barriers fail anyway, releasing radioactive substances, then the retention functions must ensure the retention or temporary containment of those substances.

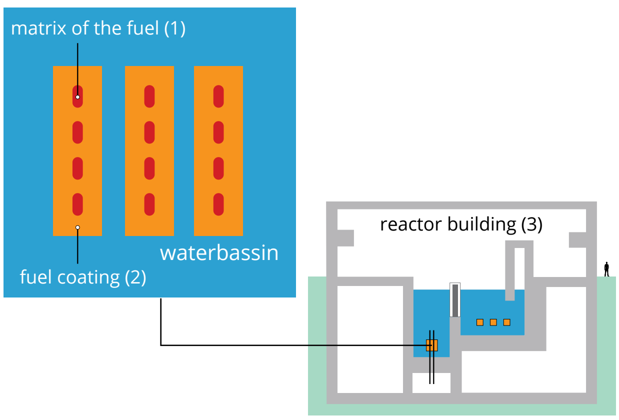

Figure 5 Barrier function illustrated schematically

3.2 Use of the reactor

The reactor is used for experiments and isotope production. The neutrons released during fission are mainly used for the medical, scientific and industrial purposes outlined hereafter:

- Medical and industrial isotope production.
- Nuclear technological research.

Isotope production

In the reactor, raw materials are radiated for the production of medical isotopes that are used in hospitals for diagnosis, pain relief and treatment (see paragraph 3.3.2). For the development of new or existing nuclear drugs, irradiation tests are carried out.
Furthermore, industrial isotopes are produced, which are used, for example, for checking pipelines in the oil and gas industry (non-destructive inspections and weld tests) and in electronic chips in the semiconductor industry.

Nuclear technological research

In terms of nuclear technological research, applications include material testing for existing and new reactors to determine the impact of radiation on the aging of materials. Fissile material research is also carried out. The aim of this is to develop a more durable fission cycle by minimizing the amount of radioactive waste and shortening the lifespan of radioactive waste.

3.3 The fissile chain and the isotopes chain

This paragraph explains the fissile chain and the isotopes chain. In a research reactor, fissile material is applied in two different ways. It is used in the reactor core as a fuel and in fissile-material retaining experiments and isotope irradiation. For this reason, the SEA distinguishes between these two applications:

- The fissile chain for fissile material as a fuel in the reactor core (paragraph 3.3.1).
- The isotopes chain for the use of fissile material in the experiments and isotope irradiation (paragraph 3.3.2).

The following paragraphs describe the steps in the fissile chain and the isotopes chain, respectively, and the site of the PALLAS-reactor in these chains. The description of the fissile chain addresses the chain from the mining of uranium right up to the processing of radioactive waste.
The last paragraph 3.3.3 covers non-proliferation. Non-proliferation intends to limit the possession of nuclear weapons.

3.3.1 Fissile chain

Fissile material is needed as fuel to operate a nuclear reactor. This paragraph describes the fissile material in outline terms. The fissile chain in an international chain, with some stages (activities) taking place in the Netherlands, and others further afield. Each stage is subject to separate statutory procedures and requirements. For these separate stages in the chain, separate permits are therefore required. These permits take account of any environmental impacts (and necessary measures) in terms of the procedures, and establishes these in line with the legislation and regulation of the country concerne The PALLAS-reactor replaces the HFR and shall use fissile material like the current HFR does. No actual changes in the fissile chain shall take place as a result of realizing the PALLAS-

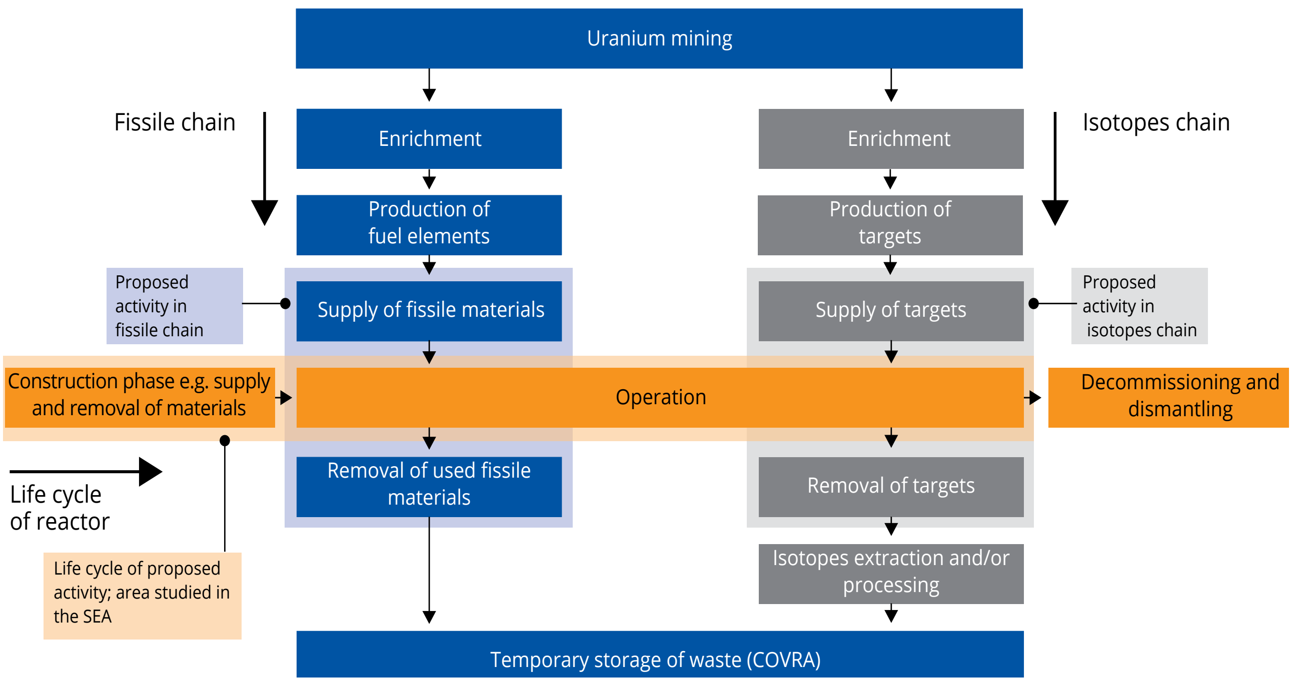

Figure 6 Schematic representation of the fissile chain and isotopes chain (orange area is discussed in this SEA)

reactor, so there is also no change in terms of environmental impact in the other stages in the chain as a result of the PALLAS-reactor. In Figure 6, the fissile chain and the place of the PALLAS-reactor within that chain are shown schematically. The separate stages are briefly explained below Figure 6.

Uranium mining

The fissile chain starts with the mining and purification of uranium ore. Uranium is mined in some 20 countries. The following countries provide 85% of worldwide production: Australia, Canada, Kazakhstan, Namibia, Niger, Russia, Brazil, China and South Africa.

Uranium-bearing ore can be mined either above-ground or below-ground using various techniques. Depending on the location, the concentration of uranium in the ore varies from 0.1% to more than 2% uranium. The mined ore is ground into powder at so-called 'ore mills', after which chemical processes extract the uranium from the ore. The remaining pulverized parent rock, the so-called tailings, is managed carefully as mining waste as it still contains radioactive substances.

Another technique for extracting uranium is called in-situ leaching. This makes use of the fact that some uranium-bearing strata are porous. By injecting water containing an (acid or alkaline) solution into drill holes, a uranium-bearing solution is pumped to the surface without having to mine the ore itself. This technique is currently used in half of all uranium mining operations. The biggest advantage of this is that it takes place with very little disruption of the ground. But uranium also comes to market as a co-product / by-product of gold, copper or phosphate mining.

The mined uranium ore is known as 'yellow cake'. Yellow cake is a stable, yellowish substance.

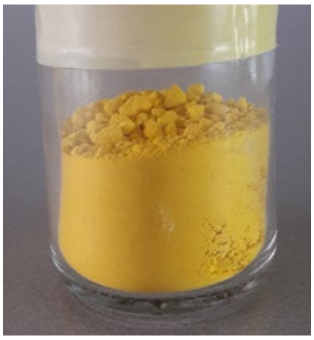
Figure 7 Yellow cake

Mining uranium can impact the health, safety and radiation protection of employees and the local population. It may also impact water quality, for instance when water wells are located in or close to the mine, due to mining water extraction or process water discharges. The 'in-situ leaching' technique in particular uses a lot of water. Effective water management and an extensive monitoring system during operations help to mitigate the impact as far as possible. The operator of the uranium mine must demonstrate in the environmental impact assessment procedure that the impact on water quality is low enough that this is acceptable to the relevant Authoritative body of the country in which the activity is carried out.

Furthermore, the waste produced by mining uranium entails a major environmental impact. The so-called 'tailings' occur in both dry and wet forms and contain heavy metals and radioactive material (primarily radon gas). These substances must be stored safely for long periods of time. This is done in special developed facilities often located at or near the mine. In recent decades, a great deal of attention has been given to reducing the negative impact of uranium mining. The report entitled 'Managing Environmental and Health Impacts of Uranium Mining' describes how a great many improvements have been implemented in practice to minimize the impact of uranium mining on the locality. In recent years, the average annual effective individual dose of exposure to fissile material by workers worldwide, particularly to radon, has fallen from 4.4 mSv in 1975 to 1.0 mSv in the year 2002. This reduction was realized partly by installing forced ventilation in underground mining operations to protect workers. The 'in-situ leaching' technique is also being used more frequently, and this does not involve any exposure for employees to fissile material and radon gas. The maximum dose for people occupationally exposed to such matter is 20 mSv (millisievert) per calendar year.

In terms of the process water, many mines are now extracting less water as they are increasingly re-using it. More and more water-treatment systems are being built with the aim of further purifying it before discharging it.

Enrichment

To use uranium in a nuclear reactor, the concentration of 0.7% uranium-235 must be increased through enrichment. To this end, 'yellow cake' is converted into uranium hexafluoride through chemical conversion. In an enrichment plant, physical separation processes are used to split the uranium hexafluoride into enriched and depleted uranium. Various filters minimize the radioactive emissions from this process. The depleted uranium oxide is usually stored to provide a strategic reserve, as it can be used (when economically viable) as a raw material, for instance, for further enrichment and the production of enriched uranium. The main environmental impact of uranium enrichment is the (very limited) safety and radiological effects on employees of the enrichment facility and the depleted uranium / radioactive waste created by the process. While the Netherlands does have an enrichment facility, it is unsure whether uranium will be enriched there for the PALLAS-reactor, as this will depend on the final choice of design of the PALLAS-reactor.

Supply of fissile material

The enriched uranium hexafluoride is converted in a plant for producing fissile material into uranium oxide and further processed into fissile elements. No fissile elements are produced in the Netherlands. The fissile elements will be transported to the PALLAS-reactor from abroad, in containers. These containers protect the fissile elements from external influences and do not require any extra radiological protection due to the low radioactivity of the new fissile elements. A separate permit is required for transport within the Netherlands. The environmental impact of the transport primarily relates to security, safety and radiological effects, and the latter of these is dealt with in the EIA.

3 Uranium 2016: Resources, Production and Demand; A Joint Report by the Nuclear Energy Agency and the International Atomic Energy Agency

Table 4 PALLAS-reactor compared to a nuclear power plant

	Nuclear power plant	PALLAS-reactor
Electrical capacity	1000 MW	0
Thermal capacity	± 3000 MWth	55 MWth
Level of enrichment	5%	Less than 20%
Uranium ore	20,000 – 40,000 tons/year	350 – 750 tons/year

Operation

The fissile elements will be deployed as fuel in the PALLAS-reactor, for operation of the reactor. These elements generate neutrons, which are required for irradiation of the experiments. The fissile material thus used will need to be periodically replaced. According to the World Nuclear Association, a modern 1000 MW nuclear power plant needs about 16,850 kg of enriched uranium per year. To produce this volume enriched to 5% requires between 20,000 and 40,000 tons of uranium ore. Translated to the PALLAS-reactor, this means that a factor of 55 less uranium ore needs to be mined.

When spent, the used fissile elements are discharged from the reactor core and temporarily stored under water (for a number of years) in the water basin. The natural depletion of the radioactive fissile products releases heat, which decreases as depletion advances. This operational stage in the chain is the object of study in the PALLAS SEA.

Removal of fissile material

After around 2 years, the heat production decreases to such an extent that the fissile elements can be transported in a special container. The fissile elements are transferred from the water basin into a specially designed container, which is then transported to COVRA (Central Organization for Radioactive Waste). Separate permits are required for transport within the Netherlands. The environmental impact of these relates specifically to security, safety and radiological effects. The latter two of these are covered in the EIA.

Radioactive waste

COVRA has been designated by the government of the Netherlands as the custodian of radioactive waste generated in the Netherlands. The policy states that the waste must be stored above-ground for 100 years, followed by final disposal. Over the 100 years, the activity of the waste declines by 90% due to spontaneous radioactive depletion, with the heat generation declining in concert. This simplifies future handling of the waste considerably with respect to final disposal. Currently the government of the Netherlands aims for geological final disposal at around 2130 with the requirement that the waste remains accessible for future use. The impact of storing the radioactive waste relates specifically to security and radiological effects.

3.3.2 Isotopes chain

The PALLAS-reactor not only produces medical isotopes and industrial isotopes, but also provides irradiation facilities for nuclear technological research. Like the fissile elements, certain isotope radiation and certain experiments also contain uranium and are therefore part of the isotopes chain. This paragraph describes the isotopes chain in outline terms. Further information can be found in the document 'Medical isotopes – Global importance and opportunities for the Netherlands'.

This chain is very comparable with the fissile chain, though a number of components deviate. This too is an international chain, with some stages (activities) taking place in the Netherlands, and others further afield. Each stage is subject to separate statutory procedures and requirements. For these separate stages in the chain, separate permits are therefore required. These permits take account of any environmental impacts (and necessary measures) in terms of the procedures, and establishes these in line with the legislation and regulation of the country concerned.

The PALLAS-reactor replaces the HFR and shall use fissile material bearing targets like the current HFR does. No actual changes in the isotope chain shall take place as a result of realizing the PALLAS-reactor, so there is also no change in terms of environmental impact in the other stages in the chain as a result of the PALLAS-reactor. Figure 6 shows not only the fissile chain schematically, but also the isotopes chain. The separate stages are briefly explained hereafter.

Uranium mining, reprocessing and enrichment

These stages are equivalent to the stages in the fissile chain (see 3.3.1).

Production of targets

Within the isotopes chain, a target is a piece of material, often made from aluminum, which contains uranium. Depending on the application, one or more targets are placed in a target holder. The target holder is then placed in or beside the reactor and irradiated.

Targets containing fissile material are made in a fissile-material production plant. First the enriched uranium powder is mixed, and this is then made into a plate or a rod, depending on the prearranged specifications. These are then placed in a gas-tight housing. Using special measuring equipment, the targets are checked to ensure they meet the required specifications, after which they are prepared for transport to the PALLAS-reactor. The packaging comes in various guises (see Figure 8 Examples of targets), protects the targets against external influences and does not require extra radiological protection due to the low radioactivity.

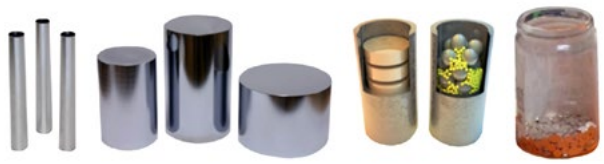

Figure 8 Examples of targets

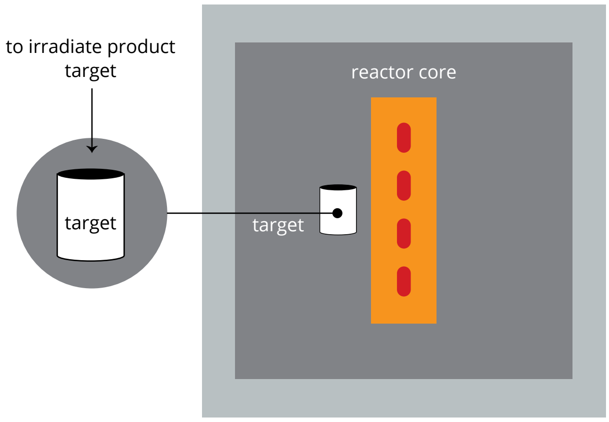

Figure 9 Schematic illustration of irradiation of a target placed next to the reactor core

Supply of targets
The targets are transported to the PALLAS-reactor in the Netherlands from abroad (from France, for example). Separate permits are required for this transport within the Netherlands. The environmental impact of these relates specifically to security, safety and radiological effects. The latter two of these are covered in the EIA.

Operation
Using special equipment, the targets are placed in target holders, which in turn are installed in or alongside the reactor core of the PALLAS-reactor. The neutrons generated in the fission process in the reactor irradiate the targets. Following a preset irradiation period, the targets are removed and placed in a container.
An irradiation period mostly varies from a few days to a month. The environmental impact in the operational phase mainly relates to radiological and safety impacts and is covered in section 5 of this SEA.

Removal of targets
Following irradiation, the targets are transported in specially designed containers for further processing, for the production of medical isotopes or conducting technological nuclear research. Most of these activities take place at the Research Location Petten.

Isotope extraction and/or processing of targets
Depending on the application, the targets are further processed using one or more processes. Most of these activities take place at the Research Location Petten. Chemical processes are used to extract and purify the various radioactive isotopes from the targets. This is carried out in a special system that is included in a number of lead cells, gas-tight glove compartments and fume cupboards. After purification, the radioactive isotopes are packed and transported to hospitals or research facilities. The environmental impact of isotope extraction and/or processing of targets is described during the permit procedures of the related process. Separate permits are required for transport within the Netherlands. Here too, the environmental impact primarily relates to security, safety and radiological impacts. As part of the fissile chain and the isotopes chain, the latter two of these are covered in the EIA.

Radioactive waste
During processing and following use at the hospitals or research institutions, the waste materials are radioactive, and are transported to COVRA in specially designed containers, where they are stored according to the Dutch policy. The impact of storing the radioactive waste relates specifically to security and radiological effects.

3.3.3 Non-proliferation
Due to the non-proliferation aspect, the PALLAS-reactor will operate with low-level enriched uranium, which means that the uranium-235 content is less than 20% of the total volume of uranium used.
The Netherlands has committed itself to these treaties, so like the existing HFR, the PALLAS-reactor will fall under the supervision of Euratom and the IAEA. This supervision involves Euratom and the IAEA having access to the relevant information relating to the fissile materials present and carrying out regular inspections.

Non-proliferation treaties
Non-proliferation intends to limit the possession of nuclear weapons. The key International treaties are the Euratom Treaty (1957) and the Non-proliferation Treaty (Treaty on the Non-Proliferation of Nuclear Weapons, New York, 1 July 1968). Under these treaties, the use of nuclear energy for peaceful purposes is only permitted under the supervision of the International Atomic Energy Agency (IAEA) and in Europe the EU (Euratom). Because it is easier to make nuclear weapons with highly enriched uranium than with low enriched uranium, the use of highly enriched uranium has been restricted worldwide. As a result of this, countries are switching as far as possible to low-enriched uranium as a fissile material in research reactors and as a raw material for the production of medical isotopes

4 Operational phase

4.1 Description of PALLAS site

The PALLAS-reactor will be located on a secure site. This site is surrounded by fencing and may only be accessed via monitored access points. Roughly speaking, the site can be divided into two parts: the nuclear island and the site surrounding the nuclear island where the supporting facilities are located.
The entire PALLAS site is a restricted access zone. A separate reception area will be built at the Research Location Petten, from which access is gained to the PALLAS site. The entire PALLAS site falls within this restricted access regime.
On the PALLAS site, the nuclear island is located in a top-security zone. This zone starts at the guard house that provides access to the nuclear island. The nuclear island includes not only the reactor building, but also the control room, meeting facilities, changing rooms and the emergency power unit.
Figure 10 shows the possible layout of the PALLAS site. The nuclear island is indicated by a black 60 m by 60 m square. The nuclear island covers a surface area of 40 x 60 m. The orientation of the nuclear island is currently not known, however.

4.1.1 The nuclear island

The nuclear island comprises the reactor building and its directly related functionalities. It is used for experiments and isotope irradiation, as described in section 3. The assumed dimensions of the nuclear island are 40 m (Width) x 60 m (Lenght) x 40 m (Height). For an impression, see Figure 11.
The ventilation shaft is some 45 m above ground level (48.5 m + NAP), and is independent of the height of the nuclear island. In or near the reactor, one or more hot cells may also be realized. A hot cell is a sealed-off treatment area in which robots are used to safely work with radioactive material.

The nuclear island also includes:

- The guard post that provides access to the nuclear island.
- Office and meeting facilities and changing rooms.
- The control room and secondary control room.
- Container handling area and workshop.
- Ventilation and (emergency) power facilities.

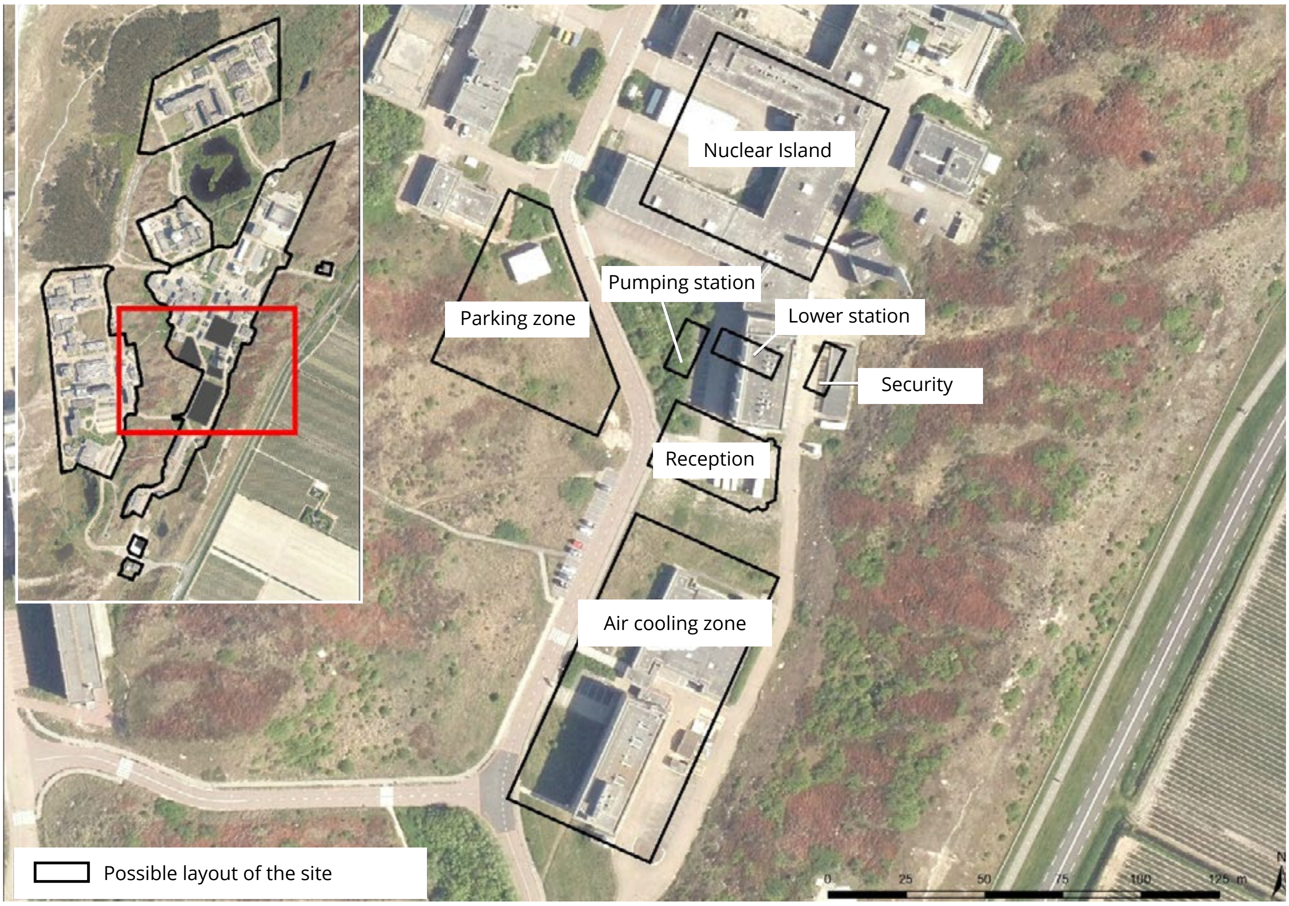

Figure 10 Possible layout of the site

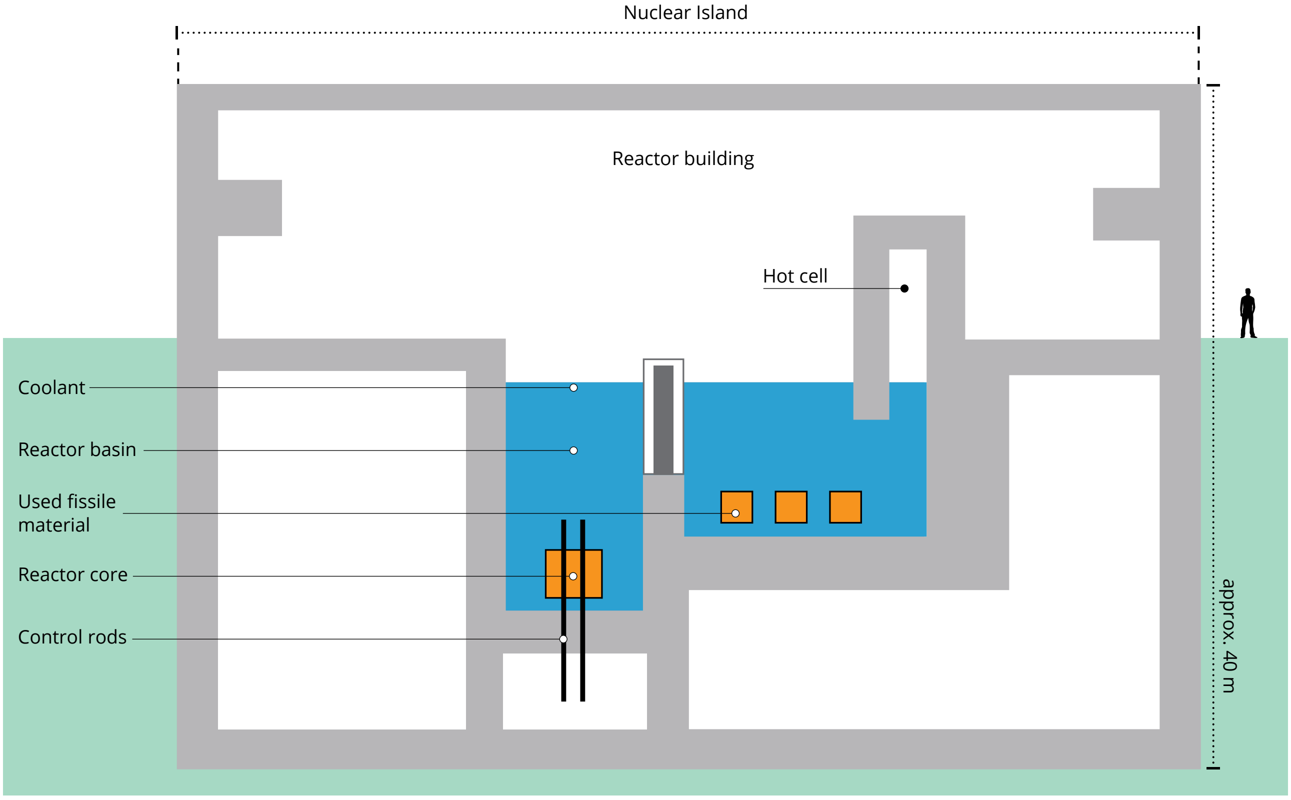

Figure 11 Schematic illustration of pool-type reactor

4.1.2 Nuclear island height and depth variants

The SEA considers three variants for the construction height and depth of the nuclear island. The variants and reasons for the choice of these variants are described hereafter.

- Variant B1: 17.5 m above ground level and 29.5 m below ground level
  This variant is determined by the height of the buildings in the current zoning plan (21.0 m + NAP, equal to 17.5 m above ground level). This would require more than half the nuclear island to be built underground. With a building height of 40 m, the nuclear island would have to be built 22.5 m below ground level. However, at this depth there is an unstable stratum. The construction method to be used for realizing the nuclear island cannot be used on an unstable stratum. For this reason, it was decided to construct the nuclear island 29.5 m below ground level, as there is a stable stratum at that depth.
- Variant B2: 24 m above ground level and 16 m below ground level
  Variant B2 is determined by the maximum permissible height in the current zoning plan, which is 24 m above ground level (27.5 m + NAP). A limited part of the nuclear island will therefore be constructed underground.
- Variant B3: 40 m above ground level and 0 m below ground level
  This height relates to the maximum building height if the nuclear island is constructed at ground level (43.5 m + NAP).

The variants B1 and B2 fall within the construction height possibilities of the current zoning plan. The maximum construction height of the zoning plan would need to be modified for variant B3.

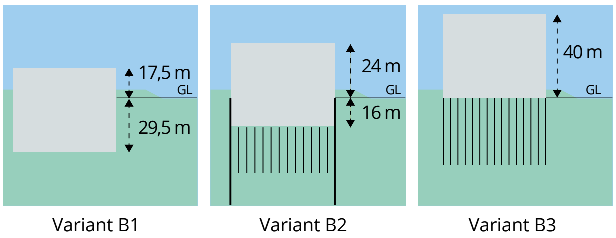

Figure 12 PALLAS nuclear island construction height variants

4.1.3 Other buildings

A list follows hereafter of the buildings and facilities on the PALLAS site:

- Reception: initial security checks are carried out here of personnel and visitors and this area may be entered with restricted access.
- Offices: this building is 24 by 42 m in size with a height of approx. 12 m. It is connected to the reception.
- Gates: the gates form the main entrance to the area with limited access and to the protected area.
- Electricity substation: the substation is 21 m by 8.2 m in size with a height of 4 m. The roof is pitched to the rear. All cables enter and exit via the ground, so a basement of 2.2 m in height will be built below the entire ground floor.
- Emergency control center: the emergency control center is not located on the PALLAS plot but adjacent to the current main entrance. It will be 18 m by 16.5 m in size and will have two floors. The entrance will be located on the upper floor, accessible using stairs. The building will be construc-

ted at 4 m + NAP. The building will provide protection against radioactive radiation, earthquakes, forest fires or floods. The walls will be about 0.5 m thick, made of heavy concrete with metal aggregate.

Dependent on the variant chosen, the pumping station on the PALLAS site will also be built. A description of this is included in section 4.2.1.

4.1.4 Parking zone

Finally, the PALLAS site also includes parking facilities:
- All cars must be parked outside the area with restricted access.
- The protected area only has parking facilities for trucks and 'unloading and loading'.
- There will be an estimated 70 parking spaces for cars in front of the PALLAS offices.
  - This estimate is based on a parking coefficient of 0.7 and 100 employees.
- There will be an estimated 30 parking spaces for cars in front of the nuclear island.
  - This estimate is based on a double shift of 20 employees (2x20) and a parking coefficient of 0.7.
- The total number of parking spaces is estimated at 100.
- If more parking spaces are needed, the option of a multistory car park will be examined.

4.2 Cooling system variants

Adequate cooling is an important basic condition for safe operation of the PALLAS-reactor. This is needed to remove the heat generated by the operation of the reactor. The PALLAS-reactor has primary and secondary cooling water systems. There are six variants for the secondary cooling system, and these can be subdivided into three main systems:
1. Variant K1: Water cooling with water extraction from the Noordhollandsch Kanaal.
2. Variant K2: Water cooling with water extraction from the North Sea.
3. Variants K3-K6: Air cooling.

The following paragraphs describe the design frameworks for each variant.

4.2.1 Variant K1: Extraction from the Noordhollandsch Kanaal and discharge into the North Sea (freshwater-saltwater variant)

This variant is derived from the current practice at the HFR. The secondary cooling system of the HFR extracts water from the Noordhollandsch Kanaal, which is freshwater. After having cooled the primary system, the water is discharged into the North Sea. This is illustrated schematically hereafter. This variant would require a new extraction point to be constructed in the Noordhollandsch Kanaal, with the inlet structure being built on piles. A new outlet point will be built in the North Sea, and this outlet is referred to under variant K2 (cooling using seawater). A cooling water pipeline would also be constructed between the reactor, the extraction point and the discharge point. The route of the cooling water pipelines has not yet been agreed. A search area has been determined in which the cooling water pipelines could be realized (see Figure 14). The cooling water pipelines will be realized in an area that is used for flower bulb cultivation.

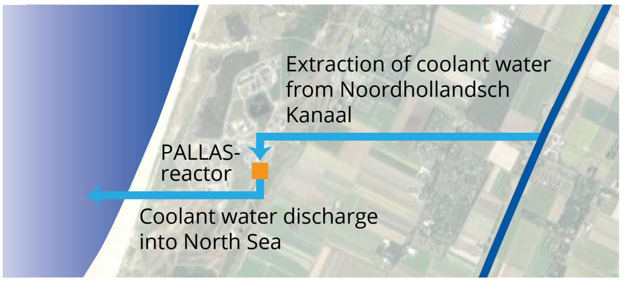

Figure 13 Schematic illustration of cooling variant K1

Between the intake point and the reactor, a pumping station will be built. This could be built at a number of locations. Variant K1 can be subdivided into two sub-variants:
- K1a: Pumping station at the canal.
- K1b: Pumping station at the Research Location Petten.

Where relevant, the background studies make a distinction between variant K1a and K1b.

Variant K1a: pumping station at the canal

Figure 15 illustrates the pumping station at the canal schematically.

The pumping station has the following facilities:
- Secondary cooling water pumps, four pumps of 1,650 m³ / hour each (two pumps fitted for built-in redundancy).
- Overhead gantry cranes.
- Filters and valves to remove most solid material from the water.
- Two inlet pipes.
- A system to protect fish to reduce the impact on fish numbers and a fish return pipe.
- The building will take up a surface area of around 12 m by 10 m, with a height of 8 m (5 m above ground level).
- The pumping station will be built on bored piles.

The total structure comprises the following elements:
- A cooling water pipe below the road, due to the lack of space between the canal and the road.
- The route from the Noordhollandsch Kanaal to PALLAS will be chosen so as to minimize the impact on the locality. This basically means that it will not run under buildings, woodland or water. This route is about 1,750 m long.
- The starting point is that the pipes will be laid using open excavation where possible.
- Two pressure-water pipes from the pumping station at the canal to the nuclear island.
- If the cooling water pipes are laid, they will have to cross two roads. These crossings will be drilled so that these roads (N9 and N502) do not have to be closed during the pipe-laying works.
- The route of the cooling water pipelines at the Research

Figure 14 Search area cooling water pipe route and intended new location of new reactor (green shaded area)

Location Petten towards the sea is the same as the salt water alternative.

Variant K1b: pumping station at the Research Location Petten
The pumping station has the following facilities:

- Secondary cooling water pumps, three pumps of 1,650 m³ / hour each (a reserve pump and a pressurized cooling water pipeline).
- Main pumps for fire-fighting water.
- Sodium hypochlorite.
- Main valves.

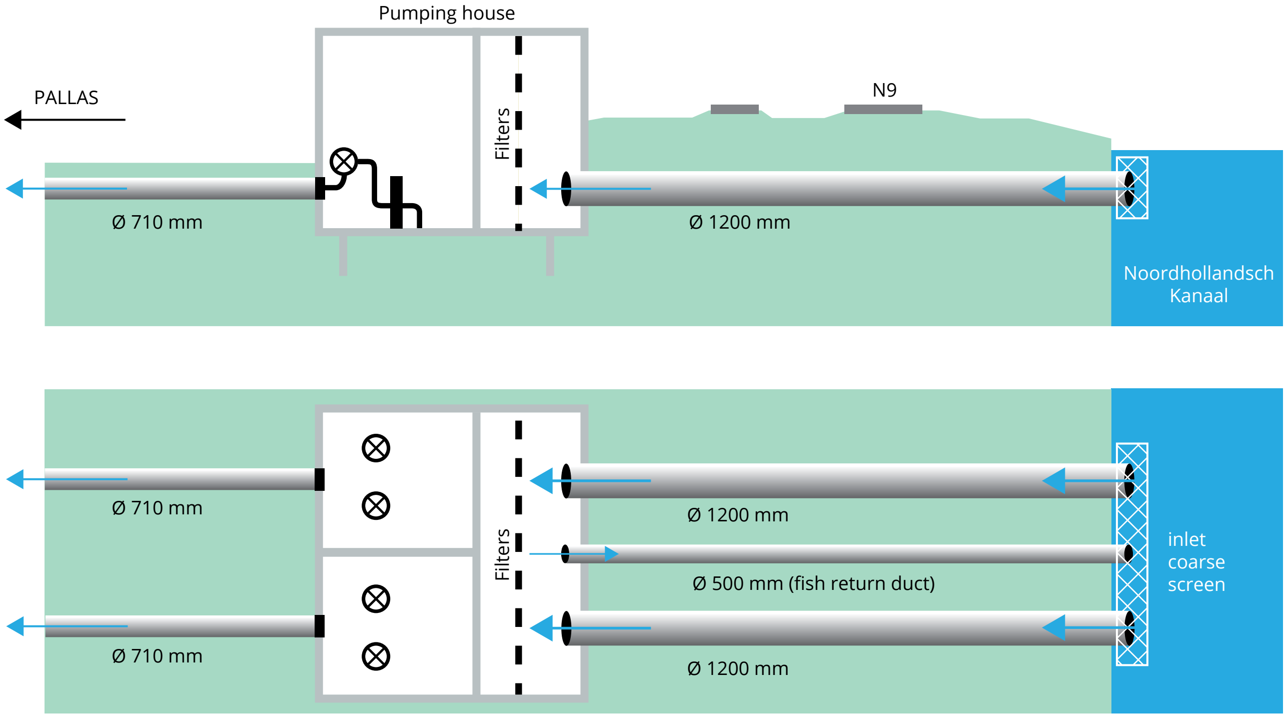

Figure 15 Side view and top view of the pumping station at the canal (variant K1a)

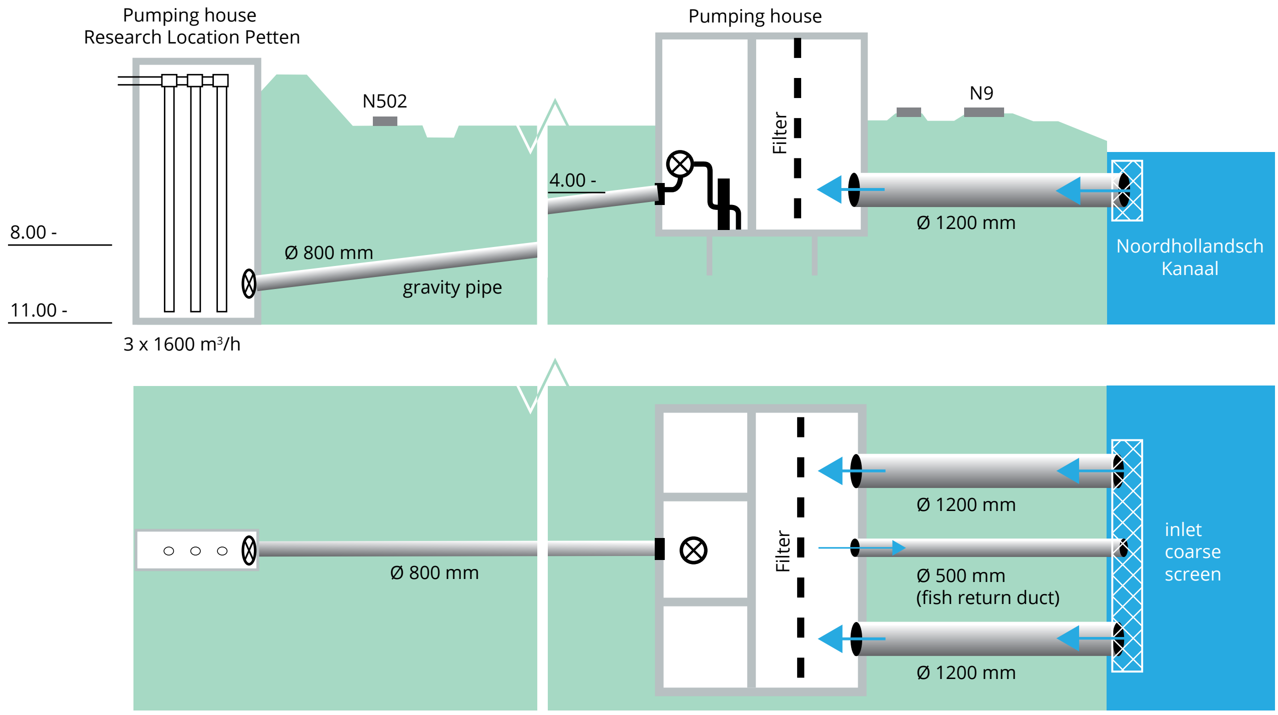

Figure 16 Side view of the pumping station at the Research Location Petten and top view of the inlet structure at the canal (variant K1b)

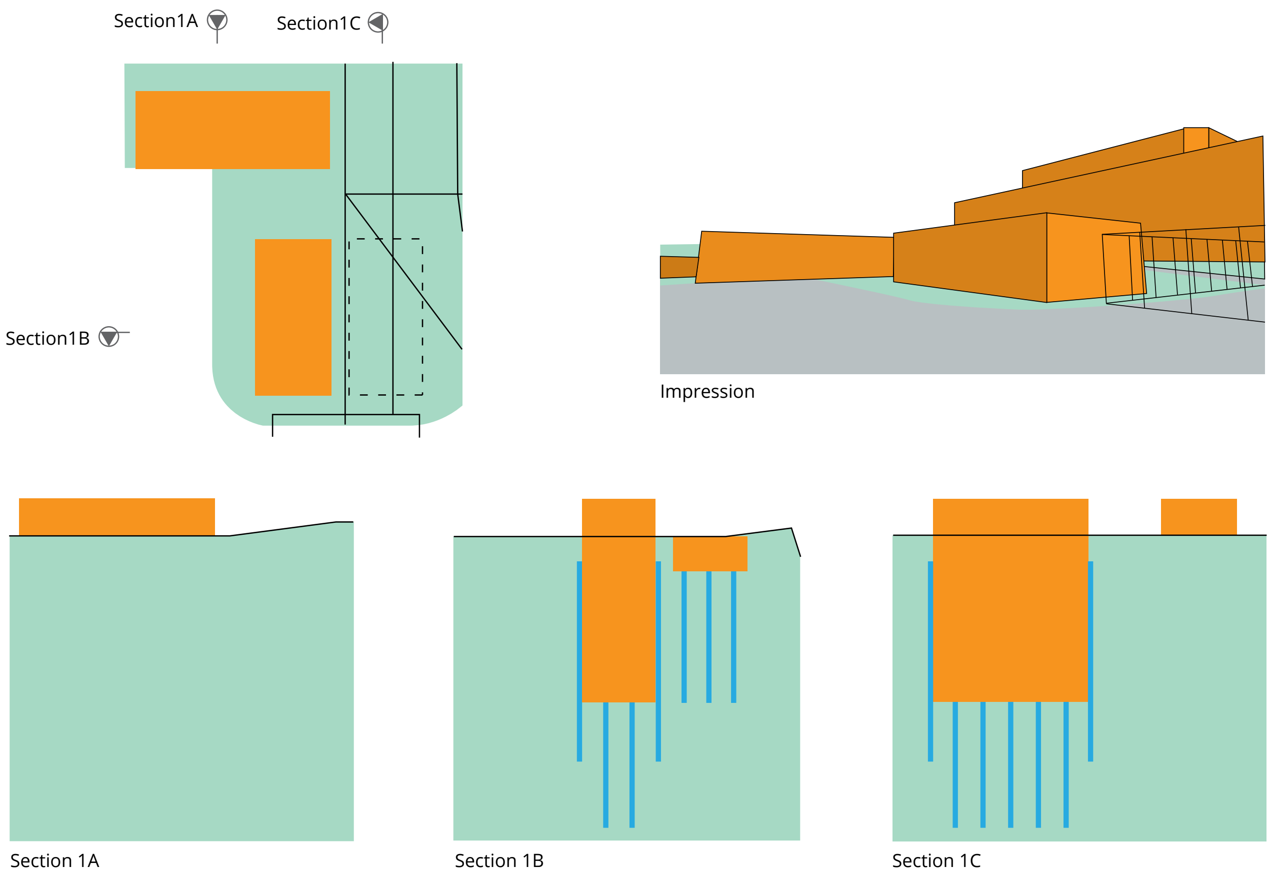

Figure 17 Pumping station at the Research Location Petten with substation

The inlet at the canal comprises the following facilities:
- A coarse inlet screen.
- Two inlet cooling water pipelines.
- A fish return pipe.
- Band screen, 2x full capacity with a housing and a concrete pit.
- A gravity-fed pipe, drilled to the location using micro tunneling.
- An intermediate booster pit for the construction of the cooling water pipeline midway, depending on the construction details.

General principles for this variant are:
- The pumping station is about 17 m by 8 m by 4 m above ground and 18 m underground.
- Due to the depth, the pipes are laid using drilling instead of open excavation.
- A separate (underground) water basin of 17 m by 8 m by 4 m in size, and designated for fire-fighting water, will be placed beside the pumping station.
- The building is 4 m in height, with a ground level of 6.5 + NAP, and the pumping station is at about 11 m – NAP.
- The diesel-powered fire-fighting water pumps are located in a fireproof room.
- The pumping station will be constructed using boring piles.

4.2.2 Variant K2: Extraction from the North Sea and discharge into the North Sea (saltwater-saltwater variant)

The proposed location of the PALLAS-reactor is in the vicinity of the North Sea, making it possible to also use saltwater from the North Sea as cooling water. In this variant, the water is extracted and then discharged again into the North Sea after having been used to extract heat from the primary system. The extraction and outlet points can be realized at 700 m (at a depth of 10 m) and 300 m (at a depth of 5 m) from the coast, respectively. The choice mainly depends on the volume of sand and fish suction and possible growth of organic material in the extraction station. The final design takes account of shipping and fisheries at the location of the inlet and outlet point. The concrete pipes are laid between the nuclear island and the sea using open excavation. For the cooling water pipes in the undersea section, a ship will dredge the trench and then lay the cooling water pipes.
There are various ways to transport the water from the sea

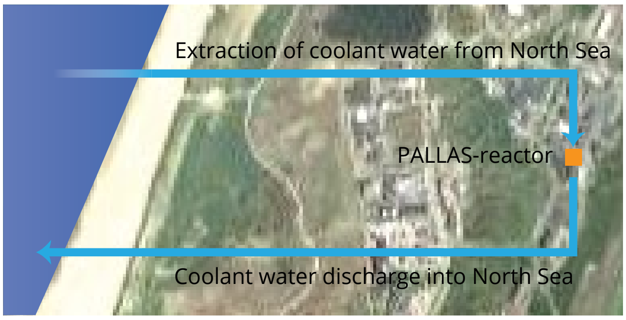

Figure 18 Schematic illustration of cooling variant K2

to the location of PALLAS. Hereafter are three variants for the location of the pumping station:
- Intake station on a platform at sea.
- Intake station on the beach.
- Intake station within the Research Location Petten.

These three variants are described hereafter.

Variant: intake station on a platform at sea
In this variant, a platform is necessary off the coast for the extraction of seawater, including facilities for chlorination, sand filtration and a fish return system. This variant has been included for assessment in the various background reports.
The specifications of this construction are as follows:
- An intake point at about 700 m off the coast at a depth of around 10 m - NAP.
- The outlet point at about 300 m off the coast at the point of outflow at 5 m - NAP.
- All electromechanical equipment, such as heat exchangers and pumps are sand and salt-water resistant.
- Construction of the intake and outlet points is realized in a trench, through partial excavation and boring from land and dredging of the seabed.
- The intake point at sea comprises the following elements:
  - Filters to remove coarse material and large fish.
  - A basin where sediments can settle and the water can calmly enter the rest of the system.
  - A system to protect fish and reduce the environmental impact.
  - Dosage system for the chlorine bleach, including the chlorine bleach, to prevent biological growth in the pipes.
  - Pumps.
- The entire intake construction is 40 by 60 m in size. The platform is about 10 by 10 m in size. The platform is built on piles, about 4 m + NAP. This brings the total height of the platform to around 10 m.

Piles must be sunk to mount the platform. All installations are then placed on the platform from a ship.

Variant: intake station on the beach
In this variant, an intake station on the beach is required. However, based on prevailing policy, a structure in the dynamic zone on the beach is not permitted, so this option is not possible and is not included in the impact assessment for this variant.

Variant: intake station within the Research Location Petten
In this variant, the intake station is within the Research Location Petten. For this option, it is necessary to drill under the primary defense for the pipe between the sea and the Research Location Petten, and this is not in compliance with prevailing policy.
However, by applying adequate technical measures to guarantee water safety, it is possible to deviate from this policy. This has not been examined in the background studies, but can be included at a later stage when further detailing the cooling water variants.

Table 5 Principles for cooling water extraction and discharge

Aspect	Principle
Capacity of reactor	$55MW_{th}$
Discharge flows	Maximum 3300 m^3 / hour water (0.92 m^3/s)
Discharge temperature	47.5 °C
Distance of discharge from the coast	300 m
Water depth	5 m
Current flow rate at discharge	0.5 m/s
Temperature of seawater at intake	Variable, determined by monitoring
Extraction flow rate from the North Sea for the PALLAS-reactor	3300 m^3 / hour water (3150 m^3 / hour water for cooling and 150 m^3 / hour for the fish return system)
Extraction flow rate from the Noordhollandsch Kanaal for the PALLAS-reactor	3300 m^3 / hour water (3150 m^3 / hour water for cooling and 150 m^3 / hour for the fish return system)

4.2.3 Principles for fresh water cooling

In cooling variant K1, cooling water is extracted from the Noordhollandsch Kanaal. In cooling variant K2, cooling water is extracted from the North Sea. In both variants, chlorine bleach (sodium hypochlorite, NaOCl) is added in controlled dosages to prevent biological growth in the cooling system. In cooling variants K1 and K2, cooling water is discharged into the North Sea to dissipate the heat load. The following table shows the features of the cooling water extraction and discharge.

4.2.4 Air cooling

For air cooling, the cooling water is air cooled after having been used to extract heat from the primary system. As the water can be largely reused once it has cooled, this variant requires considerably less water than variants K1 and K2. Furthermore, no new intake points, outlet points and long water pipes need construction outside the site.
According to the prevailing zoning plan, buildings of a maximum height of 15 m are permitted. If such systems are built at this location, they will have a maximum height of 18.5 m + NAP, which means they will be clearly visible above the dunes. This is not desirable. For that reason, it was decided that the buildings will have a maximum height of 11 m, or 14.5 m + NAP. The systems are built at the place of destination on a foundation of concrete or piles. They will possibly be assembled from prefabricated elements.

Different variants of air cooling are possible, each with its own impact on the locality. These variants can be divided into three different types:
- Wet cooling systems (comprising a cooling tower).
- Dry cooling systems (comprising an air cooler).
- Hybrid cooling systems (a combination of wet and dry cooling systems).

Dry cooling systems cannot be realized at the location as they are unable to reduce water temperatures from 35 °C to 25 °C when the outdoor temperature in the summer is higher than the required cooling water temperature. Cooling agents other than water are disadvantageous in terms of energy and chemical use. A wet system and a hybrid system have therefore been further specified for PALLAS. Both systems still require water for cooling, but this can be mains water. Another option is to tap off small amounts of canal water for this purpose from the existing pipes of the HFR.

K3: Wet cooling

Variant K3 relates to a cooling system for wet cooling with an open cooling tower. It comprises a setup of 4 cooling units (3 in use, 1 reserve), each with a cooling capacity of 18.33 MW. A forced air flow is provided by a fan. The water from the secondary cooling system is in direct contact with the outdoor air and is pumped through the system. The water loses heat through contact with the outdoor air and recirculates after treatment in a small treatment plant. Because some of the water vanishes through evaporation, the concentration of salts in the water increases. To prevent it from thickening, the water may be discharged to the sewers so that the concentration of the water reaches its required level once again. Due to water loss through evaporation and drainage, a maximum 75 m³ per hour of water will have to be added to the system. If outdoor temperatures fall below 11 degrees centigrade,

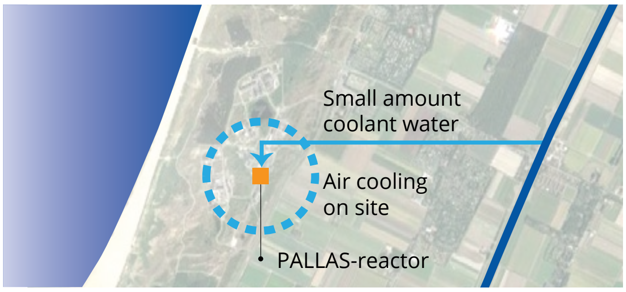

Figure 19 Schematic illustration of air-cooled variants K3 – K6

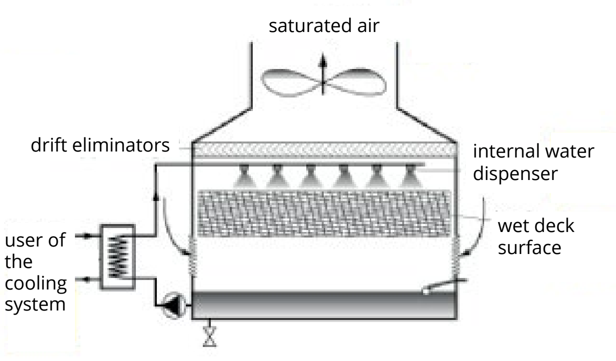

Figure 20 Indicative action of the cooling unit

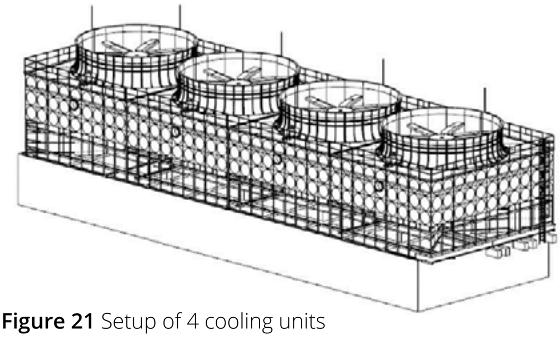

Figure 21 Setup of 4 cooling units

condensation may form under certain circumstances. These cooling units take up a surface area of around 26 m by 60 m, with a height of about 11 m. The cooling tower system produces a maximum noise level of 107 dB, together a maximum noise level of 112 dB, and visible water vapor condensation in winter.

K4 – K6: Hybrid air cooling

Hybrid air coolers have the same standard function as dry air coolers. Where large surface areas are needed, the cooling capacity can be increased by evaporating water at the air supply or allowing water to flow across the diffuser or allowing it to evaporate there. A number of types of hybrid air coolers can provide both wet and dry cooling simultaneously. These types are known as hybrid coolers, as heat is partially diffused using thermal exchange and partially through evaporation.

K4: hybrid adiabatic air cooler with one-off flow

This variant relates to a dry air cooler that is has the option of cooling incoming air flows via adiabatic humidification by spraying the water at the air intake.

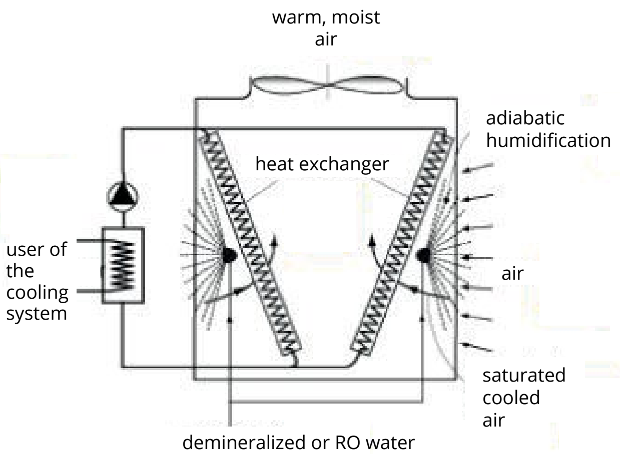

Figure 22 Hybrid adiabatic air cooler with one-off flow

The variant comprises a set-up of 27 hybrid adiabatic coolers (55 MW in total, including 1 reserve unit), a substation and water-treatment plant. To realize this, a total surface area of 85 m by 44 m is required. The cooling units are 5.4 m high and together produce a noise level of around 114 dB(A). For this variant, a maximum of 208 m³ / hour will have to be added to the system.

K5: hybrid air cooler with recirculation

This variant relates to a dry air cooler with the option of allowing water to flow over the diffuser and the option of recirculation. Despite recirculation of the water, the total maximum water consumption is still 163 m³ / hour. Contrary to variant K4, the water is not sprayed in variant K5, but flows over the diffuser's specially designed fins, see Figure 23.

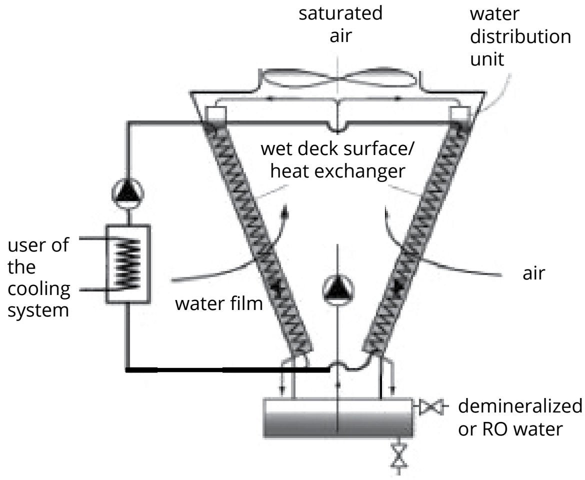

Figure 23 Hybrid air cooler with recirculation

The variant comprises a set-up of 45 hybrid air coolers with recirculation (55 MW in total, including 1 reserve unit), a substation and water-treatment plant. To realize this, a total surface area of 101 m by 41 m is required. The cooling units are 3.0 m high. The hybrid air coolers and a substation together produce a noise level of 111 dB(A).

K6: hybrid adiabatic air cooler with one-off flow (film-type)

This variant relates to a hybrid variant which, in terms of its design, lies between the designs described under K4 and K5. In this variant, the water is not sprayed but runs as a film over a cellulose layer. The water supply amounts to a maximum of 182 m³ / hour.

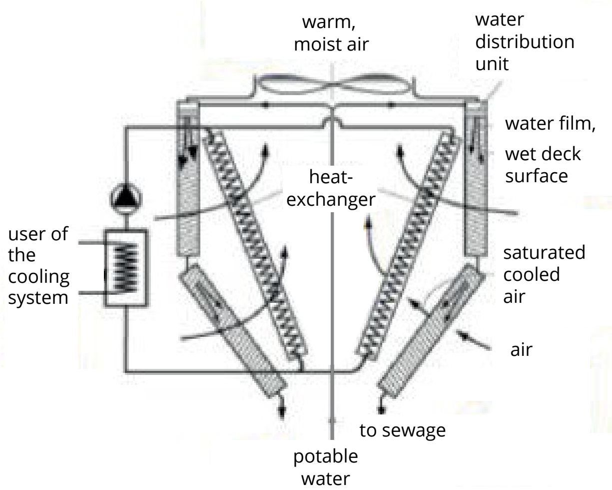

Figure 24 Hybrid adiabatic air cooler with one-off flow (film-type)

The variant comprises a set-up of 29 hybrid adiabatic coolers (55 MW, including 1 reserve unit), a substation and water-treatment plant. To realize this, a total surface area of 85 m by 41 m is required. One cooling unit is 5.0 m high. The 29 hybrid adiabatic air coolers and a substation together produce a noise level of 99 dB(A).

Air cooling in background reports
The surface area required for realizing the cooling units on the site is dependent on which type of air cooling is chosen. In principle, the cooling units on the site require a surface area of around 5,000 m². The different systems mentioned could all be applied, but variant K3 is the variant with the highest noise production and the most condensation formation. This variant therefore has the greatest impact outside the site and is thus used as the worst-case scenario in the background reports.

4.3 Radiation protection

Radiological dose limits have been established based on the requirements of the Dutch Nuclear Energy Act, the Dutch Decree on Nuclear Facilities, Ores and Fissile Material, the Dutch Decree on Radiation Protection and the related regulations and guidelines on safely designing and operating nuclear reactors. An overview of the dose limits for the general public and (exposed) employees is given in Table 6.
No radioactive waste or primary cooling water from the reactor vessel is processed at PALLAS, as it is transported to a certified processor.

Table 6 Overview of the dose limits for the general public and (exposed) employees

Radiation protection under normal operation	Aspect	Dose limit (per calendar year)
Population	• Direct radiation • Radioactive emissions to air • Radioactive emissions to water	Together: < 0.1 mSv per source (outside site) < 1 mSv (inside site)
Non-exposed employees	• Direct radiation • Radioactive emissions to air • Radioactive emissions to water	Together: < 1 mSv
Exposed employees	• Direct radiation • Radioactive emissions to air • Radioactive emissions to water	Together: < 20 mSv
	• Radioactive waste	ALARA

5 Construction phase

The nuclear island, the related systems and the related infrastructure modifications are realized during the construction phase, which will take approximately 4 years. The activities undertaken during the four years are generally as follows:

- Preparation of the site and the LDA, this phase will take approximately 4 months.
- Construction of the nuclear island, this phase will take approximately 44 months.
- Construction of the secondary cooling water system, this phase will take approximately 31 months and will be undertaken simultaneously with the reactor construction work.
- Construction of the other buildings and facilities (sewer/car park, etc.) on the site. This phase will take approximately 36 months and will be undertaken simultaneously with the reactor construction work.

The following aspects and activities are relevant to the construction phase of the PALLAS-reactor:

1. Construction of the nuclear island.
2. Construction of the other buildings.
3. Erection of the secondary cooling system.
4. Erection of the utilities and other civil-engineering works.
5. The LDA.
6. Earthworks on the PALLAS site.
7. Traffic control during the construction phase.

5.1 Construction of the nuclear island

For the time being, it is assumed that the nuclear island will involve a structure of around 40 m (Length) by 60 m (Width) by 40 m (Height). The nuclear island will be built using in-situ reinforced concrete walls, floors and a roof of potentially 1.5 m thick. Three different variants are currently available for the design of the nuclear island. These are described in paragraph 4.1.2. The construction method is discussed hereafter for variants B1, B2 and B3. All the construction methods involve carrying out the work in dry compartments, so no groundwater needs to be extracted.

5.1.1 Variant B1: 17.5 m above ground level and 29.5 m below ground level

In variant B1, more than half of the nuclear island will be constructed underground. The nuclear island will be built in-situ. Floor, roof and walls will be made of reinforced concrete with a thickness of approx. 1.5 m. In variant B1, the bottom of the nuclear island lies at a depth of 19 m – NAP (22.5 m below the current ground level). This requires building a construction pit.

Caisson method

For the construction of the nuclear island, this variant involves erecting a pneumatic caisson (concrete container). This container is as it were sunken into the ground by excavating the ground within the caisson. In a dry workspace, the ground is excavated and then transported to the surface using pipes. Because water is added to this soil, the slurry must settle in a basin (at an area yet to be determined surrounded by a temporary dike). Two of these basins are probably required, so one is in use while the other can be excavated after settling. The soil is then transported to a processing depot for re-use. An air lock provides access to the chamber at the bottom of the caisson. A schematic illustration of the method is shown in Figure 25. A dry caisson workspace is ensured using compressed air.

To safeguard the vertical load-bearing capacity of the substrata, and to limit subsidence, compressible strata are not permitted below caisson level. For this reason, the caisson method is only viable if the final depth of the caisson is below 25 m – NAP. On-site studies have not demonstrated any soft layers below this level.

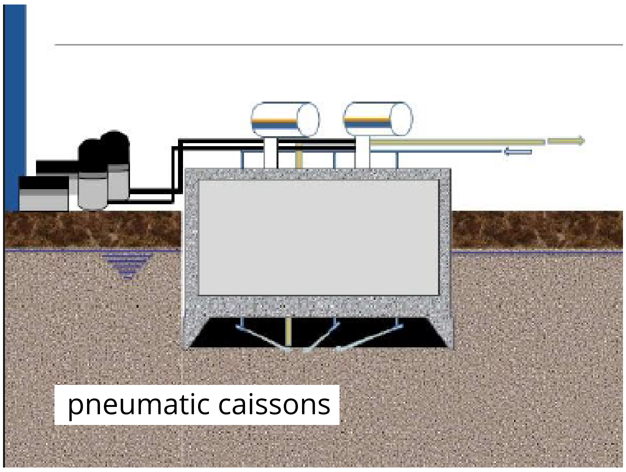

Figure 25 How the Caisson method works

Groundwater drain

Due to the groundwater flows at the site, it is necessary to place a drain to the west of the nuclear island at a depth of around 0.0 m NAP, and an infiltration drain to the east. This is necessary to maintain current groundwater levels.

5.1.2 Variant B2: 24 m above ground level and 16 m below ground level

Variant B2 involves constructing a limited part of the nuclear island underground.

Diaphragm wall method

A diaphragm wall is a wall made of reinforced concrete and constructed in the ground. The thickness of the walls may vary between 0.5 and 1.5 m. In theory, the depth of the wall is unlimited, and depths of 40 m below ground level are no exception. The wall is made up of panels, with the width being dependent on the equipment used.

Constructing a diaphragm wall

The working method for building a diaphragm wall is illustrated in Figure 26. The equipment comprises one or more excavators, concrete pumps and a bentonite installation. Construction runs as follows:

- Preparation: Firstly a frame ('guide walls' in Figure 26) is built at the location where the top of the wall will be. A trench is excavated alongside this frame. The frame ensures effective guidance for the cutters, and protects the edge of the trench.
- Excavating the trench: The trench is further excavated using special 'cutters' to the specified depth and width. The cutters are attached to the excavator by cable. The special shape of the cutter means it remains stable while descending into the trench. To protect the trench from collapse, bentonite (a thick slurry made using clay) is pumped into the trench.
- Installation: To make a continuously watertight wall, it must be possible to assemble the panels so they are watertight. Rubber or steel elements are inserted for this purpose on both sides of the wall.

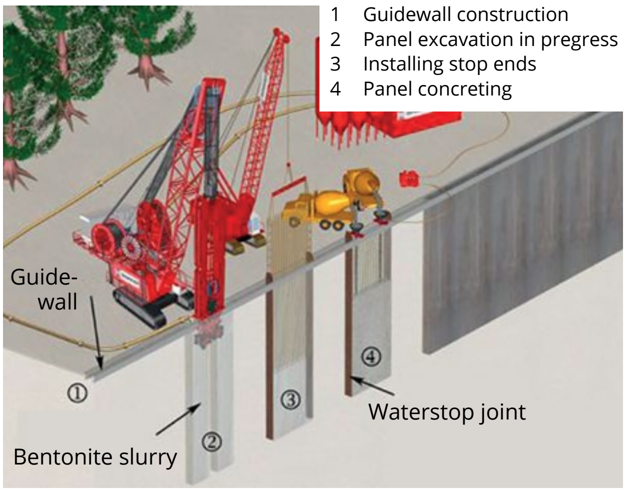

Figure 26 Working method for applying diaphragm walls

- Reinforcement: Before the concrete is poured, a cage structure is inserted into the trench. This construction absorbs the forces exerted on the walls.
- Pouring concrete: Finally, concrete is poured into the trench. Special methods ensure that the concrete is laid contiguously, and that circulation is limited as far as possible. This could hinder removal of the temporary cage structure. During this process, the bentonite is sucked from the trench and is then treated for re-use. The soil will then be re-used for the adjacent diaphragm wall at the Research Location Petten location. Once the entire diaphragm wall is finished around the construction pit, the remaining bentonite is removed.

Excavating the construction pit

After applying the diaphragm walls, the construction pit is excavated. The first meters will be excavated above the groundwater level, but the largest part will be below the groundwater level.

The structure will include struts to ensure the stability of the walls.

Applying poles and concrete floors

After excavating the pit, poles will be applied through drilling to a depth of ca. 35 m – NAP, at which depth the ground has sufficient load-bearing capacity. A concrete floor of ca. 2 m thick is constructed under water, after which the pit is pumped dry.

The pole construction and the concrete floor provide adequate tensile strength against the counter pressure of the groundwater and prevent the bottom of the pit from bursting. This is due to the vertical upwards groundwater pressure.

Construction of the nuclear island

Now that the bottom of the structure has been pumped dry, the nuclear island can be built. In all probability, this will be carried out using traditional encasement and built using in-situ concrete.

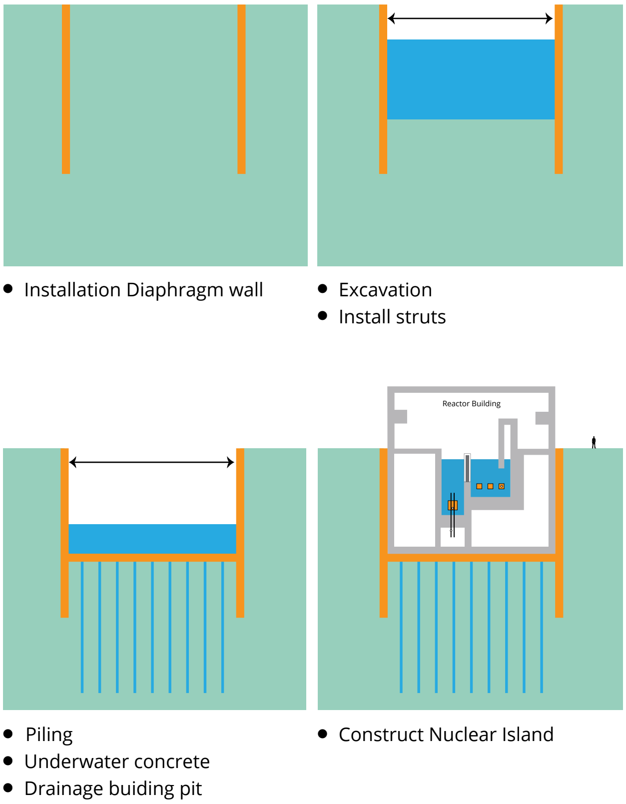

Figure 27 Construction phase

Groundwater drain

Due to the groundwater flows at the site, it is necessary to place a drain to the west of the nuclear island at a depth of around 0.0 m NAP, and an infiltration drain to the east. This is necessary to maintain current groundwater levels.

5.1.3 Variant B3: 40 m above ground level

To realize variant B3, instead of diaphragm walls, bored piles are used, spread across the area, with 1 pile for each 4 m². The pile is drilled down to the stratum with sufficient load-bearing capacity, at a depth of about 37m – NAP. After installation of the bored piles, the nuclear island is constructed in accordance with the traditional construction method (a 40 m high concrete building with thick walls and floors).

5.1.4 Subsidence

The construction phase may influence the directly adjacent nuclear facilities, the Hot Cell Laboratory (HCL) and the Molybdenum Production Facility (MPF). This influence cannot yet be determined, due to the exact location of the new reactor and the construction method not yet being known. As part of the permit procedure required for the construction phase, there will therefore need to be proof that any additional risks to neighboring installations are acceptable. This is described in brief hereafter.

With a view to radiation protection, the construction phase may result in risks for the existing nuclear installations. A construction pit is necessary for realization of the nuclear island, as this building is partially underground. Two aspects can be distinguished with regard to these risks. On the one hand, the installation of the construction pit walls, and on the other hand local subsidence as a result of excavation of the construction pit. Both aspects will affect the level of the ground and the neighboring buildings:

The installation of construction pit walls brings with it the risk of vibration hinder and noise hinder. Vibrations can also cause damage to neighboring buildings. With a view to the possible sensitivity of the neighboring brickwork buildings to vibrations, a low-vibration construction method has been chosen. The choice of slurry walling for the construction pit walls will prevent vibrations. The construction pit walls will therefore be formed by digging a trench in the ground, which is filled with concrete. For the caisson method, no diaphragm walls are used, so there is no risk of nuisance through vibrations.

Excavation of the construction pit will result in subsidence in the surrounding area. The area influenced by subsidence is 1.5 x the depth of the excavation (approximately 30 m), with the greatest subsidence occurring close to the construction pit. Whether or not the directly neighboring buildings are in this scope of influence still depends very much on the exact location of the construction pit. For the time being, the existing buildings are approximately on this borderline. Once again, control measures can be taken in order to limit subsidence.

There is no risk to the HFR, as it is way beyond the scope of influence.

5.2 Construction of the other buildings

The nuclear island is constructed by applying sand around the nuclear island up to a height of 8 m + NAP. The sand used comes from the construction pit. The buildings in the nuclear island are constructed in the standard way using materials like steel, concrete, wood, glass and stone. Application of prefab elements is an option. The buildings may use pile foundations.

5.3 Construction of utilities and other civil engineering works

Utilities are executed in the customary manner by burying the necessary pipelines and cables. Roads, pavements and car parks are also constructed in the customary manner using asphalt or stone paving. Further, fences, lighting, surveillance cameras and signaling will also be erected.

5.4 The Lay Down Area (LDA)

Outside the Research Location Petten, a temporary LDA is created. In addition to housing temporary construction trailers, offices, changing rooms and a canteen, this area also includes the storage of material, equipment and earth (in the open air). Parking spaces (for up to 400 people) can be created on the LDA for personnel during construction. The number and type of activities determines how many personnel are present on the temporary working site. This can be as many as 400 people per day.

In Figure 28, the search area is given within which the LDA could be realized. A surface area of about 50,000 m² is needed to realize the Lay Down Area.

The LDA comprises the following key components:

- The foundations of the roads and sections of the depots are made up of a layer of granulate and layer of sand.
- Depending on the type of storage, it is also possible to use supplementary geo-textile foundations.
- Roads for trucks and parking spaces are made of asphalt or concrete slabs.
- Prefabricated sections are set on concrete footings or concrete slabs.
- Construction of waste water and rainwater sewers.
- Lighting.
- Utility connections.

After the construction and test phase, the area, the roads and the entrances will be restored to the former state (agricultural ground). Any pollution created is cleared up.

Most traffic movements will run over the Westerduinweg towards the PALLAS site and the LDA. Works traffic from the LDA towards the works must cross the Westerduinweg. For this reason, traffic lights may have to be erected or a temporary diversion created.

At the Lay Down Area, a temporary concrete factory might be erected. The raw materials (sand, gravel, cement) are supplied by ship and by road. Section 5.4.2 describes this in further detail.

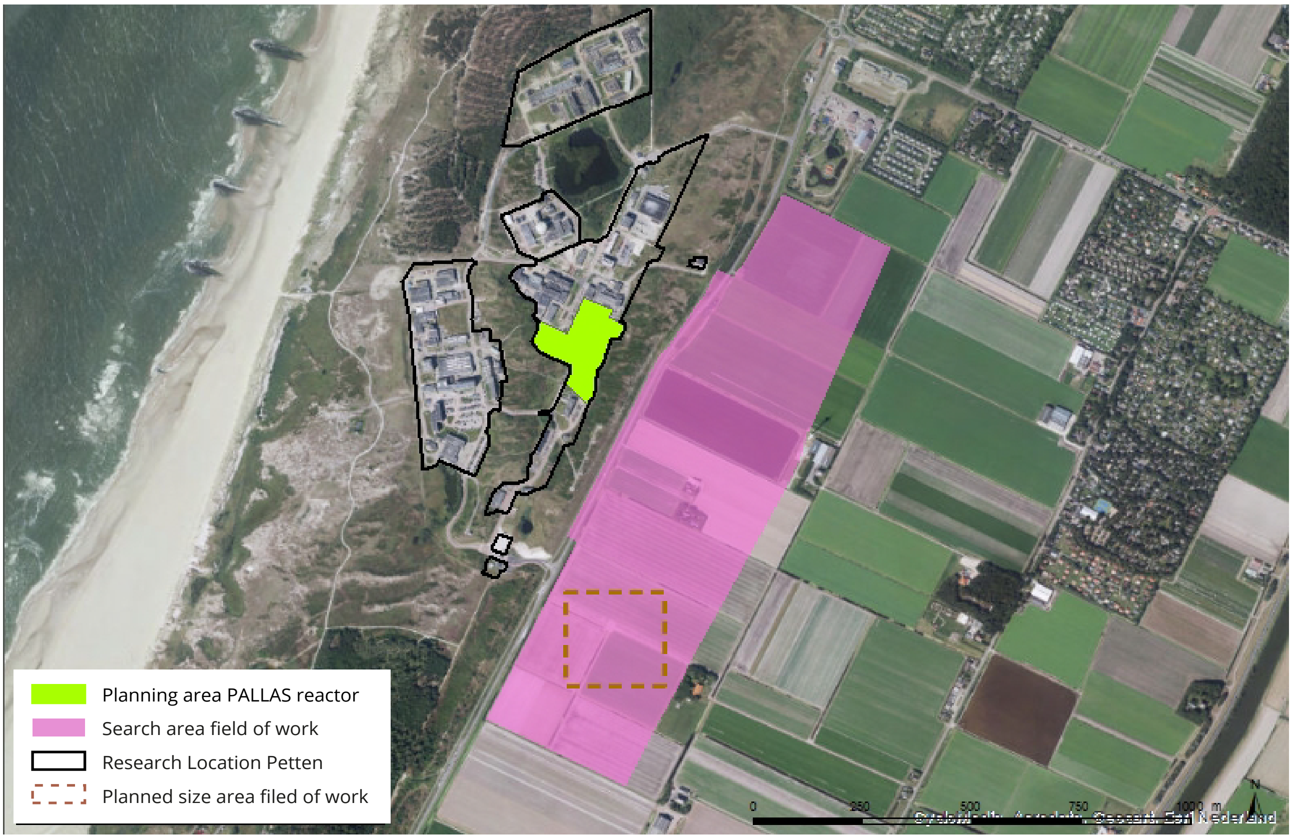

Figure 28 28 Search zone for temporary LDA

5.4.1 Depots

For the necessary surface area in the LDA, the following storage space is factored in:

- The soil depots have a maximum height of 3 – 4 m. The depots are demarcated by concrete barriers to limit the amount of space required. The space required is calculated by applying a correction factor of 1.2.
- Soil dug up from the construction site is stored temporarily at the LDA. Storage of soil at the Lay Down Area is necessary for at least the soil to be re-used and for soil that requires inspection for environmental reasons prior to removal. Depending on the selected construction variant for the nuclear island, the amount of soil could increase significantly. In variant B1, the assumption is that soil must be stored at the Lay Down Area for research purposes for around 2 weeks + 2 weeks (total 4 weeks). The transport-movement intensity is about 8,000 loads of 10 m³ sand in 3 months. This means storage of approx. 26,700 m³ in four weeks time. With a depot height of 4 m and a factor of 1.2, this corresponds to a surface area of approx. 8000 m².
- Construction materials that require temporary storage, such as: cooling water pipelines, paving materials, lighting materials and accessories related to paving, such as fences, safety materials, signs. The depot space required is largely determined by the choice of paving materials. The assumption is around 300 m² for paving material for 3 trucks.
- Construction materials, such as asphalt, sand and foundation materials, are mostly used without temporary storage at the Lay Down Area and are transported directly to the works site. It is advisable to create a small depot for storing sand and foundation materials.

5.4.2 Concrete plant

A large volume of concrete is required for the nuclear island in particular. Erection of a concrete plant at the LDA is an option for this. When designing the structure of the nuclear island, the contractor must make the following aspects clear, so it can be determined whether a concrete plant is required at the LDA:

- Volume of concrete required.
- Concrete quality and requirements.
- Required quality control.
- Period of production (time, overnight, only during the day, etc.).

A temporary concrete plant at the LDA covers an area of about 2,300 m² and has a significant impact on the locality. To examine the worst case scenario, the background documents have assumed the use of a concrete plant.

The background document on noise indicates that the maximum noise limit value could be exceeded at night. Possible measures to reduce noise at night are:

- Protection against the (main) source of the noise.
- Prioritizing of the latest technologies in the choice of type of concrete plant.
- Ensure production takes place partly at night in the existing concrete plants in the area.

The above-mentioned aspects, the limited nighttime production of concrete and the possible measures to reduce noise nuisance, all determine the feasibility and the potential benefits of a temporary concrete plant on or near the Lay Down Area.

5.5 Earthworks on the PALLAS site

Earthworks cover all activities and changes in the earthworks of the nuclear island and the Off Plot Scope, compared to the current situation. The key aspects and general principles for the design and permits are:

- The sand excavated from the dunes will be temporarily stored at the Lay Down Area prior to use at the construction site.
- Deep excavations are likely to be required at the construction site. This depends on the variant in terms of the height of the reactor.
- The area with limited access will be raised from 3.5 m + NAP to 6.5 m + NAP.
- The nuclear island will be elevated in its entirety by an additional 1.5 m to a height of 8 m + NAP, with the entrance being built above flood level (8 m + NAP).
- There is no space to the west of the site for an extra incline. For this reason, concrete retention walls will be erected over a distance of around 320 m.
- The control room will be built at ground level at a height of 4 m + NAP. Currently, the ground level is 2 m + NAP, so this will have to be raised by 2 m. The entrance and other openings for the control room will be placed at 8 m + NAP.
- Trenches will be dug for cables and small-bore pipes. These will be covered by concrete slabs. Data cables will run between the nuclear island and the control room.

5.6 Traffic control during the construction phase

Traffic during the construction phase involves freight traffic and sea-borne transport for the supply and removal of construction material, as well as personnel traffic.

5.6.1 Diesel equipment

Diesel equipment is used for the stated construction work. This includes drill rigs, excavators, cranes, pumps and transport movements of freight traffic and ships. In this phase of the project, the contractor is not (yet) known and so the exact diesel equipment to be used is also not known.
The lifespan of diesel equipment depends on the type of machine. The diesel equipment used in this project has a median lifespan[4] of between 6 and 12 years. Construction work will take place between 2018 and 2024.

Engine capacity
The engine capacity of the diesel equipment can vary strongly. For the purposes of this study, we assume relatively heavy diesel equipment.

Engine load and TAF factor
The engine load (applied engine capacity) of diesel equipment during a work cycle varies. The maximum engine capacity is rarely, if ever, used. For most diesel equipment, the average load varies between 50 and 60%.

5.6.2 Transport

The various materials are supplied and removed by ship and/or truck. Different transport numbers are required for each different background situation. To calculate the impact of noise nuisance, the maximum number of transport movements, for example, is taken as the starting point, while to calculate air emissions to the locality, the daily average of transport movements is used. The different background studies describe which principles are applied. In this design framework, it was decided to show the average transport movements.

Ships
Inland shipping vessels are used with a capacity of around 2,500 m³. Assuming a comparable weight of 1,600 kg/m³ for soil and sand, this corresponds with a capacity of around 4,000 tons per ship. This assumes a 65% load for inland shipping vessels. This applies to both incoming and outgoing ships.

Trucks and passenger vehicles
Various different trucks are used. The following categories are assumed:

- Heavy-duty vehicles: large trucks/dumpers.
- Semi-heavy vehicles: medium-sized trucks.
- Light vehicles: vans.

Transport movements during the construction phase are described in Table 7 and Table 8.

Table 7 Transport movements of vehicles

Vehicles	Number total (over 3.75 years)	Number of movements (back and forth, over 3.75 years)
Light vehicles from Burgervlotbrug to location	445,500	891,000
Light vehicles from St. Maartensvlotbrug to location	148,500	297,000

4 Taken from the TNO report 'Emissiemodel Mobiele Machines gebaseerd op machineverkopen in combinatie met brandstof Afzet, EMMA' [Emission model for mobile machines based on machinery sales combined with fuel sales] from November 2009.

Table 8 Transport movements of trucks

Trucks	Number of trucks per year	Average number of daily movements	Route
Preparation PALLAS area	20	0.1	Burgervlotbrug – Research Location Petten
Preparation Lay Down Area	3710	20.3	N502/N503 – Lay Down Area
Nuclear island construction B1	2600	14.2	N502/N503 – Research Location Petten
	8850	48.5	Burgervlotbrug – Research Location Petten
Cooling water pipelines from the canal to the nuclear island	750	4.1	N502/N503 – Research Location Petten
Canal inlet (including pumping station)	175	1.0	N502/N503 – inlet canal
Construction of cooling water pipeline from the nuclear island to the sea	250	1.4	N502/N503 - dunes

5.6.3 Nitrogen

There has been a surplus of nitrogen for years in Natura 2000 areas (ammoniac and nitrogen oxides). This is hazardous for nature. The Dutch Nitrogen Action Program (Programma Aanpak Stikstof, or PAS) regulates how much nitrogen a given activity may emit to its surroundings. PALLAS was registered on 16 May 2016 by the Province of Noord-Holland as a priority project in the context of the PAS regulations (which took force on 17 March 2017). Based on that, the PAS reserves scope for development of the project in segment 1 (priority projects subject to permit requirements).

The maximum requested reserve amounts to 16.02 mol/ha/year and is determined by the construction phase. The volumes of nitrogen emitted during the operational phase and the construction phase to Natura 2000 areas are given hereafter.

These emissions are determined by material emission factors in the construction phase. The emissions of diesel equipment are dependent on the engine capacity, the average load, the year of construction and the operating hours. The emission factors of diesel equipment, for example, are regulated at European level by technical guidelines on the vehicle and the combustion engine.

Table 9 Natura 2000 areas

Natura 2000 areas	Construction phase
Zwanenmeer & Pettemer dunes	Annually 16.02 mol nitrogen per ha
Dunes Den Helder – Callantsoog	Annually 0.10 mol nitrogen per ha
Schoorl dunes	Annually 0.07 mol nitrogen per ha

Emissions factors

The guidelines for diesel equipment have applied since 1997. The EU directives (97/68/EC and 2002/88/EC) contain standards for the maximum emissions of air pollution per capacity class in grams/kWh. Increasingly stringent emissions standards are to be implemented in four phases. The third phase has two steps: Stage IIIA for engines with a variable RPM built in 2006/2008 and Stage IIIB for engines built in 2011/2013. The fourth phase applies from 2014 (EU directive 2004/26/EC).

The lifespan of diesel equipment depends on the type of machine. The diesel equipment used in this project has a median lifespan of between 6 and 12 years. Construction work will take place between 2018 and 2024. Given the median lifespan and the year of commencement of the activities, the diesel equipment expected to be used complies with the emission requirements of Stage IIIA, IIIB and/or Stage IV. Due to the big difference in emissions between stages III and IV and the location of the works in the proximity to fragile habitat types, it has been decided to assume Stage IV.

Explanatory glossary

ALARA	As low as reasonably achievable
Direct radiation	Radiation directly originating from a nuclear installation, and not resulting from the discharge of radioactive substances, for instance
Dose	Absorbed radiation energy per unit of mass (unit: Gray, Gy)
Dose equivalent	Product of the dose and the quality factor, with the biological potency of the various types of radiation discounted (unit: sievert, Sv)
Dose criterion/limit	Maximum permissible dose established by the government
Effective dose	Dose value that serves to assess the occurrence of long-term effects (unit: sievert, Sv)
Emissions	Discharge of substances in the environment
Ingestion	Consumption of food
Inhalation	Breathing in (of radioactive substances, for instance)
Ionizing radiation	Radiation, classified as α , β or γ radiation, emitted by radioactive material
Isotopes	Different atoms of the same element with the same chemical properties, but with a different atomic weight
Molybdenum	Substance that produces they radioactive isotope Mo-99 of cancer diagnosis in hospitals
Nuclide	Type of atom
Radioactive substances	Substances that emit ionizing radiation
Radioactivity	Property of substances with unstable atoms, characterized by spontaneously occurring changes in the atomic core that cause ionizing radiation to be emitted (unit: becquerel, Bq)
Radiological	Concerning ionizing radiation
Radionuclide	see isotope
Radiotoxicity equivalent (Re)	The activity of a radionuclide that causes an effective full dose of 1 sievert for a reference person older than 17 years if ingested or inhaled directly. By expressing emission limits in terms of radiotoxicity equivalents, the limitation factor is independent of the type of radionuclide. This does however require the emission to be measured specifically per nuclide
Risk	Undesirable consequences of a certain activity in relation to the probability that such consequen-ces shall occur
Sievert (Sv)	The sievert (symbol Sv) is the SI unit for the equivalent dose of radiation to which a person is ex-posed during a certain period of time, and is equal to 1 J/kg. The sievert depends on the biological impact of radiation. The millisievert (mSv) is a one thousandth part of a sievert

Appendix D Correlation table

Correlation table for Recommendations by Authoritative Body on SEA PALLAS

Amendments to recommendations by Authoritative Body with regard to SEA Committee

The following amendments have been identified in the recommendations by the Authoritative Body versus the recommendations by the SEA Committee:

1 Natura 2000 areas to be considered (section 1). The impact on Natura 2000 areas to be studied, has been changed from "the consequences for the North Sea coastal zone and Zwanenwater & Pettemer dunes Natura 2000 areas" to "the consequences for Natura 2000 areas, particularly the North Sea coastal zone and Zwanenwater & Pettemer dunes.

2 Justification of the necessity (paragraph 2.2). Added to the justification of the necessity of a new reactor:
"Also include:
- the global production and capacity of isotopes;
- the demand for the various isotopes, now and over a period of 40 years;
- the (im)possibilities of alternative production methods, alternative isotopes and alternative production locations;
- the question of the long-term necessity of production of medical isotopes and of scientific and applied research;
- the influence of the production of isotopes by the Pallas reactor on the development of alternative production methods."

3 Motivation of choice of reactor type (paragraph 3.2.2). Text added on the choice of the reactor type: "The communication memorandum assumes a 'tank-in-pool' reactor and explains the principles of its operation. Adopt this in the SEA. Indicate the advantages of this type of reactor for the proposed activities. In the SEA, describe any other possible types of research reactors which may be suitable for conducting the proposed activities. Indicate the considerations behind the choice for the 'tank-in-pool' reactor, and the extent to which the environmental impact played a role."

4 Cooling variants (paragraph 3.2.2). Sentence added in the listing of the three variants for cooling the reactor core: "Indicate why these variants were chosen (rather than other variants)."

5 Netherlands Nature Network (paragraph 4.3). The EHS term (Ecological Network) has been updated to the new terminology Netherlands Nature Network.

6 Traffic noise during operational phase (paragraph 4.5). An addition that noise caused by traffic during the operational phase must also be studied.

Correlation table

Table 1 Recommendations by Authoritative Body on SEA PALLAS

Recommendations	In study	In paragraph / section
1 Main points		
The following information is considered to be essential for consideration of the environmental interests in a decision regarding the zoning plan, and therefore as relevant information for the SEA;		
• Justification of the intended purpose of the proposal, such as: helping to meet the demand for medical isotopes and the demand for experimental radiation research;	Part A	Sections 1 and 2
• The consequences of alternative cooling systems on nature, the landscape and land use;	Parts A and B	A: section 5 B: sections 13, 15
• The consequences of sunken/non-sunken location of the reactor on nature, groundwater and landscape;	Parts A and B	A: section 5 B: sections 8, 9, 13, 15
• The consequences for the Natura 2000 areas, particularly the North Sea coastal zone and Zwanenwater & Pettemer dunes.	Parts A and B and background report	A: section 5 B: section 13 AGD: Nature
The summary must read as an independent document	Summary	Summary

2 Delineation, justification and framework		
2.1 Delineation: EIA vs. SEA		
Generally formulated, the SEA must describe the scope of the proposal, why it is desirable or essential to make space available for this purpose and where such space can be found.	Part A	Sections 1, 2, 3
The SEA must also map out the environmental consequences of alternatives for the proposal, insofar as these are important from the planning point of view.	Parts A and B	A: section 5 B: entirely
Finally, the SEA must study those environmental consequences which may form considerable risks for the project, and which may therefore be determining factors for the feasibility of the proposal.	Parts A and B	A: section 5 B: entirely
2.2 Justification		
The Committee had already indicated what are believed to be essential in this sense, in its recommendations on the SEA project:		
• the description and purpose of the proposed activities, such as contributing to a growing need for medical isotopes;	Part A	Sections 1 and 2
• justification of the choice to construct a reactor in the Netherlands, and more specifically in the municipality of Schagen;	Part A	Section 2
• justification of the proposed scope (capacity) based on the intended use;	Part A	Sections 2 and 3
• detailing of the pros and cons of alternative production methods for medical isotopes, with a distinction being made between foreseeable and uncertain developments and their significance for the feasibility of the proposal.	Part A	Section 2
Also include: • The global production and capacity of isotopes;	Part A	Section 2
• The demand for the various isotopes, now and over a period of 40 years;	Part A	Section 2
• the (im)possibilities of alternative production methods, alternative isotopes and alternative production locations;	Part A	Section 2
• The question of the long-term necessity of production of medical isotopes and of scientific and applied research;	Part A	Section 2
• The influence of the production of isotopes by the Pallas reactor on the development of alternative production methods."	Part A	Section 2
The authoritative body particularly recommends not to limit the SEA to a description of (the effects of) the reactor. A general picture must also be gained of (the impact of) the steps taken beforehand (such as the production of fissile materials) and subsequently (such as the distribution of isotopes and the processing of nuclear fission waste.	Part A	Section 2 Appendix C
2.2 Policy framework		
Also specify the limitations (of building heights and of the location of activities using nuclear materials) in the SEA and indicate whether the zoning plan of Research Location Petten or other (municipal) spatial policy sets extra preconditions for incorporation of the proposal.	Part A	Section 1
Indicate in the SEA the extent to which the alternatives for the proposal can comply with those preconditions.	Part A	Sections 1, 5
The Committee recommends that the statutory and policy framework relevant to the Nuclear Energy Act permit be included in the SEA project, with the exception of those elements required for justification of spatial incorporation of the proposal, such as the limits set for radiation exposure at the Research Location Petten site border.	Part B	Par. 7.1

Describe the relationship between the two procedures for the SEA, such as: who is responsible for each decision and when and how decisions will be made.	Part A	Section 1

3 Proposed activity and alternatives		
3.1 General		
The proposed activity concerns the construction and operation of the new research reactor to replace the HFR. The SEA must clearly describe what is included in the activity to be incorporated, and what not. [...] Limit further description of the properties of the proposal to that which is relevant for assessment of its spatial incorporation.	Part A	Sections 1, 3
To begin with, assume maximum design specifications of the proposal. (...) Indicate the considerations behind the choice for these maximum design specifications.	Part A	Section 3
Then optimize the design of the proposal insofar this is necessary for its incorporation from a planning point of view. The Committee assumes that the construction site/depth and the manner of cooling are particularly critical for incorporation of the reactor, as also indicated in paragraph 2.4 of the memorandum.	Part A	Section 3
3.2 Alternatives		
3.2.1 Alternative locations		
The SEA must clearly indicate the considerations behind the choice of location and the extent to which the environmental impact played a role.	Part A	Section 2
The SEA must also clearly indicate whether there are alternatives for the choice of location within Research Location Petten from an environmental point of view, and if so, the reason for their rejection.	Part A	Section 3
3.2.2 Design variants		
Provide insight into the maximum cooling capacity required for the new reactor. (Partial) air cooling is new, and was not included in the memorandum used when initiating the procedure for the Nuclear Energy Act permit.	Part A	Section 2 and appendix C
Describe with regard to (partial) air cooling: • alternative provisions which would allow this form of cooling, such as the use of dry/evaporation coolers;	Part A	Appendix C
• the combination of installations required per variant;	Part A	Appendix C
• the installation properties of importance to the spatial incorporation (such as the space required, the height, the water consumption and the noise sources).	Part A	Appendix C
Map out the possible locations for extraction and discharge of cooling water, for both the 'freshwater-saltwater' and the 'saltwater-saltwater' cooling system variants. Give motivation for possible locations and pinpoint them accurately on the map. Describe:	Part A	Appendix C
• how the system can be installed;	Part A	Section 3 and appendix C
• the maximum dimensions of the inlet and outlet constructions, the depth location, flow and flow velocities;	Parts A and B	A: Appendix C B: section 8
• the intersection(s) of the primary coastal defenses;	Part B	Section 9
• possible chemical and/or thermal cleaning techniques and other measures to prevent blockage, silting or clogging of the system and to prevent corrosion (when using saltwater);	Parts A and B	A: appendix C B: section 8
• possible measures to prevent suction of fish and other organisms (sieve with fish return system, fish deflection by means of light and sound);	Parts A and B	A: par. 5.3 B: section 13

• how climate change and any possible future adaptations to the flood defense structures have been taken into account in dimensioning.	Part B	Section 9
Visualize how the cooling water supply will be guaranteed (i.e. the robustness of the cooling system) during the period when both the HFR and the new reactor are in use. Do so specifically for the situation with a freshwater-saltwater cooling system for the new reactor. Take account of changes in other sectors' requi-rements for freshwater from the Noord-Hollands Kanaal and the influence on supply.	Part B	Section 8
3.3 Reference		
The Committee supports the choice given in paragraph 3.2 of the memorandum, to visualize two reference situations.	Parts A and B	A: par. 4.1 B: section 18

4 Existing environmental situation and environmental consequences		
4.1 General		
Take the following general guidelines into consideration when describing the environmental consequences:		
• provide insight into the way in which environmental consequences have been determined by including the basic data in appendices or via an explicit reference to consulted background material;	Parts A and B	See appendices to these parts
• note any uncertainties and inaccuracies in the prediction methods and in the data used, and the significance of this for the distinction made between the working variants. An example is the uncertainty regarding the prediction of the impact of groundwater extraction, or the impact of a large underground construction volume on groundwater flows and level.	Parts A and B	See appendices to these parts B: gaps in knowledge in all paragraphs
The scope of the study area can vary per environmental aspect. Describe and provide motivation for the scope of the study area, per environmental aspect.	Part B	Paragraphs on assessment framework and methodology
When describing the environmental consequences, visualize the impact cumulatively where relevant.	Part B	Paragraphs on impact description
4.1 Water and soil		
Provide insight:		
• what volume of cooling water will be extracted and discharged (heat load) and how large a warm water plume will be formed;	Part B	Section 8
• the consequences in relation to the targets of the Water Framework Directive and the requirements of the Water act;	Part B	Section 8
• how the availability of mainly water from the Noord-Hollands Kanaal can possibly change (under the influence of climate change, for example).	Soil and water	
The prediction of the impact caused by the construction of the reactor, must be aimed at:		
• stability of the ground during excavation, pile driving or the application of soil-retaining constructions (sheet piling);	Part B	Section 8
• vibrations as the result of construction work, when installing sheet piling for example;	Part B	Section 8
• the impact on the groundwater management and water table, as a result of drainage, excavation or pile driving through the dividing layers in situ	Part B	Section 8

During the operational phase, the greatest impact will be caused by the possible sunken location of the reactor and a (temporary) increase in paved surface areas. The prediction of the impact caused by operation of the reactor, must be aimed at:		
• the water table and flows (seepage and infiltration flows), for example as a result of the possible sunken location of the reactor;	Part B	Section 8
• the scope of the freshwater lens and the location of the saltwater-freshwater transition;	Part B	Section 8
• the supply to the dune marshes, both quantitatively and qualitatively;	Part B	Section 8
• the risk of leakage from the sunken construction.	Part B	Section 8
Also discuss:		
• the decontamination of any soil contamination in situ;	Part B	Section 8
• the possibilities of and consequences of climate changes and possible flooding. In doing so, take account of the national policy for water safety. The results and improvement opportunities derived from the stress test conducted for the NRG nuclear installations at Research Location Petten can possibly be used. Take account of the fact that the operating period of the new reactor extends much further than that of the HFR.	Part B	Section 9
Map out possibilities for prevention or repair of (dehydration) damage, such as return drainage and infiltration provisions.	Part B	Section 8
4.3 Nature		
Due to a number of variants being studied in the SEA, the Committee re-commends visualization of the consequences for the variant having the least favorable impact on nature. This is expected to be a sunken construction, water-cooled reactor. By visualizing the impact of this variant and researching whether any measures can exclude a significant negative impact, certainty can be gained as to whether this variant or another variant can be incorporated.	Part B	Section 13
Construction phase		
Describes the possible impact of the construction process. In any case, pay particular attention to:		
• (underwater) noise, light and vibrations, from both traffic and construction equipment;	Part B	Sections 11, 12, 17
• the consequences of the construction of the cooling water inlet and outlet, including turbidity. Accurately indicate the extent of construction work in the Natura 2000 areas;	Part B	Section 13
• impact on groundwater (flows), seepage and infiltration, and subsequent consequences for nature;	Part B	Sections 8, 13
• NOx deposits in Natura 2000 areas. Use the AERIUS calculation program for that purpose and apply the target values of the Dutch Nitrogen Action Program to determine whether damage to natural characteristics can be excluded.	Part B	Section 13
Transition phase and operating phase		
Describe the consequences of the operational reactor for the surrounding vulnerable/protected nature and in any case pay attention to:		
• suction of fish (including juvenile fish and fish larvae) and other organisms via the cooling water, and the possible consequences for the entire food chain;	Part B	Section 13
• chemical and/or thermal cleaning of the cooling water system and the consequences of this for underwater life, and when relevant, for the further food chain (absorption of chloroform in fish when chlorination is applied, for example);	Part B	Sections 8, 13

• the individual and cumulative consequences of thermal discharge for the aquatic environment;	Part B	Sections 8, 13
• possible noise hinder caused by the air/hybrid cooling system.	Part B	Section 11
Consequences for protected areas and species		
Describe the individual and cumulative consequences of the proposal for the conservation targets for Natura 2000 areas, and particularly the 'North Sea coastal zone' and 'Zwanenwater & Pettemer dunes' areas. Pay specific attention to the indirect impact (food chain) and apply worst case scenarios in the event of gaps in knowledge.	Part B	Section 13
Describe the possible consequences for the actual characteristics and values of the surrounding NNN areas and expected changes in the populations of protected and/or red list species in the study area as a result of the proposal.	Part B	Section 13
Also describe possible measures to reduce the impact, as well as the effectiveness of these measures.	Part B	Section 13
4.4 Ionizing radiation and safety		
Provide estimations of expected emissions of radioactive substances and of the radiation level at the site border, as a result of the maximum design specifications of the proposal. Data gained from comparable installations could be used for this purpose, for example. Then indicate the extent to which the proposal can be incorporated within the total space for nuclear installations at Research Location Petten according to the current permit.	Part B	Section 7
Describe in general terms the possible external causes and consequences of calamities which may stand in the way of spatial incorporation of a new research reactor at Research Location Petten, and possible measures to control such circumstances.	Part B	Section 7
Indicate whether the regional crisis response plan complies with all current requirements for combating any radiation incidents which may be expected. If this is not the case, indicate the extent to which gaps in that plan may stand in the way of realization of a new research reactor and how such gaps can be filled, in order to justify planning of a new reactor.	Part B	Section 7
Show how cooling water pipelines which intersect the primary coastal defenses can be installed in such a manner that they comply with the water safety standards.	Part B	Section 9
4.5 Noise		
Describe the expected noise hinder during the construction process (during pile driving for example) and during operation (in the case of air cooling, for example) for noise-sensitive nature and for housing and noise-sensitive objects. Indicate whether mitigating measures are required and if so, what impact they will have.	Part B	Section 11
4.6 Landscape		
In the SEA, describe the landscape targets of the various regional and local authorities in the study area. Describe and subsequently evaluate the landscape and cultural history characteristics of the area, such as its well-preserved character and openness. Describe the impact of alternatives/variants on the landscape quality. Describe the approach of the reactor design to structural elements in the landscape for example, and whether and how the character of the landscape is preserved.	Part B	Section 15
The use of evaporation coolers can result in a visible warm water plume. Indicate the circumstances under which such a plume can be formed, and the impact of this on visibility.	Part B	Section 15
Effective visual material is essential in order to clearly show the impact. Visualizations from various angles enable integral assessment of the qualities and impact.	Part B	Section 15

5 Other aspects		
5.1 Comparison of alternatives		
The environmental impact of the alternatives must be compared both mutually and versus the reference situation. The purpose of this comparison is to provide insight into the nature of and degree to which the alternatives have a different impact. The comparison should preferably be based on quantitative information, involving the objectives and the limiting/target values of the environmental policy.	Parts A and B	A: section 4 B: entirely, appendix E
Also indicate the degree to which the set targets can be realized for each of the alternatives. Once again, use unequivocal and quantifiable assessment criteria where possible.	Parts A and B	A: sections 4, 5 B: entirely
5.2 Gaps in environmental information and uncertainties		
The SEA must refer to those environmental aspects for which insufficient information can be included, due to a lack of data. Concentrate on environmental aspects which play an important role in the further decision-making process, in order to allow assessment of the consequences of the deficit in knowledge. Also indicate whether the knowledge gaps will be supplemented by the SEA project.	Parts A and B	A: par. 5.4 B: entirely
When comparing the alternatives and assessing the alternatives in terms of (project) targets and statutory target values, take account of the uncertainties in impact determination. For that purpose, provide insight into the importance of these uncertainties for the significance of differences between alternatives, and therefore for the comparison of alternatives.	Part B	Entirely
5.2 Format and presentation		
Presentation of the comparative assessment of the alternatives must be paid special attention. The comparison should preferably be presented using tables, figures and maps. Ensure that:	Entire SEA	
• the SEA is as concise as possible, by including background data in an appendix rather than in the main text, for example;	Entire SEA	
• a glossary, a list of abbreviations and a literature list must be included;	Part A	Appendix A
• the use of recent, legible maps, with clear legends.	Entire SEA	
The summary is that part of the SEA which is mainly read by decision-makers and influencing parties, and therefore deserves special attention. It must be legible as an independent document and must be an effective reflection of the contents of the SEA. It must include the most important information, such as:	Summary	
• the proposed activity and alternatives for that activity;	Summary	
• the main impact on the environment upon execution of the proposed activity and the alternatives, the uncertainties and gaps in knowledge which apply;	Summary	
• the comparison of the alternatives and arguments in favor of selecting the preferred alternative.	Summary	

Appendix E

Overview table of environmental impact

Construction phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Radiation protection						
Effective dose	0	0	0	0	0	0
Nuclear safety						
Radiological requirements for postulated incidents	-	-	-	0	0	0
Admissible risk as a result of incidents	-	-	-	0	0	0
Soil and Water						
Groundwater						
Vegetation	0	0	0	- -	- -	0
Buildings	0	0	0	0	0	0
Dunes as part of the coastal defense	0	0	0	0	0	0
Agriculture	0	0	0	-	-	0
Groundwater extraction or infiltration systems	0	0	0	0	0	0
Mobile contaminants	0	0	0	- -	- -	0
Water quality						
Physical-chemical water quality	n/a	n/a	n/a	n/a	n/a	n/a
Biological water quality	n/a	n/a	n/a	n/a	n/a	n/a
Cooling water extraction and discharge						
Cooling water extraction	n/a	n/a	n/a	n/a	n/a	n/a
Cooling water discharge	n/a	n/a	n/a	n/a	n/a	n/a
Soil						
Soil quality	0	0	0	0	0	0
Water safety						
Water safety	0	0	0	0	0	n/a
Air quality						
Impact on NO_2	0	0	0	0	0	0
Impact on PM_{10} and $PM_{2.5}$	0	0	0	0	0	0
Noise						
Noise hindrance for local residents due to installation	0	0	0	n/a	n/a	n/a
Noise hindrance for local residents due to construction activities	- -	- -	- -	-	0	0
Indirect noise hindrance for local residents	-	-	-	n/a	n/a	n/a

Beoordelingscriterium	B1	B2	B3	K1	K2	K3
Light						
Increased light intensity in light-sensitive objects	-	-	-	- -	0	0
Nature (following mandatory measures)						
Natura 2000 area	0	0	0	-	-	0
Protected species	0	0	0	-	-	0
NNN	0	0	0	-	-	0
Red List species	0	0	0	0	0	0
Recreation and Tourism						
Influencing of recreational usage possibilities	-	-	-	-	-	-
Influencing of recreational experiential value	-	-	-	-	-	0
Accessibility	0	0	0	0	0	0
Economic value	0	0	0	0	0	0
Identity	-	-	-	-	-	0
Landscape and Cultural history						
Physical degradation to landscape characteristics/values	0	0	0	0	0	0
Physical degradation to historic geographical elements	0	0	0	0	0	0
Physical degradation to historic (urban) architecture	0	0	0	0	0	0
Experiential value	-	-	-	0	0	0
Usage value	0	0	0	0	0	0
Future value	0	0	0	0	0	0
Archaeology						
Expected archaeological values	- -	- -	- -	- -	-	0
Known archaeological values	-	-	-	-	-	0
Traffic						
Road design according to the Sustainable Safety principles – if the Zeeweg is avoided.	0	0	0	0	0	0
Road design according to the Dutch Sustainable Safety principles – if the Zeeweg is used.	-	-	-	0	0	0
Traffic movements	0	0	0	0	0	0
Vibration hinder	0	0	0	n/a	n/a	n/a

Transition phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Radiation protection						
Effective dose	-	-	-	0	0	0
Nuclear safety						
Radiological requirements for postulated incidents	-	-	-	0	0	0
Admissible risk as a result of incidents	-	-	-	0	0	0
Soil and Water						
Groundwater						
Vegetation	0	0	0	0	0	0
Buildings	0	0	0	0	0	0
Dunes as part of the coastal defense	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0
Groundwater extraction or infiltration systems	-	-	0	0	0	0
Mobile contaminants	0	0	0	0	0	0
Water quality						
Physical-chemical water quality	n/a	n/a	n/a	0	0	n/a
Biological water quality	n/a	n/a	n/a	0	0	n/a
Cooling water extraction and discharge						
Cooling water extraction	n/a	n/a	n/a	- -	0	0
Cooling water discharge	n/a	n/a	n/a	0	0	0
Soil						
Soil quality	n/a	n/a	n/a	n/a	n/a	n/a
Water safety						
Water safety	0	+	+	0	0	n/a
Air quality						
Impact on NO_2	n/a	n/a	n/a	n/a	n/a	n/a
Impact on PM_{10} and $PM_{2.5}$	n/a	n/a	n/a	n/a	n/a	n/a
Noise						
Noise hindrance for local residents due to installation	0	0	0	0	0	- -
Noise hindrance for local residents due to industrial activities	0	0	0	0	0	- -
Indirect noise hindrance for local residents	0	0	0	n/a	n/a	n/a

Beoordelingscriterium	B1	B2	B3	K1	K2	K3
Light						
Increased light intensity in light-sensitive objects	0	0	0	0	0	0
Nature (following mandatory measures)						
Natura 2000 area	0	0	0	-	-	0
Protected species	0	0	0	0	0	0
NNN	0	0	0	0	0	0
Red List species	0	0	0	0	0	0
Recreation and Tourism						
Influencing of recreational usage possibilities	0	0	0	0	-	-
Influencing of recreational experiential value	0	-	- -	0	- -	-
Accessibility	0	0	0	0	0	0
Economic value	0	0	0	0	0	0
Identity	0	-	-	0	-	-
Landscape and Cultural history						
Physical degradation to landscape characteristics/values	0	0	0	-	-	0
Physical degradation to historic geographical elements	0	0	0	0	0	0
Physical degradation to historic (urban) architecture	0	0	0	0	0	0
Experiential value	0	-	- -	0	- -	-
Usage value	0	0	0	0	0	0
Future value	0	0	0	0	0	0
Archaeology						
Expected archaeological values	n/a	n/a	n/a	n/a	n/a	n/a
Known archaeological values	n/a	n/a	n/a	n/a	n/a	n/a
Traffic						
Road design according to the Sustainable Safety principles – if the Zeeweg is avoided.	n/a	n/a	n/a	n/a	n/a	n/a
Road design according to the Dutch Sustainable Safety principles – if the Zeeweg is used.	n/a	n/a	n/a	n/a	n/a	n/a
Traffic movements	n/a	n/a	n/a	n/a	n/a	n/a
Vibration hinder	n/a	n/a	n/a	n/a	n/a	n/a

Operational phase

Assessment criterion	B1	B2	B3	K1	K2	K3
Radiation protection						
Effective dose	0	0	0	0	0	0
Nuclear safety						
Radiological requirements for postulated incidents	+	+	+	0	0	0
Admissible risk as a result of incidents	+	+	+	0	0	0
Soil and Water						
Groundwater						
Vegetation	0	0	0	0	0	0
Buildings	0	0	0	0	0	0
Dunes as part of the coastal defense	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0
Groundwater extraction or infiltration systems	-	-	0	0	0	0
Mobile contaminants	0	0	0	0	0	0
Water quality						
Physical-chemical water quality	n/a	n/a	n/a	0	0	n/a
Biological water quality	n/a	n/a	n/a	0	0	n/a
Cooling water extraction and discharge						
Cooling water extraction	n/a	n/a	n/a	0	+ +	+ +
Cooling water discharge	n/a	n/a	n/a	0	0	0
Soil						
Soil quality	n/a	n/a	n/a	n/a	n/a	n/a
Water safety						
Water safety	0	+	+	0	0	n/a
Air quality						
Impact on NO_2	n/a	n/a	n/a	n/a	n/a	n/a
Impact on PM_{10} and $PM_{2.5}$	n/a	n/a	n/a	n/a	n/a	n/a
Noise						
Noise hindrance for local residents due to installation	0	0	0	0	0	- -
Noise hindrance for local residents due to industrial activities	0	0	0	0	0	- -
Indirect noise hindrance for local residents	0	0	0	n/a	n/a	n/a

Beoordelingscriterium	B1	B2	B3	K1	K2	K3
Light						
Increased light intensity in light-sensitive objects	0	0	0	0	0	0
Nature (following mandatory measures)						
Natura 2000 area	0	0	0	-	-	0
Protected species	0	0	0	0	0	0
NNN	0	0	0	0	0	0
Red List species	0	0	0	0	0	0
Recreation and Tourism						
Influencing of recreational usage possibilities	0	0	0	0	-	-
Influencing of recreational experiential value	0	-	- -	0	- -	-
Accessibility	0	0	0	0	0	0
Economic value	0	0	0	0	0	0
Identity	0	-	-	0	-	-
Landscape and Cultural history						
Physical degradation to landscape characteristics/values	0	0	0	-	-	0
Physical degradation to historic geographical elements	0	0	0	0	0	0
Physical degradation to historic (urban) architecture	0	0	0	0	0	0
Experiential value	0	-	- -	0	- -	-
Usage value	0	0	0	0	0	0
Future value	0	0	0	0	0	0
Archaeology						
Expected archaeological values	n/a	n/a	n/a	n/a	n/a	n/a
Known archaeological values	n/a	n/a	n/a	n/a	n/a	n/a
Traffic						
Road design according to the Sustainable Safety principles – if the Zeeweg is avoided.	n/a	n/a	n/a	n/a	n/a	n/a
Road design according to the Dutch Sustainable Safety principles – if the Zeeweg is used.	n/a	n/a	n/a	n/a	n/a	n/a
Traffic movements	n/a	n/a	n/a	n/a	n/a	n/a
Vibration hinder	n/a	n/a	n/a	n/a	n/a	n/a

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Appendix F Background reports

The background reports of Appendix F have been enclosed as a separate document. The following background reports (in Dutch) can be distinguished:

Appendix	
F1	Radiation Protection
F2	Nuclear Safely
F3	Soil and Water
F4	Water quality
F5	Air quality
F6	Noise
F7	Light
F8	Nature
F9	Recreation and Tourism
F10	Landscape, Cultural history and Spatial quality
F11	Archeology
F12	Traffic

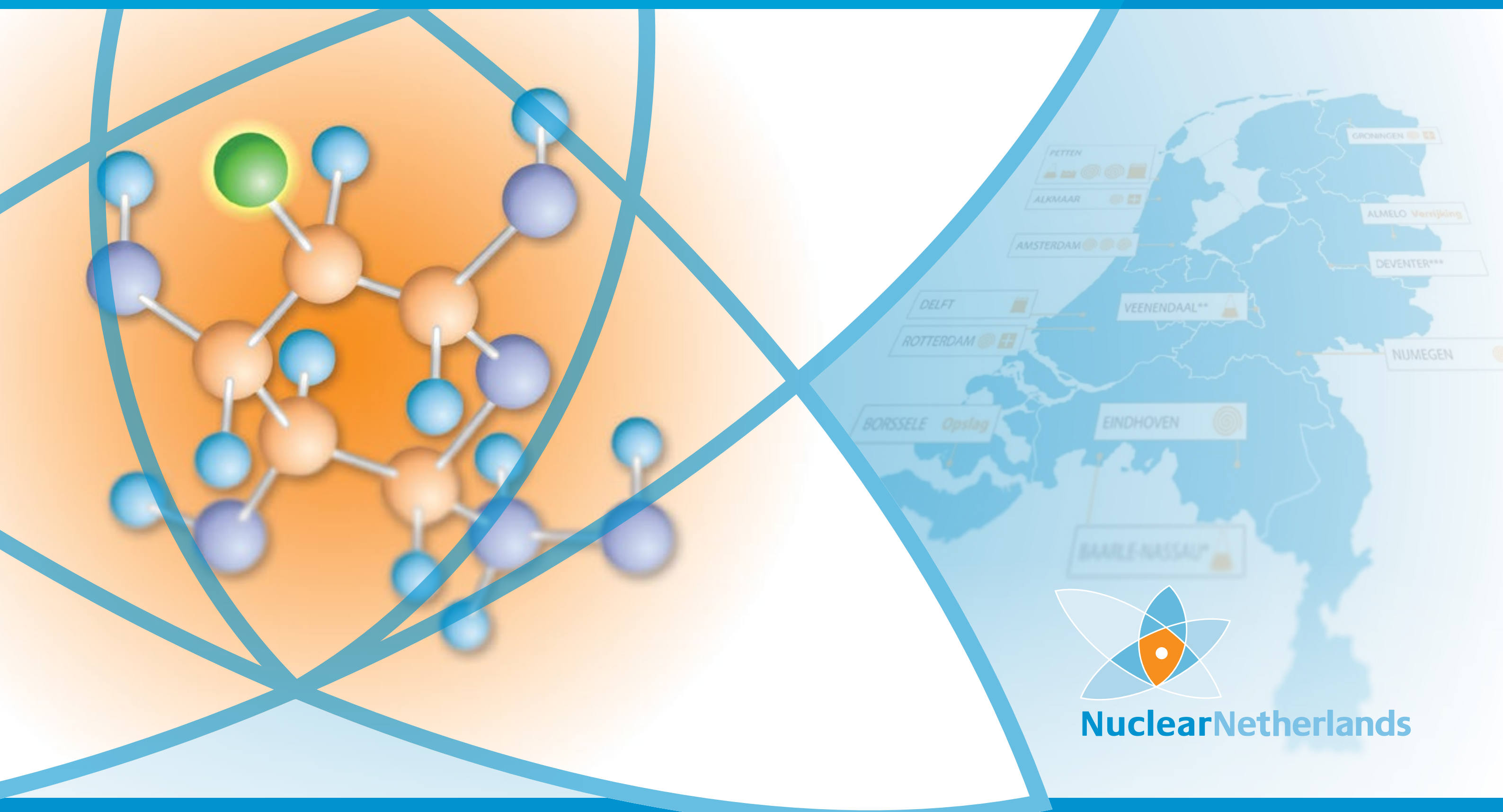
Appendix

G Paper Medical isotopes

Where in this document Mallinckrodt is written, Curium must be read.

Medical isotopes

Global importance and opportunities for The Netherlands



NuclearNetherlands

www.nuclearnetherlands.com

Table of contents

‘Medical isotopes, global importance and opportunities for The Netherlands’ is a publication of Nuclear Netherlands, March 2017.

1 Introduction

Every year, around 48 million[1] examinations and treatments involving medical isotopes take place worldwide. In more than 80% of these cases – around 40 million procedures - the medical isotope technetium-99m is used. This is a radioactive substance produced on a large scale by a handful of nuclear reactors worldwide. The other isotopes can be roughly divided into two equal groups. There is fluorine-18, which is produced in small quantities by accelerators in or near hospitals (4.2 million procedures) and there is a collective group that includes various other medical isotopes (3.8 million procedures).

For a long time, it was not very relevant for patients and nuclear medicine specialists to know where the medical isotopes came from. They were simply always available. However, this changed completely between 2008 and 2010, when unexpected production limitations in several large reactors caused major disruptions in the supply. In a short period of time, the market and all its complex links became a topic of discussion.

In addition to a widely shared vision that (new) medical isotopes are inherent to modern healthcare and that continuous availability is essential, there are also many contrasting views. This is partly due to the "multi-coloured" landscape that forms the backdrop to the term medical isotopes. There are (political) interests at international, national and local scale. There are public, semi-commercial and commercial parties that depend on each other in one production chain. Professional disciplines that would normally not come into contact have to work together. It is a nuclear activity that is subject to stringent legislation and regulations and where the public interest plays a major role. Finally, it involves a product with a medical use, which is also subject to a large amount of legislation and regulations.

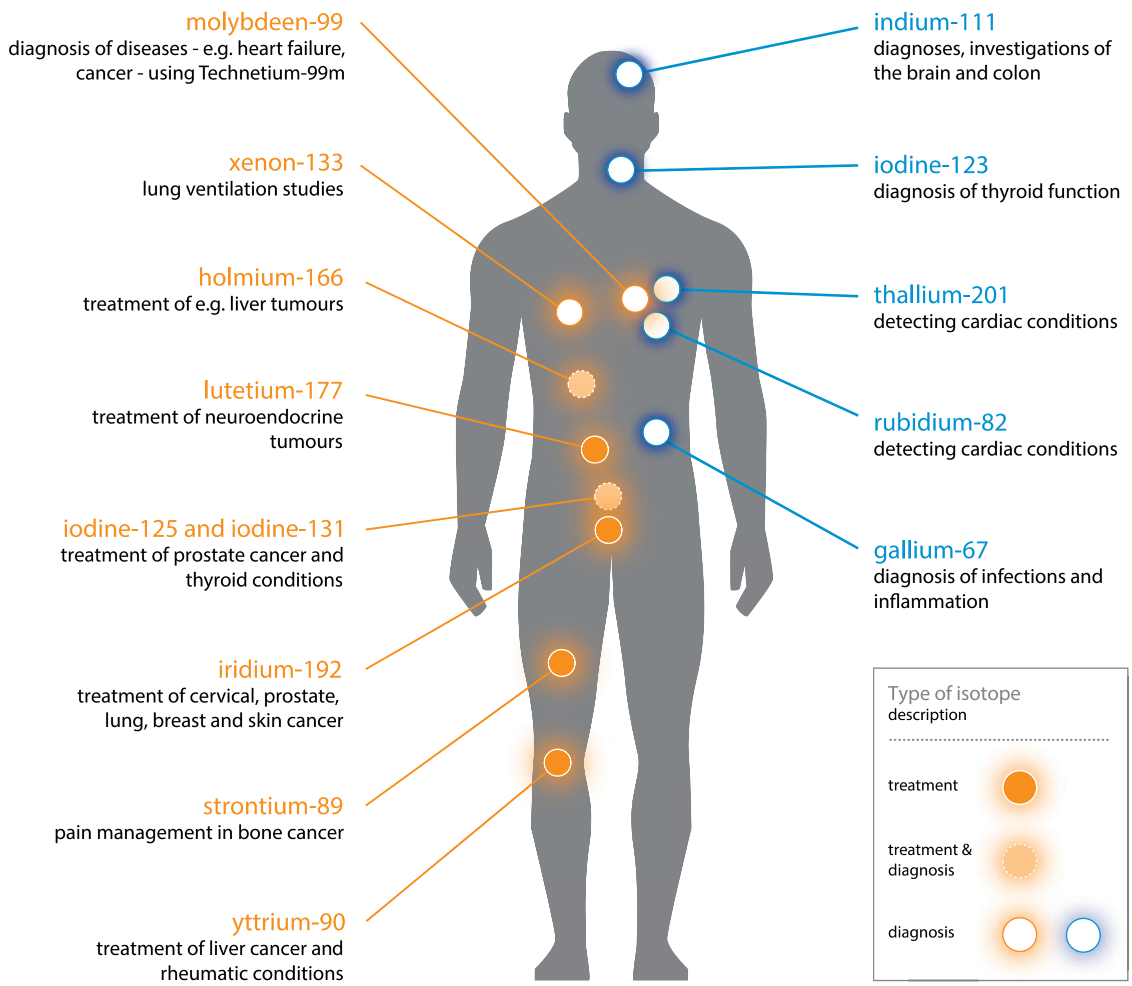
As the largest producer of medical isotopes in the world, the Netherlands has to deal with the full extent of all these elements. This document aims to make the reader better informed about the subject, reveal the connections in the chain and discuss the dependence and vulnerability of millions of patients in this context. An analysis will also be provided of the future developments and the many opportunities that the Netherlands has within its borders to perpetuate and expand its role as frontrunner.

The story begins in the hospital with a hypothetical patient suffering from one of the most common diseases. A referral to the nuclear medicine department is probable in at least four out of five cases. What happens here and the instruments and products at the disposal of nuclear medicine are discussed in Chapter 2. Chapter 3 focuses on the trends and developments that ensure that patients will receive even better care in the future.

In Chapter 4, we leave the hospital to review all the steps preceding the patient's treatment. This section explains the various steps in the production chain for medical isotopes and how they are related.
Like Chapter 3, Chapter 5 focuses on the future. This chapter discusses the scenarios for the various parties in the chain. Which (alternative) production routes will form the cornerstones of healthcare in the future? Chapter 6 looks at the situation in the Netherlands, followed by a final chapter (7) with a clear list of recommendations.

[1] MEDraysintell, June 2015

Isotopes from Petten



A patient visits the nuclear medicine specialist

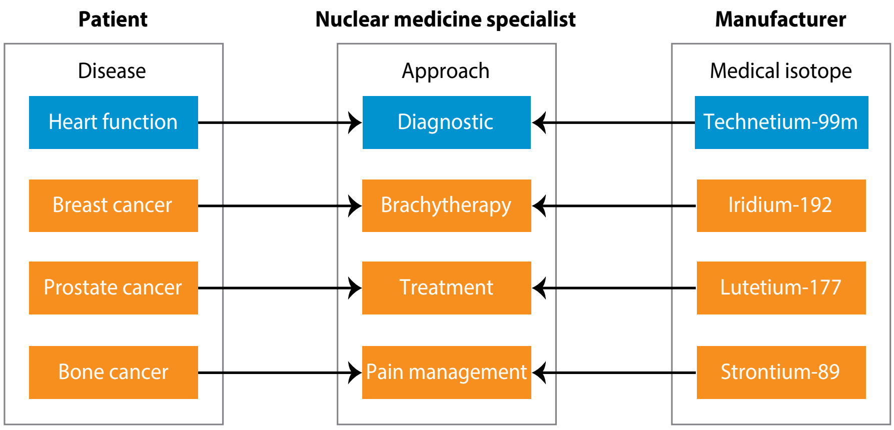
In prosperous countries, most people die of cardiovascular disease, cancer, diabetes, lung and respiratory tract conditions and dementia. In all these cases – with the exception of diabetes – the specialist is likely to refer his patient to the nuclear medicine specialist. This referral is usually to perform a scan (90% of cases), but increasingly it also involves (cancer) treatment or pain management.

Cancer has a huge and increasing economic impact, according to the World Health Organization in its "top 10 causes of death in prosperous economies" in 2015. In 2012, 14 million new cases of cancer were diagnosed worldwide and 8.2 million people died as a result of this disease. In relation to other causes of death, this is equivalent to approximately 1 in 6. The total costs of treating cancer totalled around 1.16 trillion dollars in 2010[2].

Against this backdrop and with the number of cancer cases predicted to soar (70%) over the next twenty years, all parties involved in innovative nuclear medicine are doing everything they can to find good solutions for these patients.

Disease, approach, isotope

The doctor sets up a treatment plan (diagnosis, treatment, follow-up care) for the patient. A nuclear medicine approach is selected for certain diseases. This involves the use of medical isotopes. The use of medical isotopes to tackle cancer is extremely varied. Depending on the type of cancer and the stage of the disease, the diagnosis is performed using medical isotopes, with or without subsequent radiotherapy (external radiation), brachytherapy (radiation from inside the body) and palliative treatment (pain management). The figure below provides a number of examples of diseases, followed by the treatment and the medical isotope involved.



[2] http://www.who.int/features/factfiles/cancer/en/ (fact 8)

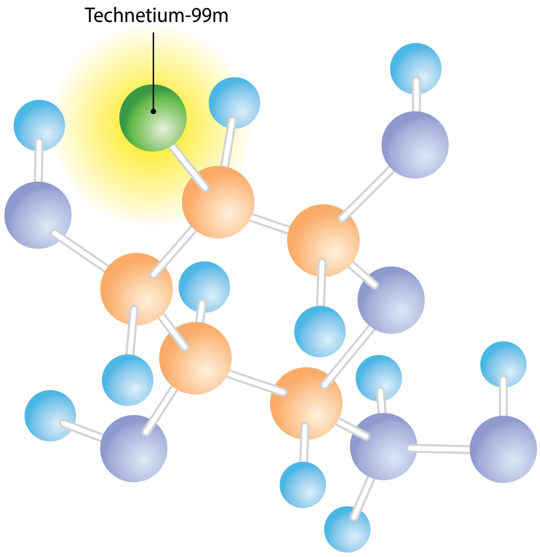
2.1 What are medical isotopes?

Nuclear medicine specialists use radioactive material to determine whether organs are functioning properly and to detect cancerous growths at an early stage (diagnostics). In addition, so-called therapeutic isotopes are used in the treatment of patients. This chapter will discuss the isotopes for diagnostic purposes and isotopes for treatment.

The radioactive substances used in diagnosis and treatment are called medical (radio) isotopes. In order to ensure that they reach the correct organ, the isotope is linked to a non-radioactive substance. By administering this combination to a patient, it is possible to trace a "trail" of radiation using a special camera, allowing the nuclear medicine specialist for example to determine how an organ is functioning or where a cancerous growth is active.

Tracer and radiopharmaceutical

By combining the right isotope (or radionuclide) with a specially developed protein (the detecting substance or tracer), it is possible to map a specific disease process. The combination is also called a radiopharmaceutical. The radiopharmaceutical is selected per examination or treatment, so that it has exactly the right specific biological and radiation properties.



2.2 Diagnostics

Any patient needing medical isotopes for diagnostic purposes is usually scheduled for a nuclear scan. This includes all types of imaging techniques that use radioactivity. These scans are particularly suitable for detecting movement and change, such as the blood flow through the heart or the metabolism in an organ.

When undergoing a scan, the patient is injected with a very small quantity of slightly radioactive liquid. The patient then has to wait several minutes to several days, depending on the examination. Once the liquid has spread through the body via the circulation, the scan can be performed. This provides an image in which the radioactive areas are visible. By detecting the radiation, it is possible to determine whether anything abnormal is going on.

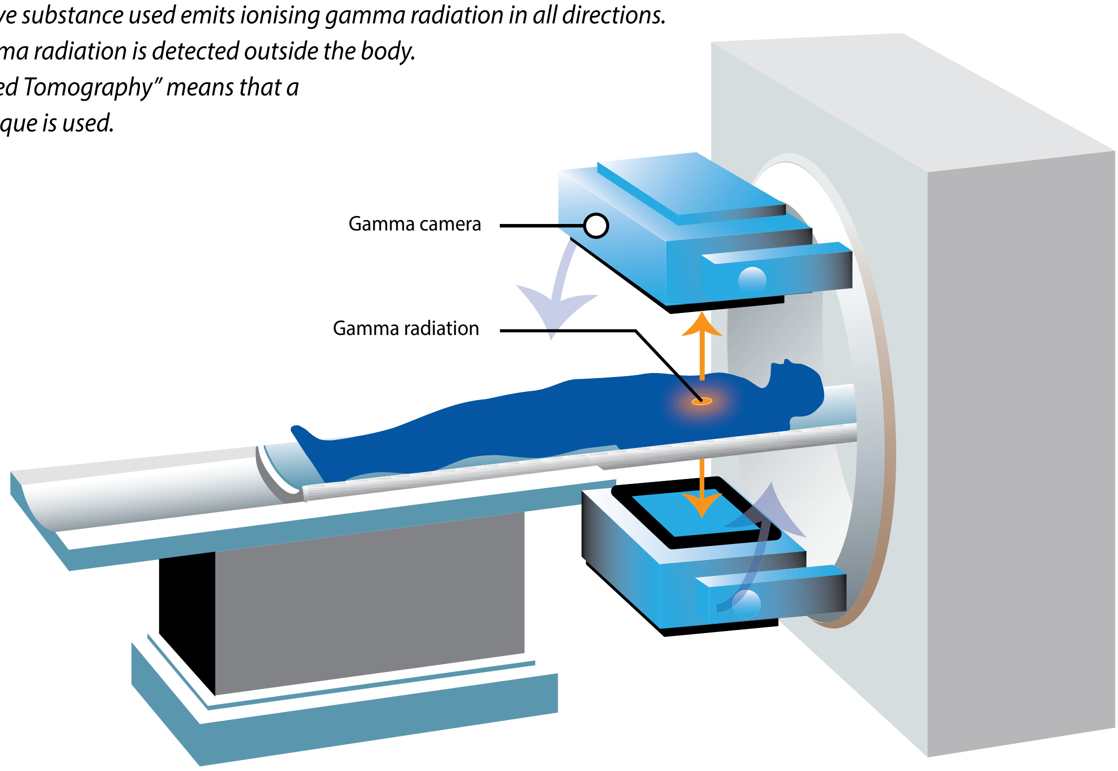
The nuclear medicine specialist has various types of cameras at his disposal. The bed and the camera can be stationary whilst taking pictures, or the bed can pass slowly below the camera or the camera can turn in a circle around the bed. It is possible to record all sorts of images, to obtain a very precise view of what is wrong with the patient.

In modern nuclear medicine, two main imaging techniques are used: PET and SPECT. Both use the gamma radiation emitted by the isotope to produce a series of images of the distribution of radioactivity in the body. Gamma radiation is one type of invisible electromagnetic radiation that a radio-isotope can emit.

PET and SPECT scans generally produce images that can only be interpreted by a specialised doctor. However, by combining them with other techniques (such as "Computed Tomography" [CT] or "Magnetic Resonance Imaging" [MRI]), we are much better able to generate very precise images of certain functions deep in the body.

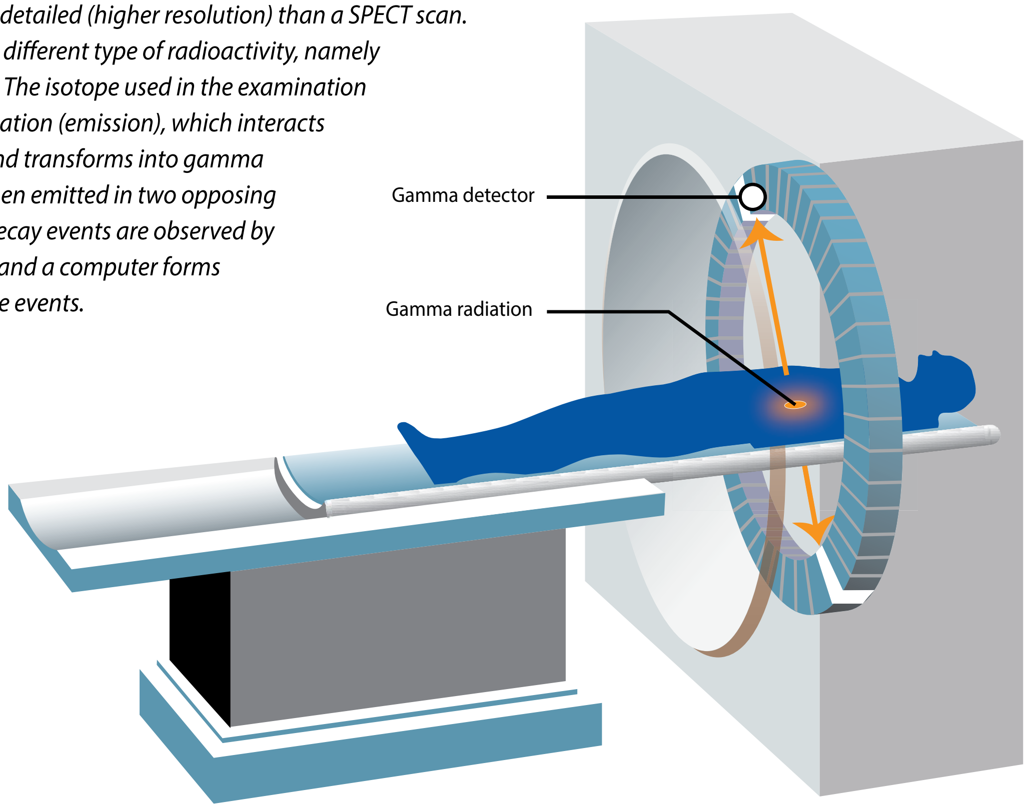
SPECT - "Single Photon Emission Computed Tomography"

A SPECT scan is most commonly used. "Single Photon Emission" means that the radioactive substance used emits ionising gamma radiation in all directions. This gamma radiation is detected outside the body. "Computed Tomography" means that a 3D technique is used.



PET - "Positron Emission Tomography"

A PET scan is more detailed (higher resolution) than a SPECT scan. This camera uses a different type of radioactivity, namely positron radiation. The isotope used in the examination emits positron radiation (emission), which interacts with an electron and transforms into gamma radiation. This is then emitted in two opposing directions. These decay events are observed by a ring of detectors and a computer forms a 3D image of these events.



Medical isotopes are very important, particularly for diagnostic purposes in oncology, cardiology and neurology. It is estimated that more than 10.000 hospitals worldwide use isotopes for diagnosis. The best known isotope for diagnostic purposes is technetium-99m. This isotope is used annually in more than 40 million diagnostic examinations worldwide, with half of these examinations taking place in North America and around 7 million in Europe. Around 250,000 procedures using technetium-99m take place each year in the Netherlands.

Technetium-99m is used in the vast majority of SPECT scans. This workhorse of diagnostics has many advantages compared to other isotopes (see 4.1 molybdenum-99 / technetium-99m). PET scans primarily use fluorine-18, which is produced in cyclotrons. PET isotopes have a (very) short half life. They are therefore produced shortly prior to use in a cyclotron that is located in or near a specialised hospital. Fluorine-18 is used to produce the radio-pharmaceutical FDG (18F-fluorodeoxyglucose), which makes the glucose consumption in the body visible. This forms an important part in the detection of growths. Other suitable PET isotopes are carbon-11, oxygen-15 and nitrogen-13.

2.3 Treatment

Treatment involving radiation can be divided into radiotherapy, nuclear medicine therapy (including brachytherapy) and palliative therapy. Radiotherapy uses external sources of radiation, while nuclear medicine therapy involves the administration of a medical isotope to a patient. In both cases, the treatment is aimed at destroying specific tissues. Palliative therapy focuses on pain management. Patients receive an administration of a medical isotope that slows down the disease process, thereby reducing pain and improving quality of life. Brachytherapy is a specific method of administering the radio-isotope, in which the isotope is administered via a catheter or needle to the site of the condition and continues to emit radiation to the diseased tissue for a shorter or longer period.

By linking the correct medical isotope to a suitable tracer, the nuclear medicine specialist is able to deliver the medical isotopes to the correct site in the body, significantly limiting the damage to healthy cells whilst effectively killing the diseased cells. The radiation dose administered during treatment is much higher than the dose used for diagnostics. The patient is even considered radioactive for a while.

The most common treatments in the Netherlands are:

- iodine-131 for thyroid conditions, in which a capsule of radioactive iodine is administered to the patient. The iodine accumulates in the thyroid, where it emits radiation (therapy).
- iridium-192 for the treatment of – for example – breast cancer and prostate cancer (brachytherapy).
- radium-223, (Xofigo®) for the treatment of bone metastases of prostate cancer.
- lutetium-177, for the treatment of neuroendocrine tumours and on an experimental basis for the treatment of prostate cancer (nuclear medicine therapy).
- strontium-89, rhenium-186 or samarium-153 for pain management of metastasised bone cancer (nuclear medicine therapy).
- yttrium-90 for the treatment of liver cancer (radio-embolisation) and certain rheumatic conditions.
- holmium-166 for the treatment of liver cancer (radio-embolisation).

Therapeutic applications are quickly gaining in importance and compared to the diagnostic applications they are mainly of qualitative importance. For example, treatment using lutetium-177 for a patient with neuroendocrine tumours – a rare and very malignant form of cancer – can extend the patient's life span on average by at least 4 years, with a relatively good quality of life[3]. This treatment was developed in the Netherlands and is now used very successfully all over the world. The number of patients who are eligible for treatment with lutetium-177 is expected to rise significantly.

[3] Erasmus MC, http://www.net-kanker.nl/

Trends and developments in nuclear medicine

Anyone observing the developments in the use of medical isotopes from a distance will observe three general trends: From the 1960s to 2015, the focus of nuclear medicine was primarily diagnostic. The development of various so-called "cold kits" (tracers), improvements in imaging technology and the availability of cameras were the driving factors in those years. The emphasis during this period was not focused so much on treatment with isotopes, although the first developments did start around that time.

The first therapeutic products were developed in the run-up to 2015, under brand names such as Xofigo® and Zevalin®. The success of these products provided an impulse for the development of other radiotherapeutic products. As it takes some time for these types of new products to reach the market, many new brands are expected to become available to patients over the next ten years.

The new therapeutic products based on lutetium-177 look particularly promising. They are a tangible example of the frequently mentioned trend of "personalised medicine", which essentially means that a therapy is tailored to the patient. This avoids excessive and ineffective treatment, which could result in cost reductions in healthcare whilst maintaining quality of life.

The third trend involves the so-called alpha emitters, which are isotopes that emit alpha particles. These medical isotopes can be used in future to find smaller "targets" more effectively, making it possible to treat so-called micro-metastases. Alpha emitters are very effective at destroying tumour cells. Various universities and companies are working on their development.

3.1 Developments in diagnosis

Although the most prominent discoveries are now being made in the field of nuclear medicine therapy, the developments in the field of diagnostics are also continuing. Major steps are still taking place in the development of new tracers and further improvements in camera and imaging techniques. This is all aimed at increasing the effectiveness of treatments.

The costs of use and purchasing the SPECT or PET cameras also play a role in diagnosis. A PET camera is much more expensive to purchase and use than a SPECT camera. However, a PET camera is often used for complicated examinations due to the higher resolution of the images. Hospitals often work together to purchase and operate the PET technology. The ratio between SPECT and PET cameras in hospitals is currently 5:1.

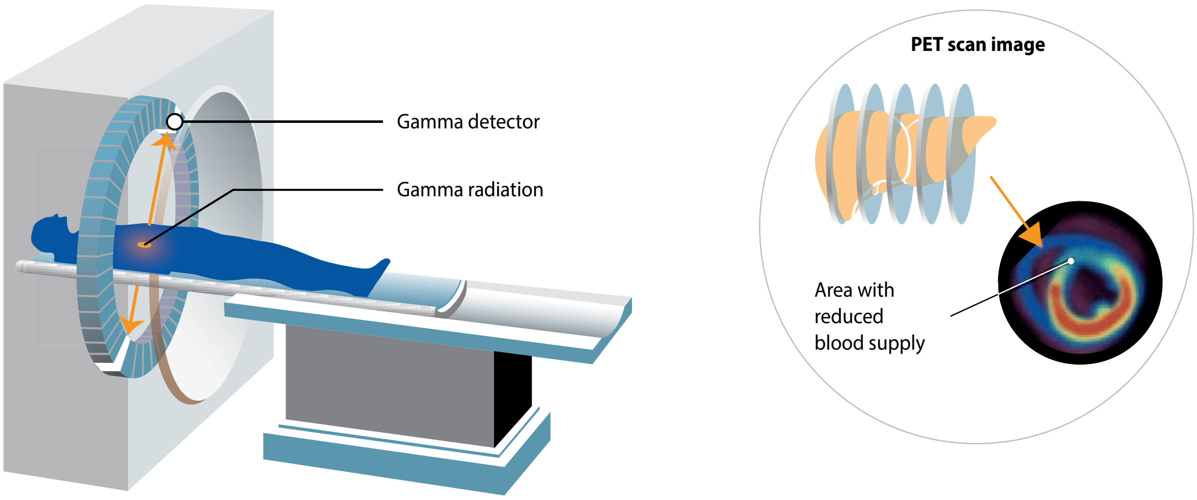
The resolution of SPECT scans is also still improving. The image quality is now approaching that of PET. Research by Technopolis in 2008[4] reveals that the choice of a certain imaging technique varies per medical specialisation. PET is strongly favoured in oncology, while SPECT is dominant in cardiology and for producing bone scans and other organ scans. Despite the growth in the use of PET cameras, fluor-18 is not expected to replace technetium-99m.

The current state of technology is that these devices are used in combination with CT: SPECT-CT and PET-CT. The CT technology basically provides detailed 3D X-ray images. By combining the data from SPECT or PET with CT, it is possible to combine the information about the functioning of the organs with the exact location in the body.

[4] Technopolis-rapport 2008

Comparison of PET and SPECT

Positron Emission Tomography (PET)



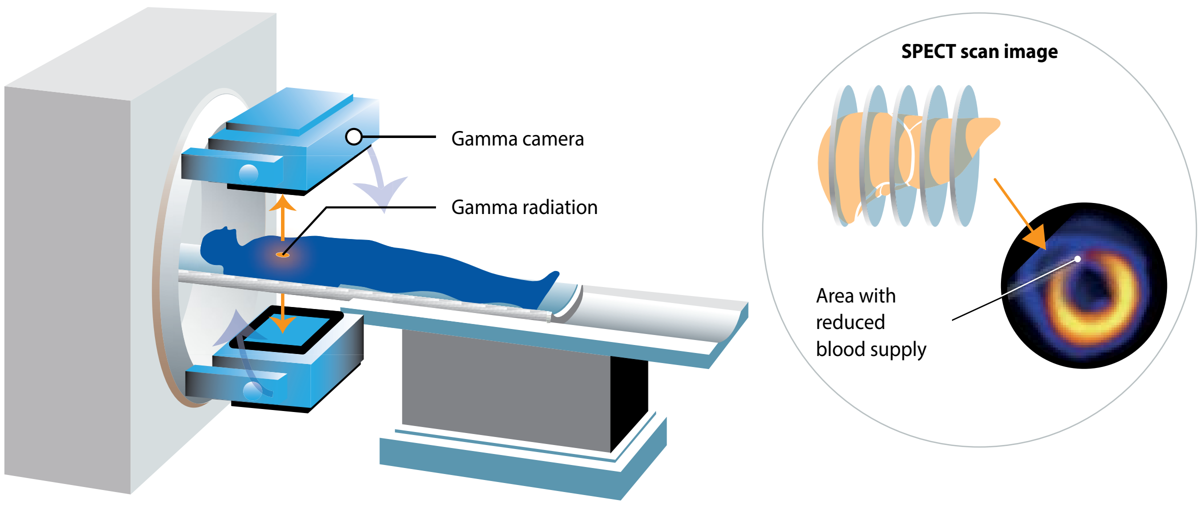
Trends in camera

- Better image quality than SPECT, but also more expensive.
- Technology trend moving towards PET/CT, makes it possible to stack multiple images.
- The global capacity is approximately 4,900 cameras (2015) increasing to 7,000 (2025).

Trends in isotopes

- Most commonly used tracer is Fludeoxyglucose (FDG), based on F-18.
- Other isotopes: Ga-68, Rb-82, C-11, N-13, O-15, Sr-92.
- New research yields new tracers (for example, for Ga-68, Rb-82), which will replace existing tracers.
- PET isotopes require local production in cyclotrons, which is less cost effective than reactor production.

Single Photon Emission Computed Tomography (SPECT)



Trends in camera

- Lower resolution, but also cheaper.
- New SPECT cameras have a similar image quality to PET.
- Same trend as for PET: moving towards hybrid technology SPECT/CT.
- The global capacity is around 26,200 cameras (2015), increasing to 29,000 (2025).

Trends in isotopes

- Most used isotope is Tc-99m, which can be linked to various tracers (available as cold kits)
- Various isotopes produced in reactors and cyclotrons can be used, but Tc-99m is the most common.
- Renewed interest from medical research is resulting in the development of new tracers.

Sources: Wikipedia, Zimmermans workshop 2016

A more recent development is the combination of these cameras with MRI. MRI provides detailed images of tissues and organs. The combination of techniques such as SPECT-MRI and PET-MRI is gaining in popularity.

G-SPECT

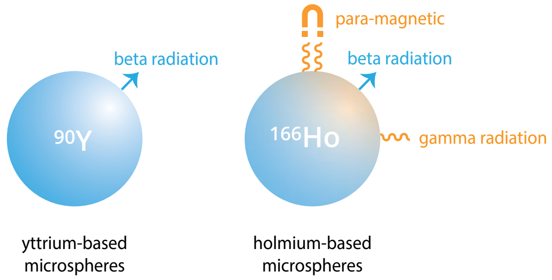
A good example of a prominent development in SPECT is the so-called G-SPECT. This is a new type of camera developed by MILabs, a "spin off" of the UMC Utrecht.
The G-SPECT has an exceptionally high resolution of 3 millimetres (normal SPECT: 7-10 mm), making the image even more clear. In addition, G-SPECT is the first technique to provide insight into a large number of rapid, dynamic processes, such as those associated with Alzheimer's disease or Parkinson's disease. Another important advantage is that G-SPECT has a high sensitivity. This means that the patient can be given a much lower dose of radioactive substance. Furthermore, it is possible to obtain a usable scan even if the patient moves in the scanner.
At the moment, scans often fail and need to be repeated for this reason. In addition, the G-SPECT can convert 3D images into a 4D film. This makes it possible to visualise how substances move in and out of structures, which can be of importance – for example – in investigations of tumours. This opens up a new field that can provide a lot of interesting information for doctors and patients.

3.2 Developments in treatment

As mentioned before, nuclear medicine is rapidly following the trends in personalised medicine. Existing methods are aimed at patient groups. Specialists are getting better all the time at determining which treatments will or will not work within these groups: "appropriate use". This results in increasingly effective treatments in which any unnecessary damage (for example due to side effects of medication or exposure to radiation) can be prevented. This increases both patient safety and the quality of life for patients. In future, the treatments will be more and more targeted at individuals.

Holmium-166

There is increasing interest in the innovative treatment using holmium-166. The University Medical Centre (UMC) Utrecht recently registered the first indication for this innovative treatment. The holmium-166 is loaded in microspheres (brachytherapy) to combat primary liver tumours from within. The holmium-166 also emits gamma radiation, allowing diagnostic images to be recorded.



The development of new therapeutic products and radiopharmaceuticals takes time. It always involves collaboration between specialists from very different fields and the involvement of scientists. Besides radiochemists, biochemists, pharmacists and organic chemists also play an important role. Nuclear physicists and various engineering disciplines are also required for the production of new radiopharmaceuticals. After all, the production of radiopharmaceuticals places very high demands on the infrastructure of the parties involved.

The combination of therapy and diagnostics, the so-called "theranostics", is an emerging application of medical isotopes that offers a great perspective. The radiopharmaceutical tracks down the tumour and once it has been absorbed properly, the same molecule is labelled with a therapeutic substance (an alpha or beta emitter). The molecule guarantees the same absorption pattern for both diagnostic and therapeutic applications. This allows the treatment to be targeted and modified for maximum effectiveness and the fewest possible side effects. Examples of this are diagnostics and therapy using the molecule PSMA. Thanks to the diagnostic gallium-67, it is known where the substance will go to in the body. This same PSMA linked to lutetium-177 then irradiates only those sites that are visible on the scan. The combination of therapy and diagnostics means that nuclear medicines will make an even greater contribution to personalised medicine.

4 De production chain of medical isotopes

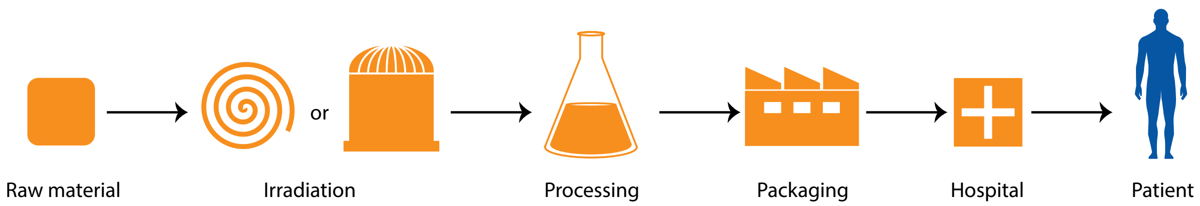
There are various ways in which medical isotopes can be produced. Isotopes can be produced in reactors and accelerators (such as cyclotrons). Both production methods are quite different. In brief: not every isotope can be produced by a reactor and not every isotope can be produced by an accelerator. So far, very few therapeutic isotopes have been produced by accelerators. The two production methods complement each other and clearly cannot replace each other.

In addition to the two aforementioned methods, there has also been an international search specifically for "new" technologies for the production of the widely used molybdenum-99 / technetium-99m. ASML's "Lighthouse" project is an example of this.
This chapter will discuss in more detail the current and new production methods.

The irradiation of the raw materials (either in a reactor, or in an accelerator) forms only a small part of the production process of medical isotopes. A series of purification and processing steps takes place in various laboratories after the irradiation. The extent to which reactors can play a role in the production of medical isotopes therefore depends strongly on the vicinity of parties who can quickly prepare the irradiated materials and transport them to the hospitals. Sophisticated logistics are vital due to the short life span of the isotopes (see the box on page 13 about half life and logistics).

The various steps in the chain are essential and must be performed with the greatest possible accuracy. For example, any trace of an undesirable isotope remaining in the final product after purification could result in an excessively high radiation dose for the patient or poor image quality, for example.

Isotopes production chain

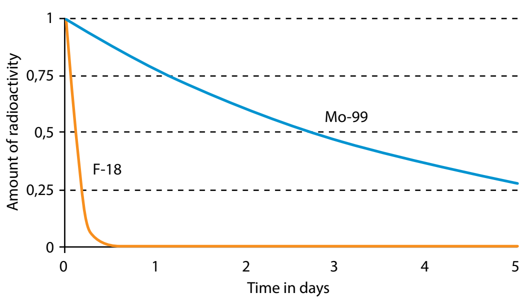


Half life and logistics

Medical isotopes are radioactive. The amount of radioactivity reduces over time as a result of the so-called radioactive decay. This means that the product loses "strength" (= radioactivity) over time. The term "half life" is used to describe this process.

The half life is the time it takes for the amount of radioactivity to halve. For many medical isotopes, this half life is in the range of several hours to several days. As the amount of product decreases rapidly over time, it is vitally important to ensure that the supply is carefully planned. This means that the time at which the medical isotopes are required in the hospital are calculated back to the production time down to the hour. This also means that as little time as possible should be lost in the chain.

Compare it to selling fresh fruit: the figure displays the decay of radioactivity for the isotopes molybdenum-99 and fluorine-18. Molybdenum-99 has a half life of 66 hours, approximately 2.5 days, whilst fluorine-18 has a half life of 109 minutes, just over 2 hours. For this reason, the production facilities (= cyclotrons) for isotopes with a shorter life span such as fluroine-18 are generally located closer to the patient than the production facilities (= reactors) for isotopes with a longer life span such as molybdenum-99.



4.1 Reactors as producer of isotopes

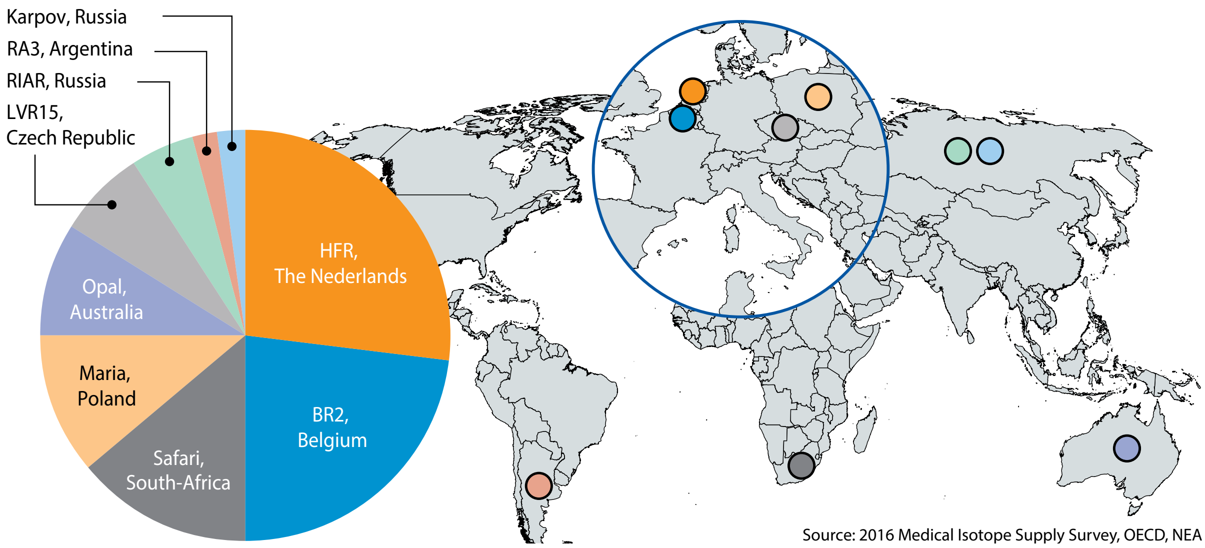
The core of a nuclear reactor constantly produces neutrons. Neutrons are atomic particles that carry no charge and they can be used to produce radioactive substances. By temporarily placing raw materials in the reactor, they are exposed to these neutrons and isotopes are subsequently formed. A large variety of medical isotopes can be produced using this method. The best known isotope currently produced by reactors is molybdenum-99 / technetium-99m.

Molybdenum-99/technetium-99m

The widely used technetium-99m is a metastable radio-isotope with a half life of 6 hours. It is a decay product of molybdenum-99, which has a half life of 66 hours. This is the time it takes for half of the molybdenum-99 to decay to form technetium-99m. Molybdenum-99 is therefore called the mother isotope. The long half life of molybdenum-99 means that it can be transported over a large distance. In practice, a delivery to the hospital only needs to take place about once a week. Doctors can have access to technetium-99m at any time of the day, seven days a week.

The technetium-99m is "tapped" in the hospital from a generator that the manufacturer has loaded with the mother isotope. The generator is a heavy cylinder that contains a vial of liquid. During the tapping process – also called elution – a chemical separation takes place. The main benefit of generators is that – due to the longer half life of the mother isotope – the generator can be used for a longer period to produce an isotope with a shorter life span. This means that a hospital does not have to place a new order every day for isotopes with a short life span, but instead has a source of isotopes that can be used for a longer period. Examples of radionuclide generators are Mo-99/Tc-99m, Ge-68/Ga-68, Rb-81/Kr-81m or Rb-82/Sr-82. The generators are used for both SPECT and PET applications.

Global reactor capacity for molybdenum-99



Currently available global reactor capacity for medical isotopes (OECD NEA).
N.B.: The Russian and Argentine reactors only produce isotopes for local use.

Over 80% of the procedures performed in the hospital use technetium-99m. In addition, nuclear reactors produce a wide range of other medical isotopes that are of importance to nuclear medicine. The most important are lutetium-177, iodine-131 and iridium-192.

There are only a few (old) reactors worldwide that account for the lion's share of medical isotope production. The most important reactor is the HFR in Petten (the Netherlands), closely followed by the BR2 reactor in Belgium. The Safari reactor in South Africa and the OPAL reactor in Australia account for a smaller share of the global production. The Maria reactor in Poland and the LVR15 reactor in the Czech Republic are mainly important as so-called spare capacity and also serve a specific local market.

4.2 Accelerators as producer of isotopes

In accelerators, charged particles (protons) are accelerated in combination with a magnetic field and an electric field, after which they collide with a target containing the raw material. This activates the raw material, thereby converting it to an isotope. Most products created in an accelerator have a very short half life.

Due to the fundamentally different process in an accelerator, this device produces isotopes that are not produced in a reactor. Known isotopes that can be produced using an accelerator are fluorine-18, oxygen-15, iodine-123 and iodine-124, carbon-11, nitrogen-13, zirconium-89, gallium-68 and rubidium-82.

Europe is closely monitoring the developments in Canada. It appears that the United Kingdom in particular will want to follow the Canadians, if they see a technical and commercial success in Canada. In other countries, the developments are being monitored primarily by the owners of existing accelerators (large enough to be able to produce technetium-99m).

In the Netherlands, accelerators for the production of medical isotopes are located in Amsterdam, Eindhoven, Petten, Alkmaar, Groningen and Rotterdam. It is not yet known whether these can be made suitable for the local production of technetium-99m.

Canada

As an alternative to building a new multi-purpose research reactor, the Canadian government opted in 2009 to release CAD 35 million for the "Non-reactor-based Isotope Supply Contribution Program" (NISP), followed in 2011 by CAD 25 million for research within the so-called "Isotope Technology Acceleration Program" (ITAP). The developments within these programmes in Canada focus mainly on the production of technetium-99m by cyclotrons. Recent scientific publications and public reporting about the progress reveals that they are still working on this solution for Canada[5]*. Despite the many investments, there is still no approved and certified producer using cyclotrons for the production of technetium-99m*[6]*. As the new production method results in a new pharmaceutical product, the entire process for the registration of new pharmaceutical products has to be completed. It has since been reported that the authorities are now working on these admission requirements.*

[5] See among others - the TRIUMF presentation during the 2016 Mo99 Topical Meeting in St Louis, http://mo99.ne.anl.gov/2016/pdfs/presentations/S7P3_Presentation_Buckley.pdf

[6] This is in contrast to what LAKA claims in http://www.laka.org/nieuws/2017/pallas-tussen-krimpende-vraag-en-groeiende-capaciteit-6336

Trends and developments in the production chain

Medical isotopes can be produced using reactors and accelerators. This chapter will discuss why these production routes complement each other and which developments are taking place in both "routes".

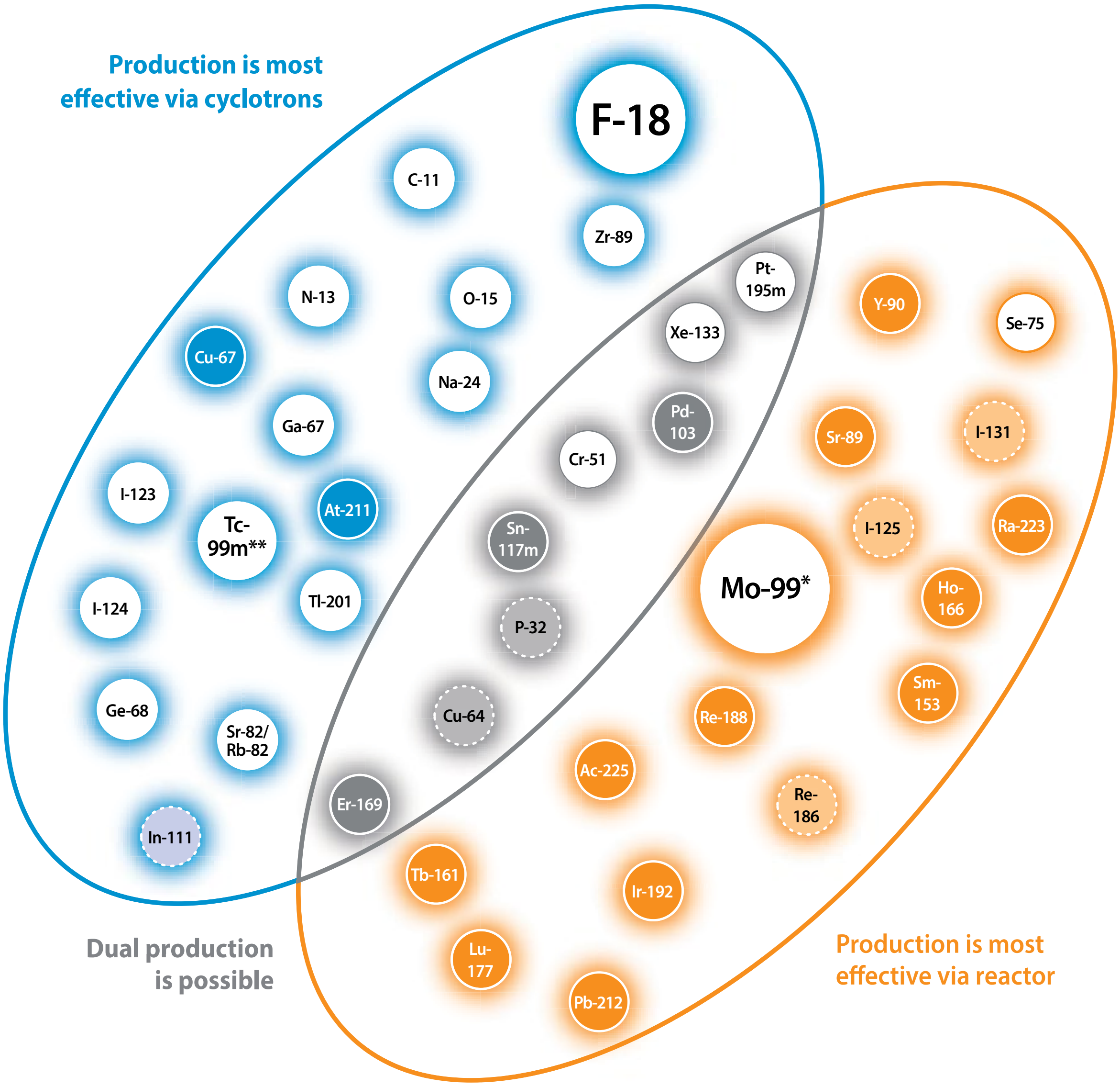
Can every medical isotope that is currently produced in a reactor also be produced in an accelerator? The answer is: No, that is not possible. The reverse is also true: not every medical isotope that is produced in an accelerator can also be produced in a reactor. This is due to the properties of the raw materials in relation to the radiation generated by an accelerator or reactor. These are physical properties that determine how much radioactivity can be generated using a reactor or an accelerator. In addition, it is also important to consider whether the medical isotope can be generated with the correct quality (purity, specific activity) and in the correct quantity (radioactivity).

Reactors and accelerators

Substances can become radioactive when they are exposed to high-energy particles. This can be achieved in many different ways, but the most relevant routes are those using neutrons or charged particles. The fission process in the reactor produces neutrons that can activate these substances. For example, non-radioactive lutetium (Lu-176) can be converted to radioactive Lu-177 when exposed to neutrons.

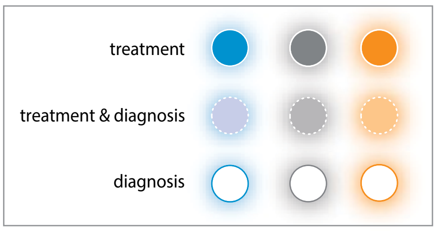
Charged particles, such as positively charged hydrogen particles (protons), can be accelerated to high speeds (= high energy) in an accelerator. This energy can be selected in such a way that these particles make other substances radioactive. There are both round accelerators (cyclotrons) and straight accelerators (LINAC, "linear accelerator"), but their function is always to accelerate charged particles. Through exposure to protons, non-radioactive oxygen-18 can be converted to radioactive fluorine-18, a widely used accelerator isotope. This fluorine-18 is used for diagnostic purposes using PET cameras.

It is and-and



* Various production routes for Mo-99 are being examined.

** The direct production of Tc-99m via accelerators is being examined.



The "and-and" figure provides an overview of the most important reactor isotopes and accelerator isotopes. The overlapping space indicates which isotopes can be produced both in a reactor and in an accelerator. This overview clearly emphasises the important of the use of reactors in the production of therapeutic isotopes.

5.1 (New) production routes for molybdenum-99

There are various ways in which molybdenum-99 can be produced. In the figure, these production methods are presented with the irradiation facility (reactor or accelerator) and the raw material (uranium or molybdenum). At the moment, the global demands for molybdenum-99 are met almost exclusively via the reactor route. In this process, uranium is irradiated in a nuclear reactor and the molybdenum-99 is then harvested from the fission products. This is the process that is performed on a large scale in Petten.

Another method that is being examined is the use of molybdenum-98 as a raw material in a nuclear reactor. This results in molybdenum-99 of a different quality, for which a special new generator has to be used. Other options that were examined were the fission of uranium (into a form of a salt) by neutrons from an accelerator and the conversion of molybdenum by photon bombardment. Again, a new generator is required due to the quality of the resulting molybdenum-99. An accelerator can produce technetium-99m directly by targeting molybdenum with protons.

Various projects have been started over the last few years, particularly in the United States, with the aim of producing molybdenum-99 via a different technique. Some projects have already stopped, such as the project by Babcock&Wilcox with the former Covidien (now Mallinckrodt/IBA-M) to create a new type of reactor and an initiative by GE Hitachi Nuclear Energy to produce molybdenum-99 in nuclear power plants.

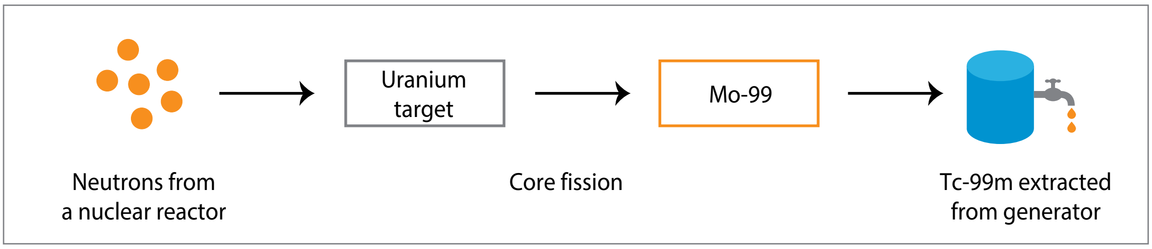
At the moment, the initiatives by Shine Medical, Northstar and Northwest Medical Isotopes are attracting the most international attention. The American government is supporting both Shine Medical and Northstar with subsidies up to $25 million per project. The (old) MURR also plays a role in some projects, as this reactor's licence was recently renewed for twenty years.

ASML Lighthouse

A special application of an accelerator is the so-called Lighthouse initiative by ASML. In this initiative, a special, intense electron accelerator is used to create very high-energy light (photons) via a converter. This light is targeted at enriched molybdenum (Mo-100) and this is used to form molybdenum-99. This production technology does not use Uranium, but does use enriched molybdenum. Urenco Netherlands has developed the technology to product this enriched molybdenum. The Lighthouse initiative, which was proclaimed a National Icon in 2016, is still in the early phase of development.

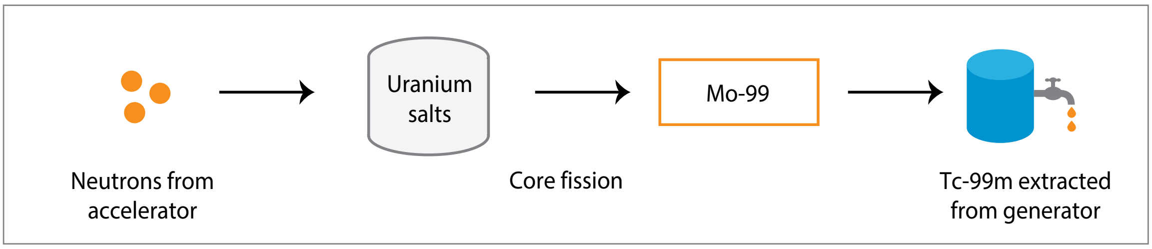
Process

Nuclear reactor

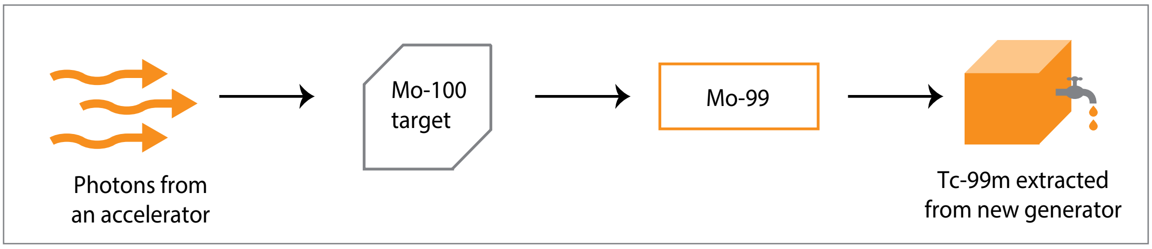


Reactor with new target (Northstar)

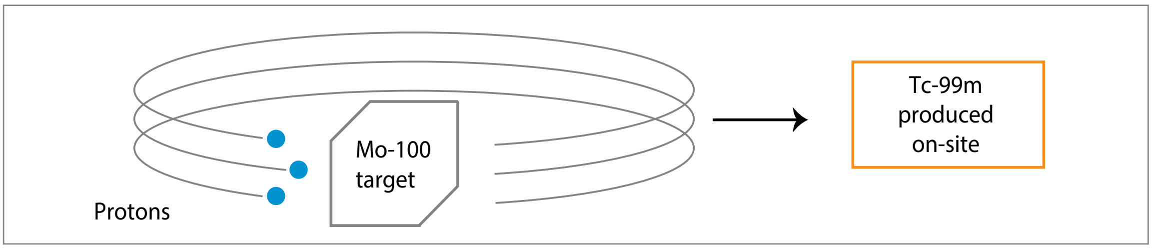
Accelerator (Shine medical technologies)



Accelerator (Northstar/Prairie Isotopes production enterprises)



Cyclotron (Triumf/Advanced Cyclotron Systems)



6 The Dutch situation

Since the closure of the Canadian NRU reactor, the Netherlands has become the largest manufacturer of medical isotopes in the world. As technetium-99m dominates by market share, the expectations for this market are crucial. A slight growth is expected over the next twenty years. This growth can be attributed mainly to countries where nuclear medicine is currently still in its infancy. In Western countries, there is mainly an increase in demand for therapeutic isotopes. For example, there are high expectations for lutetium-177 and holmium-166.

In the slightly longer term, the focus is primarily on alpha emitters, which are now showing very promising results in research projects.

The number of nuclear medicine procedures in the Netherlands has doubled over the past twenty years. The total number of procedures involving medical isotopes in the Netherlands is approximately 418,000 per year. This number includes both diagnostics and treatment. This figure includes both reactor isotopes and accelerator isotopes.

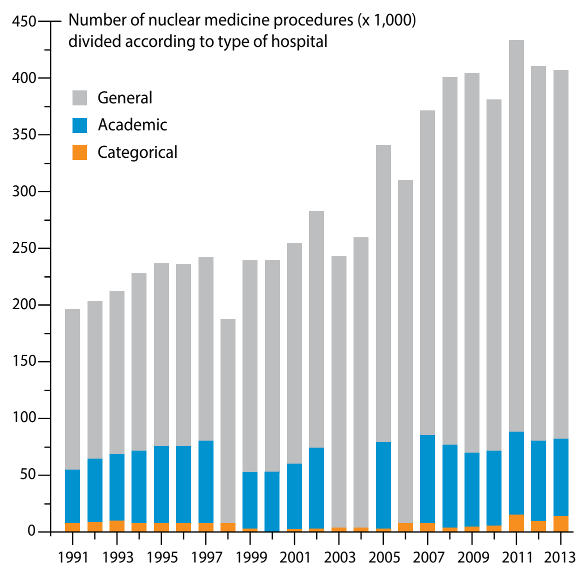
The number of therapeutic treatments (both curative and palliative) in the Netherlands is relatively low. Based on figures from the RIVM and an inventory by reactor operator NRG (Petten), it is estimated that the current figure is over 4,600 treatments per year. It is hard to measure a total, as many treatments take place on an experimental basis and are not always included in the figures issued by insurance companies or the RIVM.

Global use of reactor isotopes in nuclear medicine and expected trend over the next 20 years

Isotope	Number of procedures using medical isotopes worldwide in 2017	Expected trend in the next 10 years
Tc-99m	40 million	+
I-131	1 million	=
Ra-223	10,000	++
Xe-133	100,000	- -
Y-90	20,000	+
Ho-166	400	++
Lu-177	15,000	+++
Ir-192	120,000	-
Alpha emitters	2,000	+++
Sr/Re/Sm	10,000-20,000	- - -
I-125	27,000	+
Pt-195m	3	+++

Drafted based on data from OECD, IAEA and NRG

Medical nuclear procedures in the Netherlands



Source: RIVM

The importance of PET scans is also expected to rise in the Netherlands compared to SPECT scans. As SPECT is cheaper, simpler and faster, the ratio between these imaging modalities is expected to stabilise at 60:40 or 50:50.

Use of medical isotopes for nuclear medicine procedures in the Netherlands

Isotope	Production	Objective	Indication	Numbers
Tc-99m	Reactor	Diagnostic		284,000
F-18, FDG, In-111, I-123, Ga-67	Cyclotron	Diagnostic		129,000
I-131	Reactor	Treatment	Hyperthyroidism	2,000
Ir-192	Reactor	Treatment	Breast/prostate cancer	1,500
Ra-223	Reactor	Treatment	Metastasised prostate cancer	500
Y-90	Reactor	Treatment	Liver cancer, Non-Hodgkin's Lymphoma	100
Lu-177	Reactor	Treatment	NE tumours, PSMA	400
Re-186	Reactor	Pain management	Bone metastases	100
Sm-153	Reactor	Pain management	Bone metastases	30
Sr-89	Reactor	Pain management	Bone metastases	10

Source: Composed based on DDM2 reports, OpenDis database, own information NRG.

The RIVM performs a yearly inventory of the number of medical nuclear procedures that take place. This has revealed a growth in the number of diagnostic procedures.

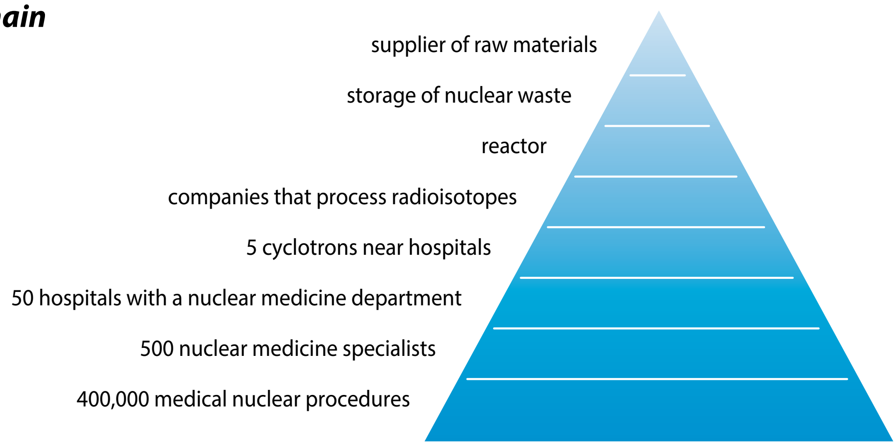
6.1 The nuclear medicine infrastructure

The Dutch nuclear knowledge infrastructure[7] includes strong expertise and extensive applications in the field of medical, materials science, energy and dealing with nuclear facilities and materials. As a result of this excellent knowledge and infrastructure, the Netherlands is in a very good international starting position in the field of medical isotopes, both in production and in use. The complete supply chain for the production, processing and delivery of medical isotopes is represented in the Netherlands. In addition, the Netherlands has a very well equipped nuclear medicine infrastructure.

A survey amongst participants in the previously mentioned Technopolis study (2016) revealed that safeguarding the Dutch nuclear knowledge infrastructure is deemed important for healthcare and safety in the Netherlands. The participants in the survey state that the Netherlands occupies a leading position in the field of medical isotopes. The nuclear and medical infrastructure is ideal for performing fundamental and applied scientific research in the field of medical isotopes. All steps in the chain are present in order to perform own research, but also to contribute to international developments and "clinical trials".

[7] Nuclear knowledge infrastructure in the Netherlands, Inventory and relation to public interests, Technopolis (2016), and position paper Nuclear knowledge infrastructure in the Netherlands, published by Nucleair Nederland (2016)

Dutch production chain

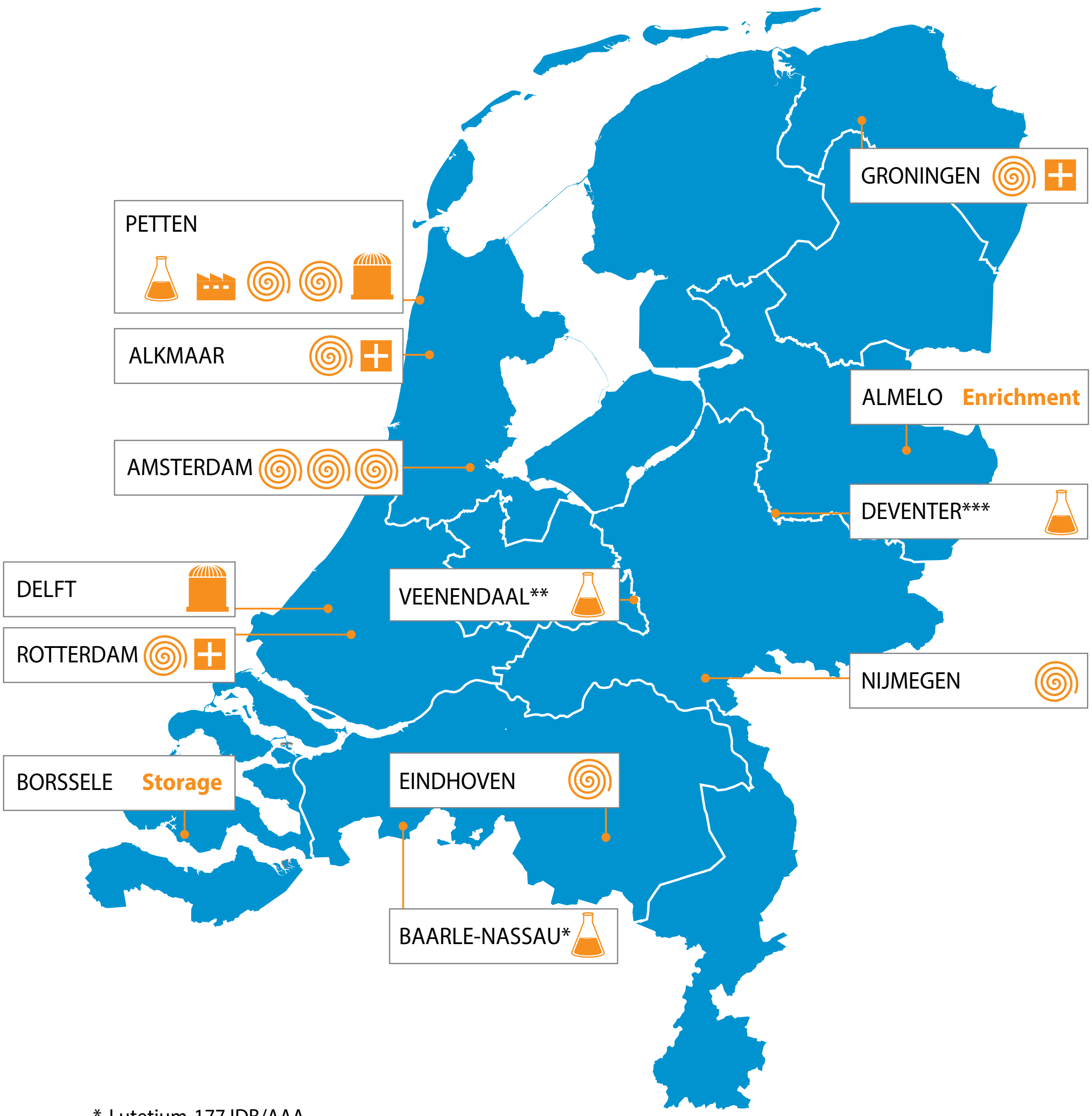


The Dutch nuclear and medical infrastructure provides a production chain in which medical isotopes can be supplied to patients worldwide. In addition, the Netherlands has an extensive nuclear medicine service, resulting in more than 400,000 procedures being performed in the Netherlands annually.

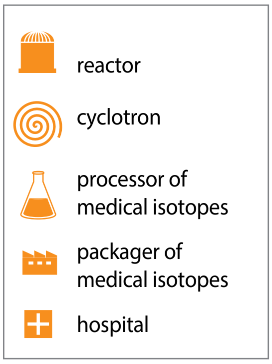
- Together with its radio-pharmaceutical partners, reactor operator NRG is the largest producer of molybdenum-99 in the world. The Petten-based company develops and optimises the production of molybdenum-99, supplies various therapeutic isotopes and conducts research into the production of isotopes for new radio-pharmaceuticals, particularly for therapeutic applications.
- TU Delft (Reactor Institute Delft) conducts research into alternative techniques for the production of molybdenum-99, examines generator chemistry and studies the radio-chemistry of other production processes.
- The Stichting Voorbereiding PALLAS-reactor (Foundation for preparation of the PALLAS reactor) is working on the successor to the High Flux Reactor in Petten. The PALLAS reactor will focus strongly on the production and development of (new) medical isotopes. In addition, the PALLAS reactor offers a flexible infrastructure to perform energy research.
- Processor Mallinckrodt/IBA-M supplies and distributes a wide range of medical isotopes to hospitals all over the world.
- IBD Holland/AAA processes and distributes lutetium-177
- With its stable isotope department, Urenco has developed production routes for enrichment of raw materials for the production of medical isotopes. Examples of this include the enrichment of iridium and xenon for the production of iridium-192 and iodine-125. Urenco is also working on a production route for the enrichment of molybdenum.
- Various academic centres are working on their own research and are participating in international studies. Some examples:
  - holmium-166 was developed in the UMC, in collaboration with TU Delft and NRG, among others.
  - the Erasmus Medical Centre is internationally renowned as an expert in the field of lutetium-177. The development of lutetium-177 (production process) was initiated by Erasmus MC and NRG.
  - The NKI and Radboud University Medical Centre are working together with NRG to develop the clinical application of Pt-195m for the treatment of head & neck cancer and lung cancer.
  - Through its cyclotrons and a radio-therapeutic centre, the VU Medical Centre has specialised in the development of medical isotopes.
  - The AZL performs fundamental research into carriers/tracers with fluorescent techniques.

International institutes, companies and medical centres know how to seek out Dutch companies and medical centres, to gain access to their expertise, products and input for clinical research.

Dutch nuclear value chain for medical isotopes



* Lutetium-177 IDB/AAA
** Brachytherapy Elekta
*** Holmium-166 Quirem



7 Recommendations

This publication has described how important it is that patients in the Netherlands, Europe and worldwide can rely on a continuous availability of medical isotopes. This publication also makes clear that the entire chain is working hard on innovations that should ensure that patients receive even better care in the future. The development of new therapeutic isotopes is a good example of this. The Netherlands occupies a unique position in this situation: it is the largest international producer of technetium-99m, it accommodates all chain partners within its own borders, it has a long-standing tradition of collaborations in the chain, internationally groundbreaking new treatments and examinations are being developed and work is being put into achieving a new multi-functional facility for medical isotopes, the PALLAS reactor.

In recent years, the Dutch government has played an important active and stimulating role in the nuclear medical field. There is support for example for the PALLAS reactor, both financially and at a policy level, the financial problems at ECN/NRG are being examined and tackled and the Reactor Institute Delft has received funding for its OYSTER project. Furthermore, active contributions are being made to a new international policy for a healthy price for medical isotopes (under the name "full cost recovery"). The Netherlands has an important voice in forums such as the OECD-NEA and the European Commission.

However, the preservation and expansion of the Dutch position is not a given. Therefore, this publication will conclude with a number of recommendations to everyone who is active in this field. This includes the medical sector, the pharmaceutical sector, the industry, governments and stakeholder groups.

- **Always act in the interests of the patient**
  It is essential and directly in the patients' interests to offer long-term supply security for medical isotopes. The supply chain for medical isotopes is fragile and currently cannot function without active government involvement. Neither is it in patients' interests to think in terms of contradictions. For example, alternative production routes (accelerators) do not make the current reactor routes redundant. As has been clearly stated in this publication, the routes are clearly complementary. The realisation of the PALLAS reactor in Petten is useful and necessary and should be actively encouraged through government policy and international cooperation.

- **Stimulate European cooperation and profiling**
  Large research and production facilities for medical isotopes should be created per continent (and not per country). European harmonisation and the coordinated use of available public funding is therefore urgently required. It is important to profile "Petten" as the leading European centre of expertise in the field of medical isotopes (production and research). Placing the PALLAS reactor on the long-term agenda of the "European Strategy Forum on Research Infrastructures" (2018) offers the opportunity to gain access to European infrastructure and research resources.

- **Set up a national research agenda**
  A national agenda for research needs to be developed in order to remain a leading player in the development of customised therapeutic applications. This can be incorporated in the European research agendas. The involvement of university hospitals (UMCs) and patient organisations is vital. The agenda

should also be aligned with the Top Sectors policy. On a European scale, the Netherlands can form a leading group with other European countries that have production facilities (particularly Belgium, followed by Poland, Czech Republic, France and Germany). The research programme of the European Joint Research Centre in Petten can also be developed further towards research in the field of medical isotopes. This will form a stronger connection with the agenda of the European Commission.

- **Claim the Dutch leader's position**
  The Netherlands could do more to profile itself internationally as one of the few countries in the world that has fully implemented a non-proliferation policy for research reactors and the production of medical isotopes. The purchasing policy for medical isotopes in an increasing number of countries should take this into consideration.

- **Remain committed to the efforts of achieving a healthy market**
  An internationally recognised problem is the role that subsidies play in (a part of) the market for medical isotopes. These subsidies impede the process of attracting private funding for both facilities and for product development and block the growth towards a "mature" market. The "OECD NEA High Level Group on Medical RadioIsotopes" has been working on international harmonisation of the policy regarding this matter for eight years. The Dutch government successfully placed this topic on the agenda of the European Commission during its EU Presidency in 2016. It is equally important to follow through on this. The playing field for private investors should be levelled, at least on a European scale. This also means that the care sector will gradually have to accept higher rates, in exchange for a sustainable market that is able to attract private investments. However, this does not automatically mean that prices will increase for the patient. The costs for using radioisotopes currently only account for 3% of the costs for the total "end product". Instead, a shift in the cost-benefit ratio within the chain itself will have to take place.

- **Stimulate cooperation in the Dutch nuclear sector**
  The most important players in the nuclear field in the Netherlands (NRG, PALLAS, TU Delft, Urenco, various UMCs, NWO, TI Pharma and the other parties) should increase their efforts to develop a joint research and innovation agenda for improved nuclear medicine applications. The government can contribute by stimulating this cooperation.

- **Invest in university curricula**
  In order to boost the knowledge and skills in the Netherlands on an ongoing basis, university curricula can be developed in the field of the application of nuclear medicine, specifically focusing on the nuclear technology for the production of medical isotopes.

- **Strengthen the international profile of the nuclear sector**
  The Dutch nuclear industry can further strengthen the international profile of the Netherlands in the field of medical isotopes by working together on research, development and production of (new) medical isotopes and their applications. Also focus on the knowledge and skills required to optimise the process and reduce the waste flows. The further promotion of Petten as a leading "Centre of Excellence" in the field of nuclear medicine can also form part of this cooperation. Finally, there should be a greater focus on public information campaigns about medical isotopes.

Overview of international developments in the production chains

Canada, once the world's largest producer of medical isotopes with the NRU reactor, has decided to stop production medical isotopes permanently in 2018. In anticipation of this move, Canada terminated the production of isotopes in October 2016 and the NRU reactor is only available until 2018 for the production of medical isotopes in situations of a global shortage. The company Nordion's adjacent chemical factory (the "molybdenum processing facility") has also been decommissioned and is on "stand-by" until 2018. Canada has decided to focus completely on research into alternative production methods and will limit itself in future to the home market. There are political reasons underlying this decision. In the past, Canada has built two isotope reactors (the MAPLE reactors). However, these reactors could not be commissioned due to design errors. There is no support, either political or social, for the repair of these errors.

The ***United States*** does not have a large-scale production capacity for molybdenum produced in reactors. They have always relied on deliveries, primarily from Canada and the Netherlands. The American "Medical Isotopes Production Act" was passed in 2012, a so-called technology neutral law that aims to reduce dependence on foreign suppliers. This Act released $163 million for research. This budget will be used to ensure that producers of medical isotopes worldwide will switch from using Highly Enriched Uranium ("HEU") to Low-Enriched Uranium ("LEU"), both as a fuel for research reactors and for the uranium "targets" that are irradiated to produce molybdenum-99. In the Netherlands, the HFR reactor started using LEU fuel in 2006. A licence was requested in the Netherlands at the end of 2016 as part of the Nuclear Energy Act for the conversion to LEU targets.

A large-scale producer of medical isotopes is located near Sydney, ***Australia***: ANSTO. The OPAL reactor is relatively young (has now been operating for 10 years) and the government institute ANSTO is currently investing in replacing the old molybdenum processing facility. As a result, Australia will soon have the most modern infrastructure in the world.

Europe traditionally plays an important role in the production of medical isotopes by reactors. Not only are there various reactors contributing (mainly in the Netherlands, Belgium, Poland and Czech Republic in 2017), but there are also two molybdenum processing facilities in Europe (in the Netherlands and Belgium). In the future, the FRM2 reactor in Germany and the JHR reactor in France that is currently under construction should be able to contribute.

The Netherlands occupies a special position in Europe: not only is the Netherlands currently the largest producer of medical isotopes in the world, along with Australia it is also the only country that has the reactor and the molybdenum-processing facility in the same location. This offers many advantages, not least the fact that radioactive materials do not need to be transported by road. As transportation times are non-existent, the yield of the entire production process is also higher (less decay of molybdenum during the process) and this results in less waste.

In ***Africa***, only the SAFARI reactor in South Africa – in combination with NTP Radioisotopes, both in government hands – is globally active in the production of medical isotopes.

In ***Russia, China, Korea*** and ***Argentina***, the production of medical isotopes takes place on a small scale using reactors. These countries usually produce only for the local market, which is still small in each of these countries.

NuclearNetherlands

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