BGE TECHNOLOGY GmbH

Cost Estimation

Update Cost Estimation for a Repository in Rock Salt in the Netherlands

BGE TEC 2025-04

Final Report

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Author(s)	Philipp Herold Juliane Leonhard Bernt Haverkamp

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„Update Cost Estimation for a Repository in Rock Salt in the Netherlands"

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1 Introduction

The study in hand summarises the updated cost assessment for the planning, operation, and closure of a potential Dutch Geological Disposal Facility (GDF) in a rock salt formation. Since the last cost estimation of Herold et al. (2024), the assumptions related to the waste inventory and some design choices about the layout of the geological disposal facility have changed. The costing covers the exploration of the site, the planning, the construction of surface facilities needed for the operation, the connection to the surface, and construction of the underground facilities, as well as an observation period, and the dismantling and closure of the facility.

Regarding deep geological disposal, there are potentially two different host rocks, clay formations and rock salt, available in the Netherlands. The latest cost estimate for a GDF in rock salt goes back to 1999 (Grupa & Jansma 1999) and has to be updated not only because of the time that has passed since then, but also because in contrast to the 1999 costing, the disposal of other waste streams in addition to high-level waste shall now be taken into account. BGE TECHNOLOGY GmbH (BGE TEC) has been commissioned to perform the cost estimation for such a GDF in a domal salt formation based on the boundary conditions given by the Dutch radioactive waste management strategy.

BGE TECHNOLOGY GmbH divided the project into three phases. The main objective of Phase I of the project is a review of the current Dutch disposal concept inside a domal rock salt formation to assess the technical feasibility of this concept, focusing on:

- Assessment of the feasibility of construction and mechanical stability, including dimensions and pillar sizes of the layout
- Assessment of the operational period and planned work loads
- Assessment of the period of closure
- Identification of potential improvements that would reduce the costs or increase the operational and/or long-term safety

The results of Phase I are documented in Herold & Leonhard (2023) as a separate technical report.

The objectives in Phase II of the project are:

- Preparation of a list of cost items that need to be included in the cost calculation
- Preparation of a schedule for construction, operation, and closure of the GDF
- Preparation of a base cost list for the identified cost items

The objectives in Phase III of the project are:

- Calculation of the costs based on schedule and base costs prepared in Phase II

The report in hand summarises the work and outcomes of Phase II and Phase III.

2 Methodology

2.1 General methodology and SSK method

COVRA requires that the cost estimation in Phase III has to follow the SSK method (Standaard Systematiek Kostenramingen) (SSK 2023) and must be based on (EURAD 2021). (EURAD 2021) gives a guideline for preparing consistent and reliable cost estimations as a basis for providing sufficient funding for radioactive waste disposal programmes. The recommendations of this guideline serve as a basis for the cost estimate. Eight main steps of a cost estimation are defined:

1. Define the purpose of the cost estimate
2. Develop the baseline document
3. Select the method for cost estimation
4. Prepare the work breakdown structure of the disposal programme
5. Perform the cost estimate
6. Conduct uncertainty and risk analysis and make provisions for them
7. Document the estimate
8. Perform an independent review of the estimate

Within the needs and the given boundary conditions, all of these main steps are considered in the work programme. For example: with the SSK, a bottom-up-like cost estimation method was selected. The SSK method is a system for drawing up, recording, and sharing estimates, particularly in civil engineering and residential and commercial construction in the Netherlands. The system offers a uniform method and structure and unambiguous conceptual framework. This makes estimates transparent and directly comparable. This is of special importance for comparing the estimated costs for a repository in rock salt with the cost estimation for poorly indurated clay. COVRA has provided BGE TECHNOLOGY GmbH with the current guidelines for the SSK method to be applied for the project at hand. According to the recommendations by COVRA, the following assumptions and preferences have been used:

- The waste will be disposed in an area of a (Zechstein) salt dome that will consist primarily of pure rock salt (halite), although there may be traces of other types of salt present (e.g. anhydrite).
- In a parallel project, BGE TECHNOLOGY GmbH has developed a shielded disposal waste package for COVRA, see (Wunderlich et al. 2023). The results of this project, including the cost estimate for waste package production, are implemented in this cost estimate.
- For the type and amount of waste, the most recent expected amount of waste according to COVRA is used for the planning.
- The lifecycle of the Dutch GDF follows the main stages: Siting, Site preparation, Repository construction, Disposal campaign of HLW (High Level Waste), Disposal campaign of LILW (Low and Intermediate Level Waste) and (TE)NORM (Technically Enhanced Naturally Occurring Radioactive Materials) waste, Underground observation phase, Repository closure, Post-closure phase

In addition, the following technical assumptions for the project were made by BGE TEC:

- The geological data for the generic salt dome were taken from the German RESUS project (Bertrams et al. 2020). This project considered a salt dome consisting primarily of pure rock salt (halite) of sufficient extension and thickness without excluding the presence of other salt types as typical for such domal formations (A summary of the proposed repository design in a domal rock salt formation in the Netherlands is currently in preparation and will be available as draft version (Bartol et al. 2025)).
- An underground observation phase of twenty years is included to facilitate retrieval of waste packages before closure.

For the SSK Method, a predefined excel sheet was provided by COVRA as template. The use of the SSK Method excel sheet is intended to ensure the comparability of the rock salt cost assessment with the clay cost assessment. To get the datasets for the SSK method sheet, the assumptions in Chapter 3 regarding the boundary conditions, the time schedule of Chapter 4 and the cost items calculations within Chapter 5 are fundamental. The basic assumptions and calculations for the conditioning facility (CF) for the HLW are made in Chapter 5 of this report. The resulting data set is then imported into the SSK Method excel sheet and presented in Chapter 6. Chapters 7 and 8 discuss the risk and opportunities as well as uncertainties related to the cost estimation and the current planning stage of the repository concept.

To determine the costs, a stepwise method was used. The method is reflected in the project phases. In a first step, the unit price costs of the different systems, structures, and components (SSC) were estimated. In a second step, the schedule was estimated. Finally, by multiplying the unit costs with the duration or needed amounts depending on the character of the unit costs, the base costs were calculated.

2.2 Cost breakdown structure

For a systematic structure of the SSC, a cost breakdown structure (CBS) with three levels was established. Level 1 represents the already mentioned phases of the GDF lifetime:

1. Site preparation
2. Repository construction
3. LILW and (TE)NORM waste disposal campaign
4. HLW disposal campaign
5. Underground observation
6. Repository closure
7. Post-operational phase

Practically, Phase 7 (post-operational phase) was not included in the costing. It was assumed that the project ends after closure, which ends the direct generation of costs as well. However, indirect costs will be incurred, e.g. for institutional control. Furthermore, a potential retrieval of the waste is not considered.

The second level is represented by so-called cost groups. These cost groups summarise typical cost items and in some cases, the same cost groups appear in different phases. (CBS level 1). Table 2-1 summarises the cost groups in each phase.

Table 2-1: Overview cost groups within the cost phases

Site preparation	Repository construction	LILW and (TE)NORM waste disposal	HLW disposal	Underground observation	Repository Closure
Land purchase	Construction and outfitting shafts	Disposal	Disposal	Maintenance surface	Backfilling and sealing tunnel and ramp
Site infrastructure works	Construction and outfitting upper level main area	Backfilling and sealing	Backfilling and sealing	Insurance	Backfilling and sealing shafts
Site facility construction	Construction and outfitting HLW main area and bunker	Utility consumption	Utility consumption	Utility consumption	D&D nuclear facilities
Security installation	Construction and outfitting HLW disposal area	Maintenance surface	Maintenance surface	Human resources	Site dismantling and clearance
Utility consumption	Construction and outfitting LILW and (TE)NORM disposal galleries	Insurance	Insurance		Utility consumption
Human resources	Surface facility construction	Human resources	Human resources		Human resources
	Maintenance surface				
	Insurance				
	Utility consumption				
	Human resources				

Within the cost groups, a further separation into different cost items is applied. Each cost group is connected to specific cost items. For example, each cost group "Maintenance surface" includes the cost items "Maintenance of the surface facilities" and "Maintenance of the surface areas". The cost items can give an actual unit price or can represent a summary value of different single unit prices and properties, as the following examples will illustrate.

The summary of unit prices within a cost item is useful to

a) reduce the number of items
b) connect strongly linked activities and costs
c) use comparative values from other applications where a further separation is not possible or where the individual subordinate cost positions differ.

The cost item "Maintenance of the surface facilities" gives the unit cost of 2%. 2% of the investment for buildings are annually needed for maintenance. The cost item "Outfitting" within the cost groups related to construction gives a fixed unit cost of 100 € per m. This includes costs for e.g. electrical installations and fire protection. The unit costs rely on comparative values from other underground repositories and represent an average value as a detailed design of the facility is not yet available.

In this regard, single cost items can include a further internal cost breakdown structure. In this case, the unit price of an SSC is multiplied with a property of the GDF, e.g. the length of a gallery or the volume of a chamber. Background information on each cost item is given in Chapter 5.

2.3 Frame schedule and assumed fix points

The detailed project schedule assumed for the cost estimation will be discussed in Chapter 4. The general radioactive waste management strategy of COVRA, respectively the Netherlands, gives a general frame for this schedule. For example, in (Verhoef et al. 2017), the implementation of a Dutch GDF will start after an interim storage period of at least 100 years. As a result, the operation of the GDF will start in 2130, which is assumed as fix point. Design and Construction can start before 2030. However, to be able to start in 2130, different activities will have to be performed before. Figure 2-1 illustrates the general schedule, including the fix point 2130 and a schematic categorisation of the phases considered in the cost estimation.

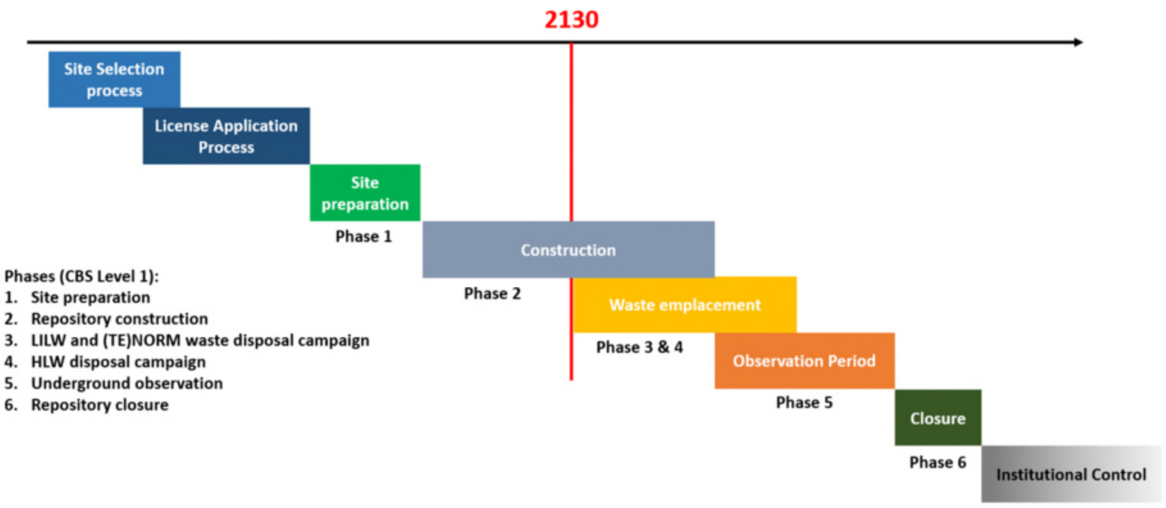

Figure 2-1: Illustration of the frame schedule including the phases

3 Technical boundary conditions for the cost estimation

3.1 Site characteristics

For the cost estimation, a generic domal salt formation in the Netherlands is assumed. A site selection has not yet been performed and no specific location has been taken into account so far. However, in the Netherlands, numerous salt formations, including domal formations, are known. These formations are the Permian aged Rotliegend group, the Permian aged Zechstein group, the Triassic Röt formation, the Triassic Muschelkalk formation, the Triassic Keuper formation and the Jurassic Weiteveen formation. For the cost study, disposal in a domal salt formation in Zechstein is assumed.

The evaporation residues of the Zechstein formation sedimented approximately 250 Ma ago (late Permian). They were formed in the Zechstein Basin, which stretches from the east coast of England through Germany to northern Poland. Lithological, the Zechstein succession contains clastic sediments, carbonate and anhydrite rocks, rock salt, and potash seams, representing evaporitic cycles. In total, the group can be divided into four, locally five, evaporitic cycles (e.g. (J.P.H. Kaasschieter 1992). In the further course of geologic history, the rock salt subsided to greater depths and was overlain by other rock types.

The mineralogical-geochemical conditions of the Zechstein salts in the Netherlands and in northern Germany are comparable. In both countries, the salts often occur in the form of salt domes or salt diapirs. They are a result of halokinesis, a process that describes the movement of salt under the influence of gravity. Halokinesis causes folding of the rock strata in a salt dome. Layers of carbonate and anhydrite rocks are fractured during folding of the rock salt and exist as discrete blocks within the salt dome.

Figure 3-1 shows a generic salt dome formation with an exemplary illustration of the disposal facility concept. The disposal galleries will be placed in central rock salt layers. It is assumed that this area covers no significant amounts of other minerals or evaporation residues. Only the shaft crosses the overburden, the cap rock, and the upper parts of the salt dome, where e.g. potash could be present.

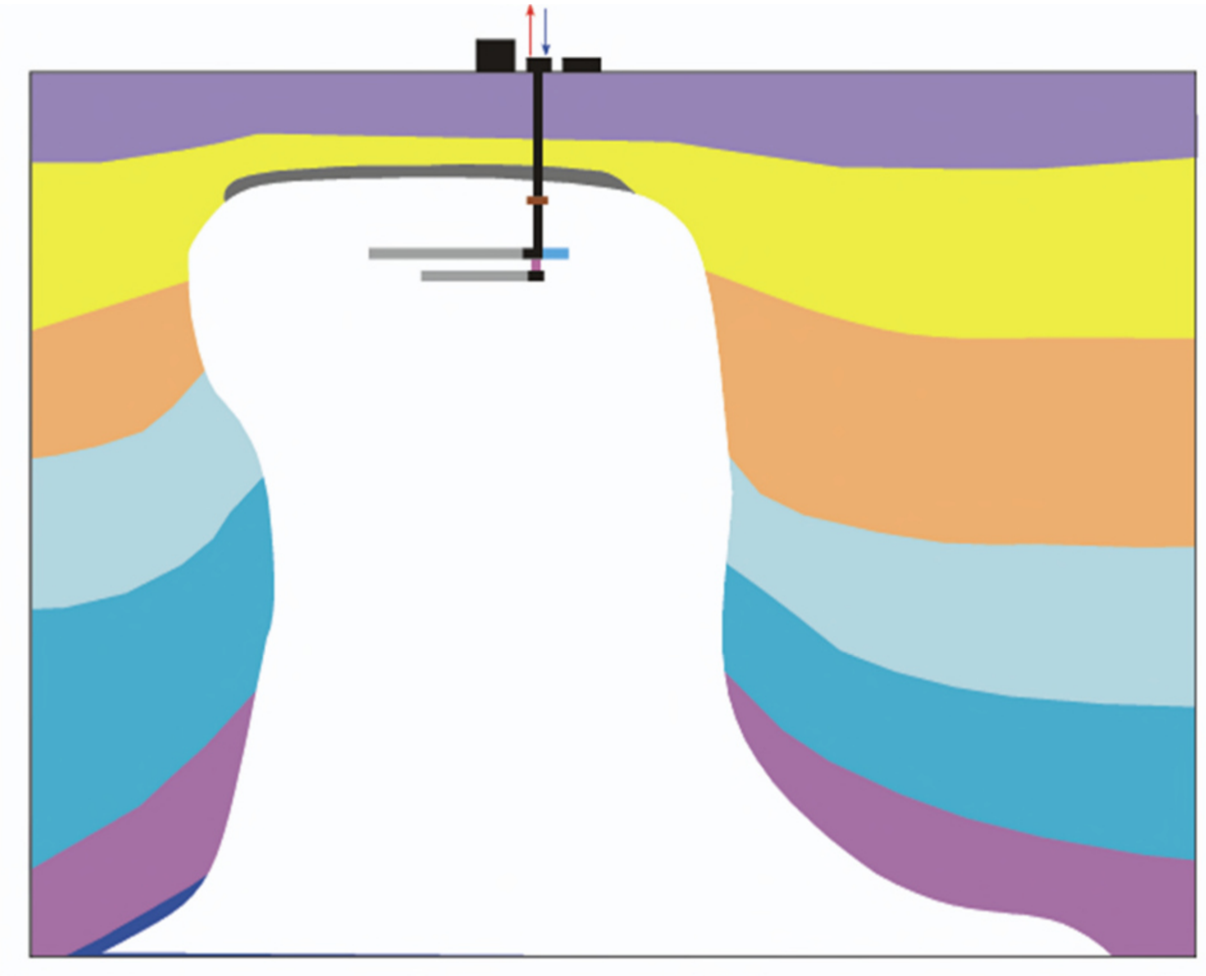

Figure 3-1: Disposal concept in a generic salt dome, based on (Bartol et al. 2025)

3.2 Design basis

The repository concept includes a two level design for the GDF. The upper level at a depth of approximately 750 m is planned for LILW and (TE)NORM Waste Packages (Appendix 1). The lower level at a depth of approximately 850 m is planned for HLW (Appendix 2). The connection to the surface is realised by shafts. The waste shaft with an inner diameter of 8 m will be constructed up to the upper level. The upper and the lower level will be connected by a ramp. The ventilation shaft and the personnel transport shaft (both with an inner diameter of 5 m) will be constructed up to the lower level, due to ventilation and safety reasons in case of emergency. Both shafts represent independent escape routes. The waste shaft will be used for the return of used air to ensure no spread of radionuclides trough the GDF in case of leakage. The personnel shaft as well as the ventilation shaft are used for the fresh air intake, to ensure a safe ventilation condition for the personnel transport. The ventilation shaft is used as personnel emergency exit.

3.2.1 Disposal concept

Regarding the COVRA concept, the emplacement of the HLW containers follows the scheme of Figure 3-2 and Figure 3-3. Emplacement and backfilling are carried out alternately until one gallery is completely filled. Afterwards the gallery sealing element is installed immediately before the emplacement in another gallery begins.

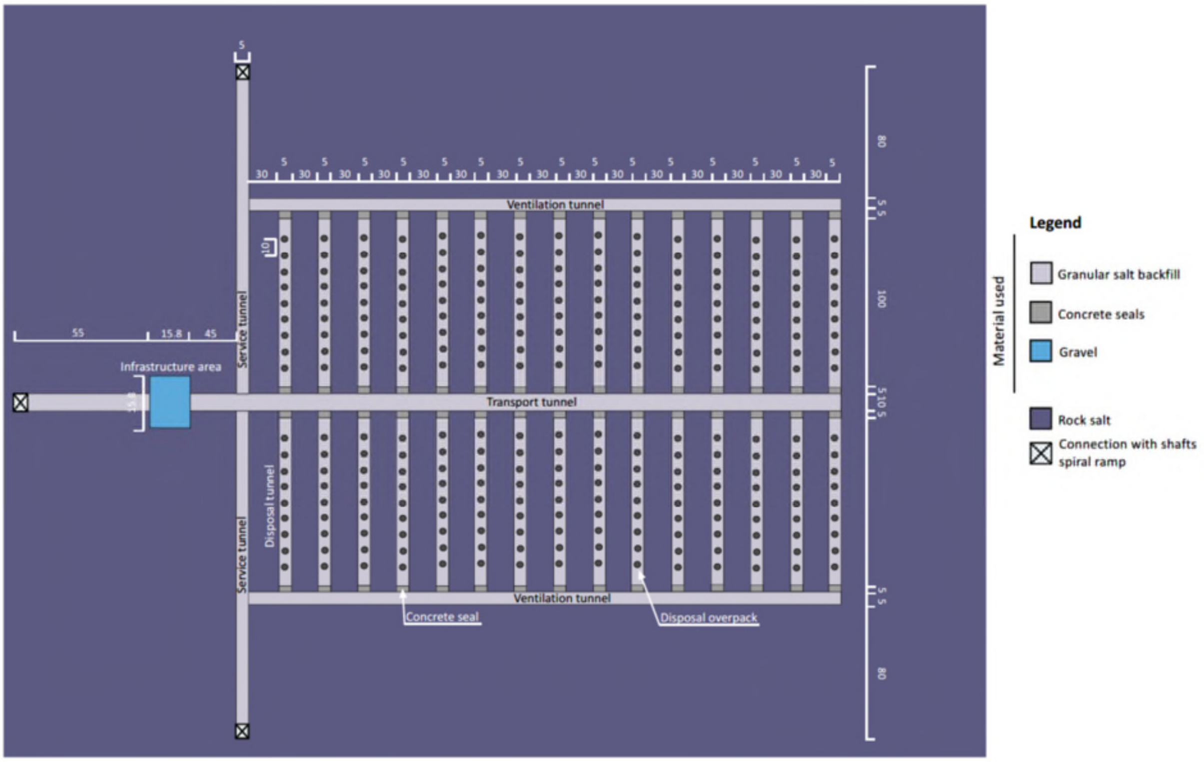

Figure 3-2: **Disposal concept lower level according to COVRA (Bartol et al. 2025)**

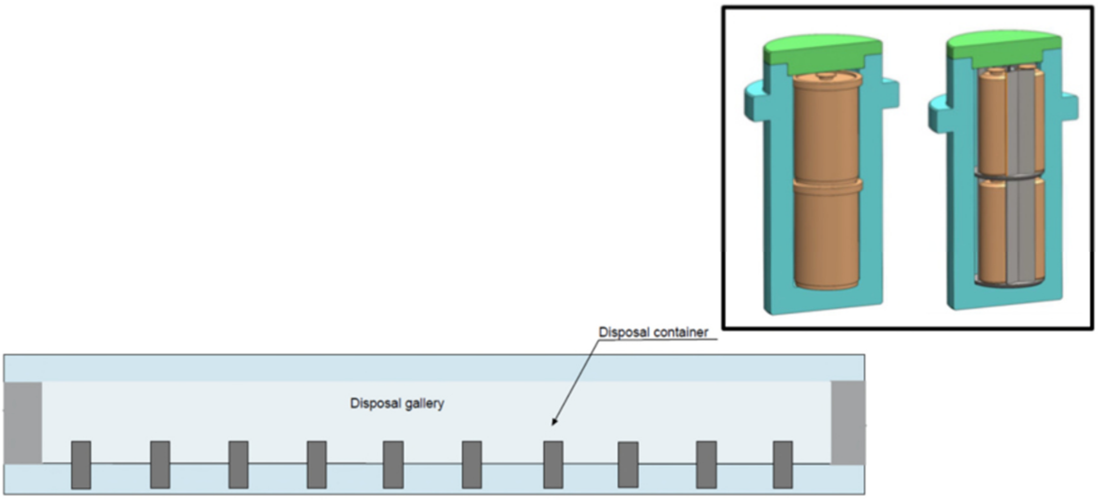

Figure 3-3: **Disposal concept lower level according to (Bartol et al. 2025), DWP design based on (Wunderlich et al. 2023)**

The emplacement of the LILW and TE(NORM) waste container at the upper level follows the scheme of Figure 3-4. The waste containers are sorted by type and placed in the disposal tunnels. As soon as the emplacement in one disposal gallery is completed, the backfilling is done and a sealing element is installed at the end of the gallery.

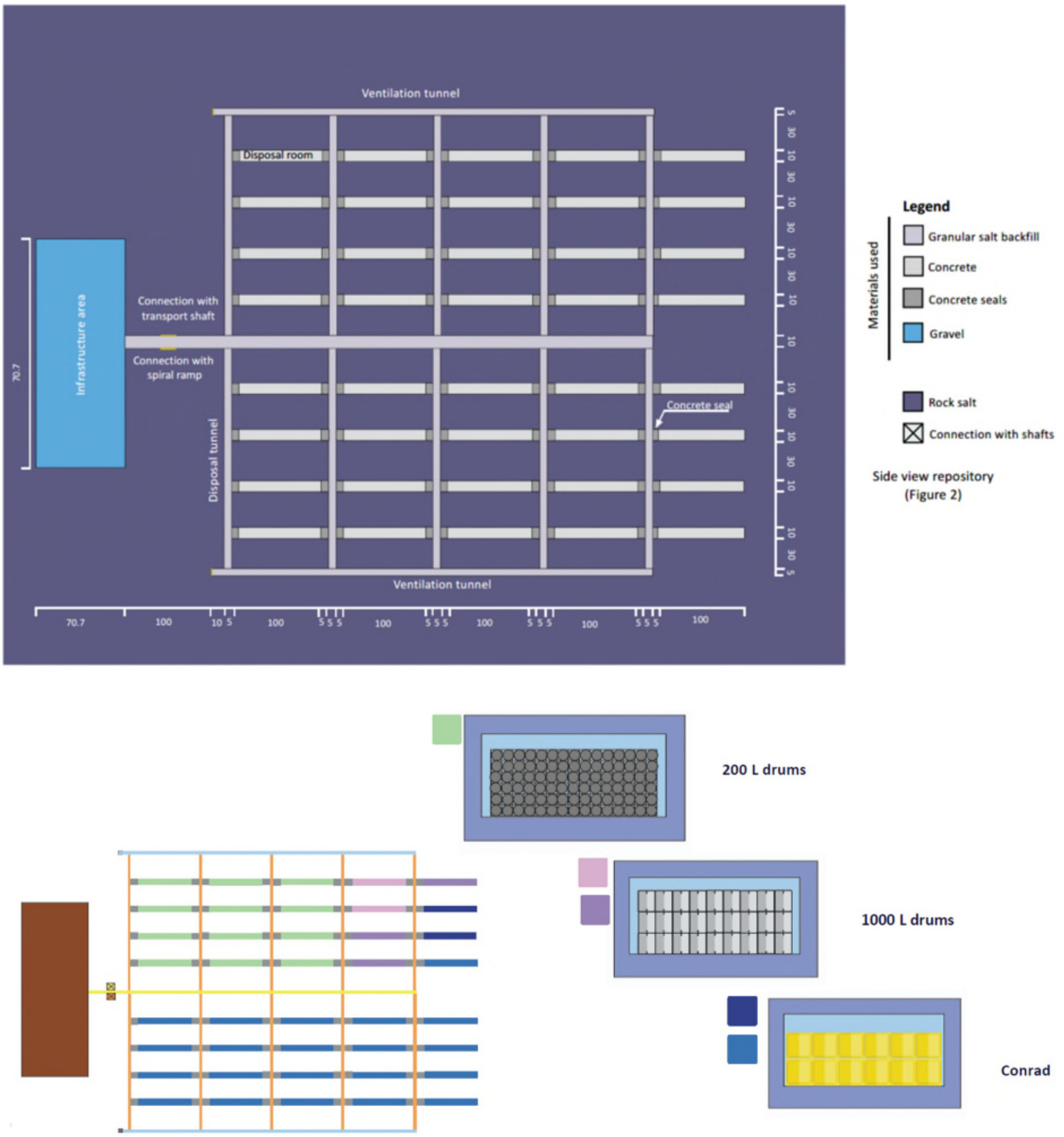

Figure 3-4: **Disposal concept upper level according to COVRA (Bartol et al. 2025)**

3.2.2 Inventory and number of DWP

Figure 3-5 shows the waste families that have to be disposed of. The numbers of containers and canisters are based on (Bartol et al. 2025).

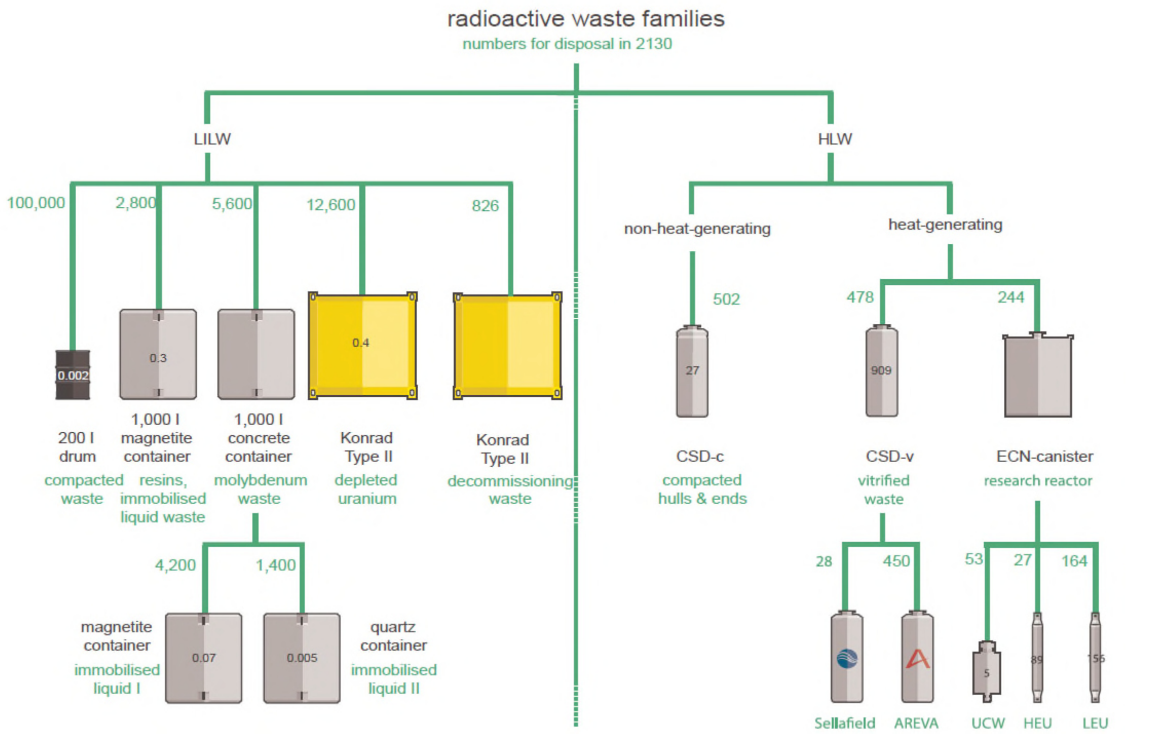

Figure 3-5: **Waste families in the Dutch inventory and their relevant containers and canisters in which the waste is stored and/or conditioned. Expected numbers of each container type are indicated in green, (Bartol et al. 2025)**

The Dutch heat-generating HLW consists of two waste types: CSD-V (Colis Standard de Déchets-vitrifié) canisters filled with vitrified waste and ECN canisters filled with spent fuel from research reactors. The spent fuel from commercial nuclear power plants is reprocessed in France and in the United Kingdom. 478 CSD-V canisters with heat-generating vitrified waste (CSD-V) have to be disposed. Based on the DWP concept developed by (Wunderlich et al. 2023), a total amount of 122 DWP type ECN and 164 DWP type CSD are expected to be disposed.

3.2.3 Backfilling sequence and closure concept

The backfilling concept is described in (Bartol et al. 2025) and is directly linked to the sequence of operational periods. First, the lower level will be filled. The HLW disposal campaign at the lower level is accompanied by a direct backfill of the disposal gallery following the emplacement procedure. Each emplaced DWP will immediately be backfilled within the tunnel. Both, emplacement and backfilling are performed in an alternating operation mode. Crushed rock salt (processed excavation material) will be used as backfilling material. The endings of the disposal tunnels are closed by seals. The seals will be made of MgO-concrete. For the cost estimation, a concrete mixture that consists of 63.7 % rock salt, 11.3 % MgO and 25 % $MgCl_2$ is assumed.

The ventilation and transport tunnel of the lower level remains open, even after the disposal of all HLW DWPs. Backfilling of these areas will be done after a so-called observation period. This observation period covers a phase after the disposal and backfilling of the emplacement tunnels at the lower level and the emplacement chambers at the upper level in which just the main galleries remain open and a monitoring is done. The observation phase for the lower level starts earlier and runs partly parallel to the disposal of the upper level. It is assumed that the observation phase of both levels covers a period of 10 years.

The backfilling of the upper level follows basically the same concept as for the lower level. After emplacement of a defined number of containers, the remaining voids will be backfilled. For the LILW-disposal chambers, a concrete-based backfill is used. The endings of the disposal tunnels are closed by seals made of MgO-concrete as well. Finally, the main tunnels at both levels will be backfilled. The backfilling of these main tunnels can be done with crushed rock salt using processed excavation material.

The decision to backfill the main tunnels represents the first step of the closure of the GDF. After that, the final backfilling of the infrastructure areas and the ramp closure as well as the shaft dismantling and backfilling is done.

The closure concept is not yet described in detail. The cost estimation, sealing, and closure elements from generic R&D studies are used, see e.g. (Bertrams et al. 2020) and (Müller-Hoeppe et al. 2012). The following main elements are considered:

- MgO-concrete seals inside the ramp between lower and upper level
- Gravel backfill inside the infrastructure area and the salt bunker
- Several sealing elements inside the shafts, made of different materials to provide a redundant design

Examples for shaft sealing concepts in domal rock salt formations are given in (Bertrams et al. 2020) and (Müller-Hoeppe et al. 2012). Figure 3-6 illustrates both shaft sealing concepts. In both cases the shaft seals consist of short-term sealing elements, long-term sealing elements, abutments, and storage elements or filling columns. The position of each element is related to the exact geological structure. The concept on the left includes special sealing elements at the horizons of the so called “Gorleben Bank” layers to meet the higher requirements for a sealing element. The illustrations represent just examples. At the position of the sealing elements and abutments, the excavation disturbed zone (EDZ) has to be removed, which results in a larger diameter at these positions. Possible sealing elements are e.g. bentonite, salt concrete, MgO-concrete, and crushed salt.

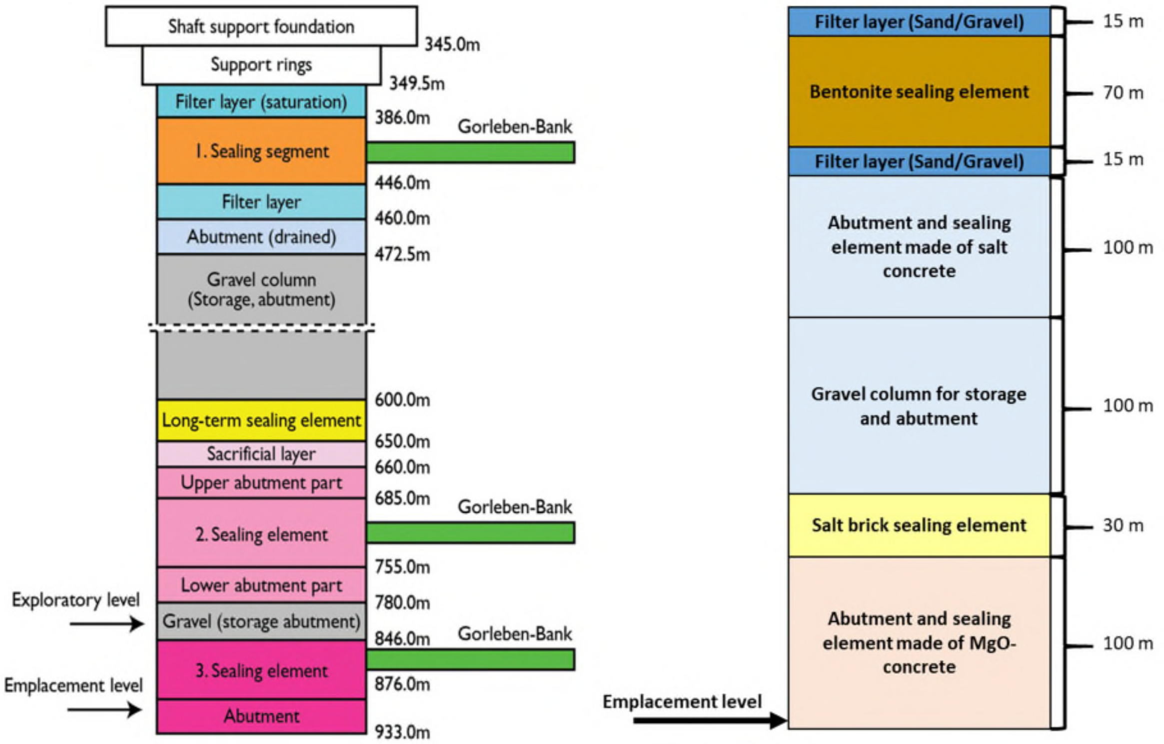

Figure 3-6: **Shaft sealing concept for domal rock salt formations (without scale), left based on (Müller-Hoeppe et al. 2012), right based on (Bertrams et al. 2020)**

3.2.4 Personnel costs

The operation of the GDF willl be done non-automated by workers of COVRA or a third operator. It is assumed that COVRA will provide the general management, administrative functions, and partly safety-relevant functions of the GDF operation. The actual workforce needed for different functions varies between the phases of the GDF lifetime. Table 3-2: summarises the functions considered within the phases for COVRA. Table 3-3 summarises the functions considered within the phases for the operator. The workforce of the operator covers all functions that are not performed by COVRAs employees and that are mostly specific to single phases. Site preparation, excavation, and also sealing of mine openings are typical examples. These activities will most likely be done by specialised companies. As a simplification, all activities are allocated to one generic operator.

The preliminary personnel structure includes the personnel needed based on the different functions. The personnel structure does not reflect the exact amount of persons needed for the phases. As the work load in hours per year is given, holidays and downtimes due to illness are not considered. It is assumed that every function is available for the required number of hours per year and will be paid for this work. For COVRA, as well as for the operator, it is assumed that a fulltime equivalent of work force compares to 1,650 h per year. The hourly rates for the employees vary based on the professional background. For both, COVRA and the operator, the same rates of salary are considered (see Table 3-1).

Table 3-1: Salary based on professional background/qualification

Professional background/qualification	Salary code COVRA/Operator (relevant for **Table 3-2:**)
Managing board	136
Manager, coordinator, key expert	62
Project leader, engineer, expert	47
Technician	35
Supporting services, secretariat	32

Table 3-2: Functions and personnel costs COVRA

Function	salary code	Salary [EUR/hour]	Involvement [hours/year]	Phase 1 Site preparation	Phase 2 Repository construction	Phase 3 Disposal campaign LILW and (TE)NORM waste	Phase 4 Disposal campaign HLW waste	Phase 5 Underground observation phase	Phase 6 Repository closure	Phase 7 Post-operational phase
STRATEGIC MANAGEMENT										
General management				100%	100%	100%	100%	100%	100%	0%
Chief executive officer	200	136.00	1720	1720	1720	1720	1720	1720	1720	0
Deputy director-general	201	62.00	1720	1720	1720	1720	1720	1720	1720	0
Secretary	203	35.00	1720	1720	1720	1720	1720	1720	1720	0
Staff functions				100%	100%	100%	100%	50%	25%	0%
Head of physical inspection	201	62.00	1720	1720	1720	1720	1720	860	430	0
Internal service for prevention and protection at work	201	62.00	1720	1720	1720	1720	1720	860	430	0
Quality manager	201	62.00	1720	1720	1720	1720	1720	860	430	0
Safety strategy & environment protection	201	62.00	1720	1720	1720	1720	1720	860	430	0
Safety officer	201	62.00	1720	1720	1720	1720	1720	860	430	0
GENERAL SERVICES										
Management				50%	100%	100%	100%	100%	100%	0%
Director for general services	201	62.00	1720.00	860	1720	1720	1720	1720	1720	0
General administration				100%	100%	100%	100%	100%	100%	0%
Administrative assistant (human resources)	204	32.00	1720.00	1720	1720	1720	1720	1720	1720	0
Administrative assistant (logistics)	204	32.00	1720.00	1720	1720	1720	1720	1720	1720	0
ICT technician	202	47.00	1720.00	1720	1720	1720	1720	1720	1720	0
Legal advice				100%	100%	100%	100%	100%	100%	10%
Legal advisor	201	62.00	1720.00	1720	1720	1720	1720	1720	1720	0
Financial administration				100%	100%	100%	100%	100%	100%	10%
Accountant	201	62.00	1720.00	1720	1720	1720	1720	1720	1720	0
Purchasing & contracts				100%	100%	100%	100%	100%	100%	10%
Purchaser	201	62.00	1720.00	1720	1720	1720	1720	1720	1720	0
Communications				100%	100%	100%	100%	100%	100%	100%
Communications expert	201	62.00	1720.00	1720	1720	1720	1720	1720	1720	0

Table 3-2 1: Functions and personnel costs COVRA

WASTE MANAGEMENT PLANNING										
Management				0%	50%	100%	100%	50%	50%	0%
Director for pre waste management	201	62.00	1720.00	0	860	1720	1720	860	860	0
Secretary	204	32.00	1720.00	0	860	1720	1720	860	860	0
Waste inventory				0%	50%	100%	100%	25%	25%	0%
Radioactive waste treatment & conditioning expert	201	62.00	1720.00	0	860	1720	1720	430	430	0
Cost evaluations				0%	50%	100%	100%	0%	0%	0%
Cost engineer	201	62.00	1720.00	0	860	1720	1720	0	0	0
Asset & Liability management (ALM)				0%	50%	100%	100%	0%	0%	0%
Financial analyst	201	62.00	1720.00	0	860	1720	1720	0	0	0
LONG-TERM WASTE MANAGEMENT										
Management				50%	50%	100%	100%	100%	50%	10%
Director for long-term waste management	200	136.00	1720	860	860	1720	1720	1720	860	0
RD&D geological disposal and licensing				100%	100%	100%	100%	100%	50%	10%
Geotechnical engineer	201	62.00	1720	1720	1720	1720	1720	1720	860	0
Nuclear physicist	201	62.00	1720	1720	1720	1720	1720	1720	860	0
Geologist	201	62.00	1720	1720	1720	1720	1720	1720	860	0
Chemist	201	62.00	1720	1720	1720	1720	1720	1720	860	0

Table 3-2 2: Functions and personnel costs COVRA

CONTEMPORARY WASTE MANAGEMENT										
Management				50%	50%	100%	100%	50%	50%	10%
Director for contemporary waste management	201	62.00	1720	860	860	1720	1720	860	860	0
Waste acceptance				50%	50%	100%	100%	50%	50%	10%
Waste acceptance coordinator	201	62.00	1720	860	860	1720	1720	860	860	0
Inspection of radioactive waste for post-conditioning	203	35.00	1720	860	860	1720	1720	860	860	0
Inspection of monoliths or supercontainers	203	35.00	1720	860	860	1720	1720	860	860	0
Installations management				50%	50%	100%	100%	50%	50%	10%
Management of the post-conditioning installations	201	62.00	1720	860	860	1720	1720	860	860	0
Installations dismantling				50%	50%	100%	100%	50%	50%	10%
Dismantling of the post-conditioning installations	201	62.00	1720	860	860	1720	1720	860	860	0
OPERATOR HUMAN RESOURCES										
Total salary costs	**[EUR/year]**		**[EUR]**	2,421,760	2,715,880	3,347,120	3,347,120	2,432,940	1,969,400	0
Various expenses (3% of the salary costs)	**[EUR/year]**		**[EUR]**	72,653	81,476	100,414	100,414	72,988	59,082	0
TOTAL COSTS				**2,494,413**	**2,797,356**	**3,447,534**	**3,447,534**	**2,505,928**	**2,028,482**	**0**

Table 3-3: Functions and personnel costs operator

Function	Headcount	Salary [EUR/hour]	Involvement [hours/year]	Site preparation	Repository construction	Disposal campaign LILW and (TE)NORM waste	Disposal campaign HLW waste	Underground observation phase	Repository closure	Post-operational phase	(ADM: administration; CZ: controlled zone)
General management				100%	100%	100%	100%	0%	100%	0%	
Chief executive officer	1	136.00	1720.00	233,920.00 €	233,920.00 €	233,920.00 €	233,920.00 €	0.00 €	233,920.00 €	- €	ADM
Secretary	1	35.00	1720.00	60,200.00 €	60,200.00 €	60,200.00 €	60,200.00 €	- €	60,200.00 €	- €	ADM
Human resources				100%	100%	100%	100%	0%	100%	0%	
Legal advisor	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	0.00 €	106,640.00 €	- €	ADM
Administrative assistant	1	32.00	1720.00	55,040.00 €	55,040.00 €	55,040.00 €	55,040.00 €	- €	55,040.00 €	- €	ADM
Finance				100%	100%	100%	100%	0%	100%	0%	
Financial controller	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	0.00 €	106,640.00 €	- €	ADM
Accountant	1	47.00	1720.00	80,840.00 €	80,840.00 €	80,840.00 €	80,840.00 €	- €	80,840.00 €	- €	ADM
Contracts				100%	100%	100%	100%	0%	100%	0%	
Contract specialist	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	0.00 €	106,640.00 €	- €	ADM
Administrative assistant	1	32.00	1720.00	55,040.00 €	55,040.00 €	55,040.00 €	55,040.00 €	- €	55,040.00 €	- €	ADM
Archival				50%	100%	100%	100%	100%	100%	0%	
Knowledge management officer	1	62.00	1720.00	53,320.00 €	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	ADM
Filing clerk	1	32.00	1720.00	27,520.00 €	55,040.00 €	55,040.00 €	55,040.00 €	55,040.00 €	55,040.00 €	- €	ADM
ICT				100%	100%	100%	100%	0%	100%	0%	
ICT coordinator	1	47.00	1720.00	80,840.00 €	80,840.00 €	80,840.00 €	80,840.00 €	- €	80,840.00 €	- €	ADM
ICT assistant	1	35.00	1720.00	60,200.00 €	60,200.00 €	60,200.00 €	60,200.00 €	- €	60,200.00 €	- €	ADM
Visitors centre				100%	100%	100%	100%	100%	100%	100%	
Supervisor	1	47.00	1720.00	80,840.00 €	80,840.00 €	80,840.00 €	80,840.00 €	80,840.00 €	80,840.00 €	- €	ADM
Receptionist	1	32.00	1720.00	55,040.00 €	55,040.00 €	55,040.00 €	55,040.00 €	55,040.00 €	55,040.00 €	- €	ADM
Touring guide	3	32.00	1720.00	165,120.00 €	165,120.00 €	165,120.00 €	165,120.00 €	165,120.00 €	165,120.00 €	- €	ADM
Service management				100%	100%	100%	100%	0%	100%	0%	
Service manager	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	0.00 €	106,640.00 €	- €	ADM
General maintenance (non-industrial site infrastructure)				0%	100%	100%	100%	100%	50%	0%	
Supervisor	1	47.00	1720.00	0.00 €	80,840.00 €	80,840.00 €	80,840.00 €	80,840.00 €	40,420.00 €	- €	ADM
Maintenance technician	4	35.00	1720.00	0.00 €	240,800.00 €	240,800.00 €	240,800.00 €	240,800.00 €	120,400.00 €	- €	ADM
Materials/stock manager	1	35.00	1720.00	0.00 €	60,200.00 €	60,200.00 €	60,200.00 €	60,200.00 €	30,100.00 €	- €	ADM

Table 3-3 1: Functions and personnel costs operator

Radiological laboratory				100%	100%	100%	100%	0%	100%	0%	
Radiological laboratory technician	1	47.00	1720.00	80,840.00 €	80,840.00 €	80,840.00 €	80,840.00 €	0.00 €	80,840.00 €	- €	CZ
Land survey (surface + underground)				100%	100%	100%	100%	100%	100%	0%	
land surveyor	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	ADM
Assistant land surveyor	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	ADM
Fire brigade				100%	100%	100%	100%	100%	50%	0%	
Fire brigade captain	1	47.00	1720.00	80,840.00 €	80,840.00 €	80,840.00 €	80,840.00 €	80,840.00 €	40,420.00 €	- €	ADM
Site security management				100%	100%	100%	100%	0%	100%	0%	
Security manager	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €		106,640.00 €	- €	ADM
Permanent security outer perimeter				100%	100%	100%	100%	100%	100%	0%	
Entry/exit control guard	4	32.00	1720.00	220,160.00 €	220,160.00 €	220,160.00 €	220,160.00 €	220,160.00 €	220,160.00 €	0.00 €	ADM
Patrol guard	4	32.00	1720.00	220,160.00 €	220,160.00 €	220,160.00 €	220,160.00 €	220,160.00 €	220,160.00 €	0.00 €	ADM
Daytime reinforcement outer perimeter				100%	100%	100%	100%	0%	100%	0%	
Entry/exit control guard	1.5	32.00	1720.00	82,560.00 €	82,560.00 €	82,560.00 €	82,560.00 €	- €	82,560.00 €	- €	ADM
Patrol guard	1.5	32.00	1720.00	82,560.00 €	82,560.00 €	82,560.00 €	82,560.00 €	- €	82,560.00 €	- €	ADM
Permanent security inner perimeter				100%	100%	100%	100%	0%	100%	0%	
Entry/exit control guard	4	35.00	1720.00	240,800.00 €	240,800.00 €	240,800.00 €	240,800.00 €	- €	240,800.00 €	- €	ADM
Patrol guard	4	35.00	1720.00	240,800.00 €	240,800.00 €	240,800.00 €	240,800.00 €	- €	240,800.00 €	- €	ADM
Daytime reinforcement inner perimeter				100%	100%	100%	100%	0%	100%	0%	
Entry/exit control guard	1	35.00	1720.00	60,200.00 €	60,200.00 €	60,200.00 €	60,200.00 €	- €	60,200.00 €	- €	ADM
General tasks				100%	100%	100%	100%	0%	100%	0%	
Operational safety coordinator	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	ADM
Nuclear safety coordinator	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	ADM
Environmental protection coordinator	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	ADM
General QA coordinator	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	ADM
Emergency management				100%	100%	100%	100%	0%	100%	0%	
Emergency manager	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	ADM
Follow-up team				100%	100%	100%	100%	0%	100%	0%	
Construction engineer	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	CZ
Geotechnical engineer	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	CZ
Electro-mechanical engineer	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	CZ
Nuclear engineer	1	62.00	1720.00	106,640.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	CZ
Industrial operations management department				50%	100%	100%	100%	0%	100%	0%	
Industrial operations manager	1	62.00	1720.00	53,320.00 €	106,640.00 €	106,640.00 €	106,640.00 €	- €	106,640.00 €	- €	CZ
Planning coordinator	1	35.00	1720.00	30,100.00 €	60,200.00 €	60,200.00 €	60,200.00 €	- €	60,200.00 €	- €	CZ

Table 3-3 2: Functions and personnel costs operator

Post-conditioning facility				0%	50%	100%	100%	0%	50%	0%	
Shift supervisor	1	47.00	1720.00	- €	40,420.00 €	80,840.00 €	80,840.00 €	- €	40,420.00 €	- €	CZ
Operator	8	35.00	1720.00	- €	240,800.00 €	481,600.00 €	481,600.00 €	- €	240,800.00 €	- €	CZ
Radiological protection supervisor	1	35.00	1720.00	- €	30,100.00 €	60,200.00 €	60,200.00 €	- €	30,100.00 €	- €	CZ
QA supervisor	1	35.00	1720.00	- €	30,100.00 €	60,200.00 €	60,200.00 €	- €	30,100.00 €	- €	CZ
Waste bookkeeper	0	47.00	1720.00	- €	- €	- €	- €	- €	- €	- €	CZ
Administrative assistant	0	32.00	1720.00	- €	- €	- €	- €	- €	- €	- €	CZ
Maintenance technician – foreman	1	47.00	1720.00	- €	40,420.00 €	80,840.00 €	80,840.00 €	- €	40,420.00 €	- €	CZ
Maintenance technician	2	35.00	1720.00	- €	60,200.00 €	120,400.00 €	120,400.00 €	- €	60,200.00 €	- €	CZ
Underground operations support department				0%	50%	100%	100%	50%	100%	0%	
Underground shift supervisor	1	47.00	1720.00	- €	40,420.00 €	80,840.00 €	80,840.00 €	40,420.00 €	80,840.00 €	- €	CZ
Underground radiological protection supervisor	1	35.00	1720.00	- €	30,100.00 €	60,200.00 €	60,200.00 €	30,100.00 €	60,200.00 €	- €	CZ
Maintenance technician – foreman	1	47.00	1720.00	- €	40,420.00 €	80,840.00 €	80,840.00 €	40,420.00 €	80,840.00 €	- €	CZ
Maintenance technician	3	35.00	1720.00	- €	90,300.00 €	180,600.00 €	180,600.00 €	90,300.00 €	180,600.00 €	- €	CZ
Shaft and ramp operation and maintenance department				0%	100%	100%	100%	0%	50%	0%	
Supervisor (mechanical)	1	47.00	1720.00	- €	80,840.00 €	80,840.00 €	80,840.00 €	- €	40,420.00 €	- €	CZ
Supervisor (electrical)	1	47.00	1720.00	- €	80,840.00 €	80,840.00 €	80,840.00 €	- €	40,420.00 €	- €	CZ
Maintenance electrician	5	47.00	1720.00	- €	404,200.00 €	404,200.00 €	404,200.00 €	- €	202,100.00 €	- €	CZ
Maintenance mechanic	5	35.00	1720.00	- €	301,000.00 €	301,000.00 €	301,000.00 €	- €	150,500.00 €	- €	CZ
Mine rescue team				0%	100%	100%	100%	0%	50%	0%	
Team captain	1	47.00	1720.00	- €	80,840.00 €	80,840.00 €	80,840.00 €	- €	40,420.00 €	- €	CZ
Waste disposal department				0%	0%	100%	100%	0%	0%	0%	
Waste cart pilot	2	35.00	1720.00	- €	- €	120,400.00 €	120,400.00 €	- €	- €	- €	CZ
Waste cart co-pilot	2	35.00	1720.00	- €	- €	120,400.00 €	120,400.00 €	- €	- €	- €	CZ
Operator preparing the next disposal gallery section	2	35.00	1720.00	- €	- €	120,400.00 €	120,400.00 €	- €	- €	- €	CZ
Backfilling of disposal galleries				0%	0%	100%	100%	0%	0%	0%	
Shift supervisor	1	47.00	1720.00	- €	- €	80,840.00 €	80,840.00 €	- €	- €	- €	CZ
Radiological protection supervisor	1	35.00	1720.00	- €	- €	60,200.00 €	60,200.00 €	- €	- €	- €	CZ
Operator	3	35.00	1720.00	- €	- €	180,600.00 €	180,600.00 €	- €	- €	- €	CZ
Sealing of disposal galleries				0%	0%	100%	100%	0%	0%	0%	
Shift supervisor	1	47.00	1720.00	- €	- €	80,840.00 €	80,840.00 €	- €	- €	- €	CZ
Operator	5	35.00	1720.00	- €	- €	301,000.00 €	301,000.00 €	- €	- €	- €	CZ
Backfilling and sealing of access galleries, shafts and ramp				0%	0%	0%	0%	0%	100%	0%	
Shift supervisor	1	47.00	1720.00	- €	- €	- €	- €	- €	80,840.00 €	- €	CZ
Operator	10	35.00	1720.00	- €	- €	- €	- €	- €	602,000.00 €	- €	CZ

OPERATOR HUMAN RESOURCES										
Total salary costs	**[EUR/year]**			4,106,500	6,243,600	7,951,560	7,951,560	1,780,200	6,422,480	0
Various expenses (1% of the salary costs)	**[EUR/year]**			41,065	62,436	79,516	79,516	17,802	64,225	0
Overall personnel costs	**[EUR/year]**			4,147,565	6,306,036	8,031,076	8,031,076	1,798,002	6,486,705	0
BOARD OF DIRECTORS	**[EUR/year]**			25,000	25,000	25,000	25,000	25,000	25,000	0
TOTAL COSTS	**[EUR/year]**			**4,172,565**	**6,331,036**	8,056,076	8,056,076	1,823,002	6,511,705	0

3.2.5 Repair, maintenance, and replacement estimations

For mobile and fixed equipment as well as buildings, costs for maintenance & replacement have been included in the cost estimate. A typical example for mobile equipment are load haul dumper (LHD) and other mining vehicles. Shaft hoisting systems represent examples for fixed equipment.

The rates considered for repair and maintenance depend on the cost item. Typically, they are calculated by estimating an annual repair and maintenance costs percentage of the procurement costs for the individual equipment and multiplying this value with the duration of the respective project phase. The respective annual percentage values were taken from the Baugeräteliste (BGL) (Bauverlag 2015) and from recent experience from the operation of BGE' s facilities. Baugeräteliste is a catalogue and construction equipment list with over 15,000 data records and has been a recognised standard work for many decades. It includes all common types of equipment and unit sizes for construction and site installation. The individual items contain technical and economic average values, supplemented by explanations of the design and equipment as well as for operational use. The construction equipment list is typically used in the construction sector in areas like inter-company allocation of equipment costs, basis for the organisation and disposition of equipment in construction companies or as a tool for the assessment of equipment and machine costs etc.

The repair costs given in the BGL 2015 include repair costs and maintenance costs required to maintain and restore operational readiness. The given costs are divided into 60% personnel costs and 40% material costs (costs for repair materials and spare parts including delivery to repair shop without VAT).

For the buildings (surface facilities), 2 % of the investment costs are considered as annual repair and maintenance effort. For surface areas, such as green field or parking spaces, 1% of the investment are considered as annual repair and maintenance effort.

For the mobile excavation equipment, a uniform maintenance rate of 300,000 € per year is considered. This value represents a combination of percentages based on (Bauverlag 2015) and the operational experience of road headers in existing salt mines. For the mobile transport and emplacement equipment, a uniform maintenance rate of 150,000 € per year is considered and for the mobile backfilling equipment, a uniform maintenance rate of 200,000 € per year. In both cases, the same approach was chosen. The unit price per year is determined as a combination of (Bauverlag 2015) and operational experience in salt mines.

3.2.6 Architect and engineering fees

Engineering costs are considered as extra cost item for buildings and constructions. The engineering costs are – according to COVRA – 30 % for underground operations and 15 % for operations above ground. For non-nuclear facilities, architectural and engineering fees between 12 % and 20 % can be assumed, see e.g. (Lawinsider 2023). For nuclear constructions, a higher fee is assumed, because of the increased complexity. This increase in costs is in line with the experience of BGE made in the German repository projects.

3.2.7 Site selection

Since the site selection is a topic that is subject to high uncertainties, only a rough estimation of the costs can be done in advance. An estimation and breakdown of exploration costs was done by COVRA and was provided for the cost estimation (see Table 3-4). Depending on the requirements for the comparison of different sites, the exploration costs could be significantly higher, especially if more complex exploration methods such as e.g. high-resolution seismic surveys are required. The exploration cost estimation in Table 3-4 refers to the exploration at one site. For the total cost estimation the exploration of two sites is estimated and includes a correction of inflation based on input given by COVRA.

Table 3-4: Exploration cost estimation

Site Selection	Unit price [€]	amount	Total [€]
Review additional data			1,000,000
2D seismic sections	35,000 / km	34 km	1,190,000
3D seismic sections	250,000 / km	50 km²	12,500,000
Deep boreholes	800,000 / borehole	6	4,800,000
Shallow boreholes	100,000 / borehole	10	1,000,000
Hydro-chemical laboratory tests	10,000 / test	20	200,000
Geo-data management software			900,000
Exploration during excavation and construction			3,000,000
Total			21,590,000
Reserve			5,000,000
Total including reserve			**26,590,000**

4 Project Schedule

The disposal of HLW in a deep geological formation is one of the currently considered options for radioactive waste management in the Netherlands. However, the Dutch law stipulates 100 years of interim storage before disposal. Consequently, a possible start of disposal operations could be the year 2130. Figure 4-1 illustrates the preliminary schedule of the repository lifetime. For the cost estimation, a more detailed illustration of the sub-phases and their specific duration is needed, as already explained in Chapter 2.3. The detailed schedule, including the duration of the cost groups and main cost items, is presented in Chapter 4.5.

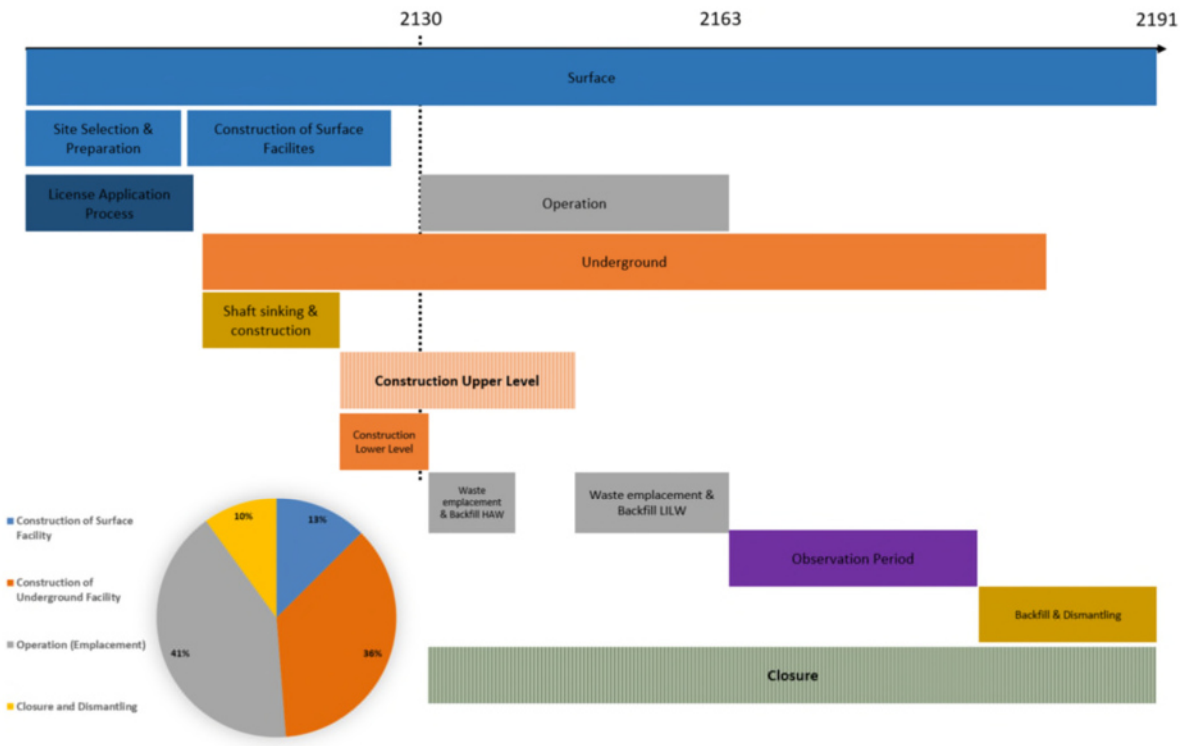

Figure 4-1: Schedule of the overall GDF project

The cost estimation does not include the site selection process and the licensing itself, but only some basic exploration activities, see (3.2.7). Design and construction belong to the first phase considered. This phase is further separated into the following cost groups:

- Site exploration (Surface and subsurface)
- Site preparation
- Repository construction (Surface and subsurface)

These cost groups will be implemented before 2130. To be ready for disposal in 2130, the first step – site characterisation – has to start in 2093. The site preparation, including e.g. landscaping and installation of utilities, will start in 2111. The actual construction starts with the surface facilities around 2116. Once the basic site preparation, e.g. installation of the fence, is finished, the subsurface construction can start. The actual underground construction of the repository can be divided into four main phases:

1. Shaft sinking
2. Excavation of the infrastructure area and ramps
3. Excavation of the lower level
4. Excavation of the upper level

For the later cost estimation, it is of great importance to determine the duration of every phase and sub-phase of the excavation period. A first, very rough estimation is presented below. The presented times focus on mining-related activities only. Additional times, e.g. for planning and licensing, are not considered because of the related high level of uncertainty. The cost estimation starts at the beginning of the site preparation, when a site has already been selected and the exploration work on site starts.

4.1 Shaft sinking, excavation and connection of central area

The state of the art in shaft sinking includes freezing technique. For preparation, freezing itself, the actual shaft sinking and the installation of the shaft hoisting equipment, a duration of four years is assumed for the main shaft with a diameter of 8 m, see e.g. (Redpath 2023a). The excavation of the main shaft will start before the other shafts.

The duration of sinking the ventilation as well as the personnel shaft with a diameter of 5 m is estimated to be three years each. This time estimate relies on literature data from comparable projects and experience of shaft sinking projects, e.g. run by Thyssen Schachtbau GmbH, see (Thyssen 2023) and (Redpath 2023b).

The excavation sequence for the main area of the deep geological facility is illustrated in Figure 4-2. After shaft sinking, connection galleries will be excavated to establish a steady airflow. After this, the central infrastructure area at the upper level will be excavated. The infrastructure area is needed for supporting activities such as maintenance of the underground equipment, storage rooms, or utility supply. The central area is completed by the excavation of the ramp down to the lower level (see Table 4-1:). The estimation is done for a one-shift operation. Every third shift is needed for maintenance. 220 working days per year, considering the maintenance lead to approximately 150 days per year for the running operation with the continuous miner. 6 effective working hours per shift are assumed.

Table 4-1: Excavation time of the connection ramp

Lower level [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	m³ total
Ramp	4	10	1,920	40	76,800
Excavation time ramp	1,920 h				

Ramp Excavation: 1,920 h (320 d)

Time needed to finish the excavation, maintenance intervals included: 2.2 y

Total: 2.2 y

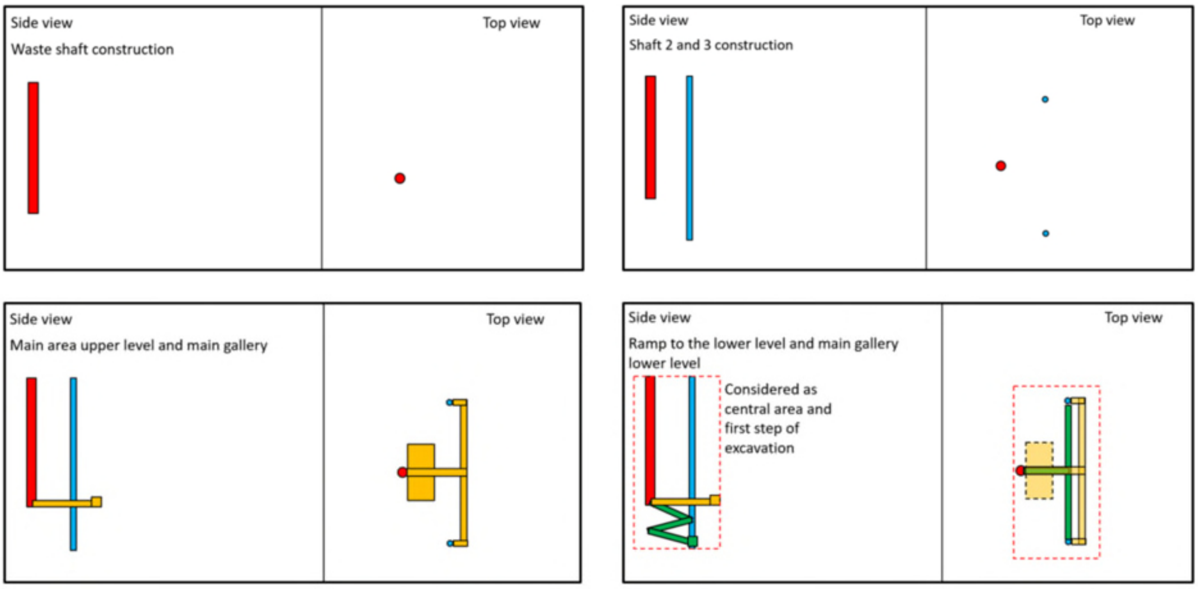

Figure 4-2: **Excavation, emplacement, and backfilling sequence (Part 1), red = Waste Shaft, blue = Service Shaft, Yellow = upper level, green = lower level (adjustments to the layout are still possible as part of the planning process)**

4.2 Excavation of the upper level

The sequence of excavation, operation, backfilling and closure of the two emplacement levels is illustrated in Figure 4-3 to Figure 4-5.

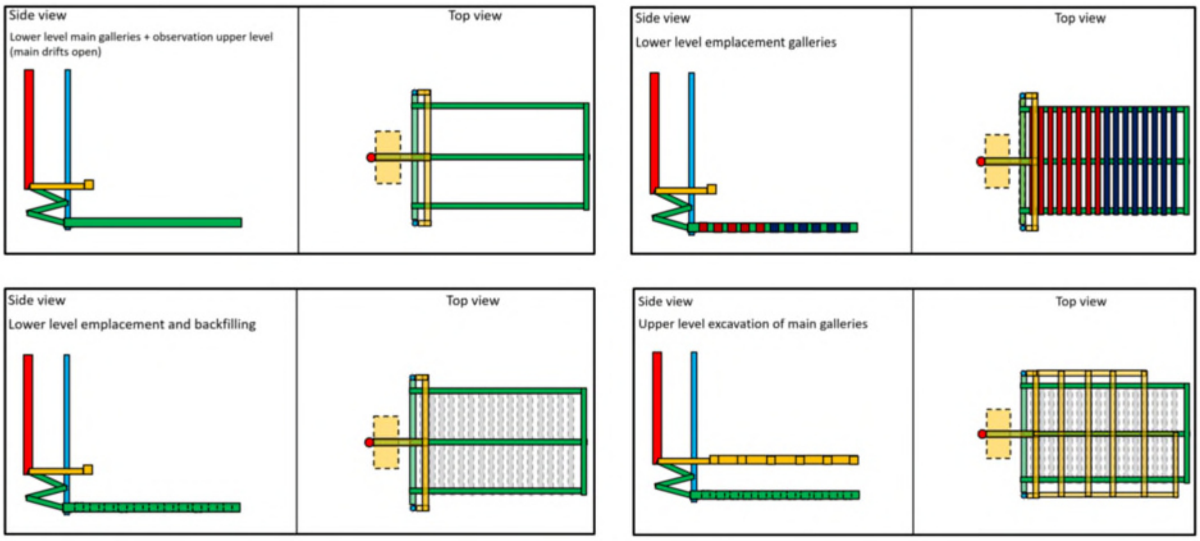

Figure 4-3: **Excavation, emplacement, and backfilling sequence (Part 2), red = Waste Shaft, blue = Service Shaft, Yellow = upper level, green = lower level, orange+purple = disposal galleries, grey = backfilled (adjustments to the layout are still possible as part of the planning process)**

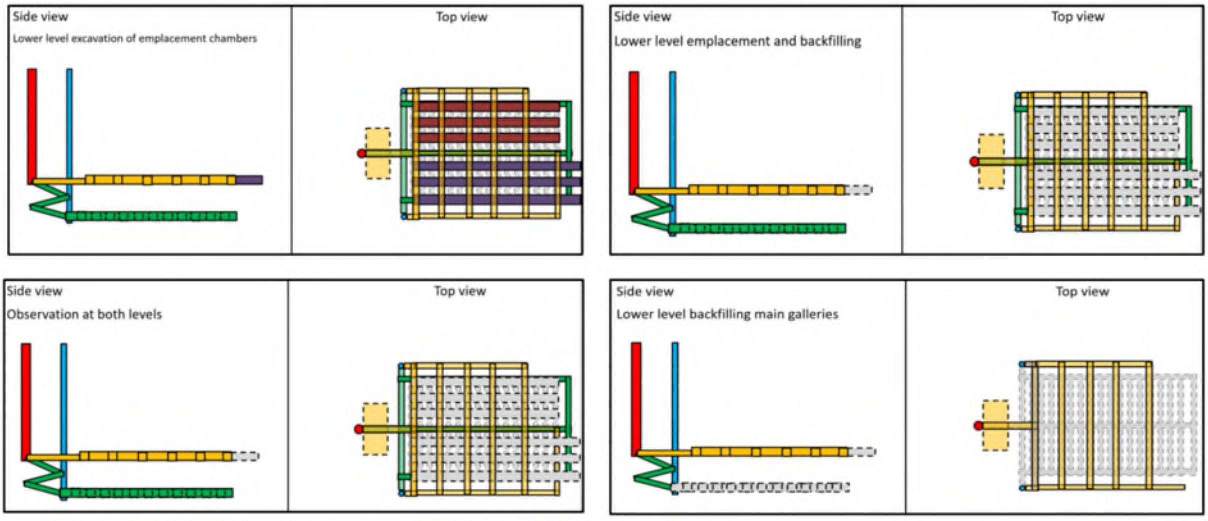

Figure 4-4: **Excavation, emplacement, and backfilling sequence (Part 3), red = Waste Shaft, blue = Service Shaft, Yellow = upper level, green = lower level, orange+purple = disposal galleries, grey = backfilled (adjustments to the layout are still possible as part of the planning process)**

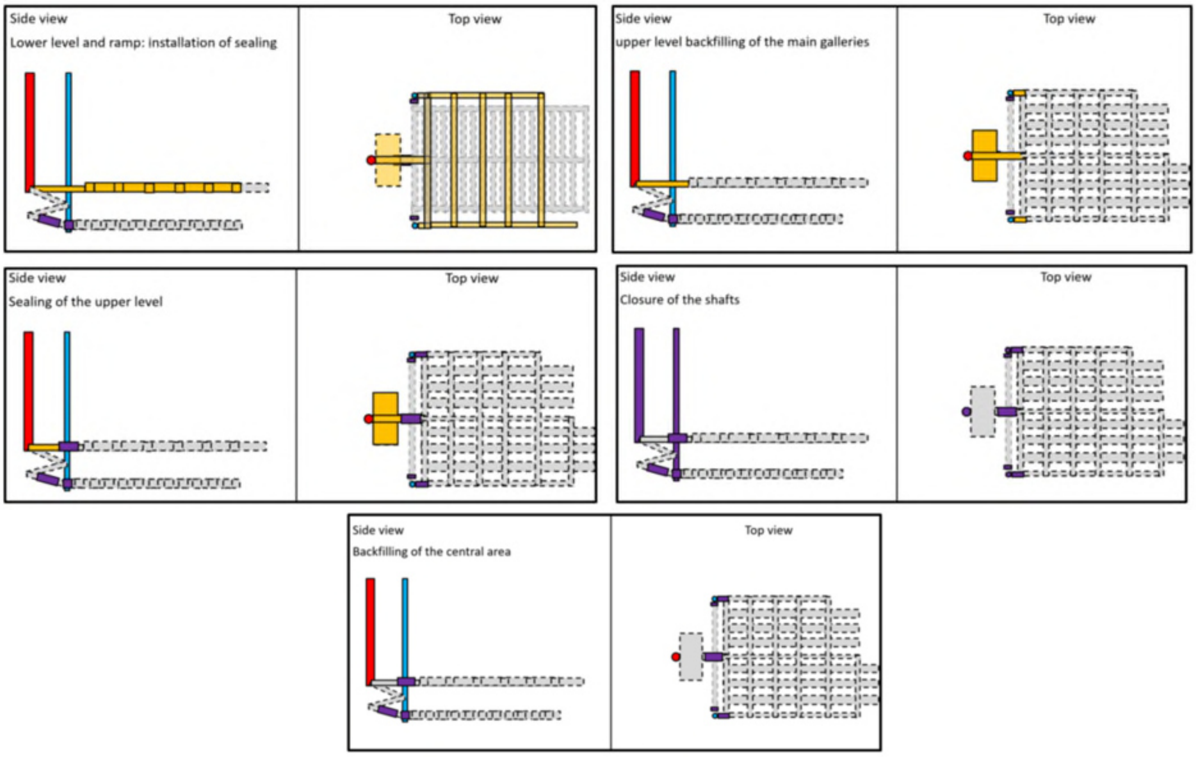

Figure 4-5: **Excavation, emplacement, and backfilling sequence (Part 4), red = Waste Shaft, blue = Service Shaft, Yellow = upper level, green = lower level, purple = sealings, grey = backfilled (adjustments to the layout are still possible as part of the planning process)**

Grimscheid (2005) offers calculation models to determine performances of mining and tunnelling equipment, including road header excavations. The planned cross sections were given by COVRA (see appendices 1 & 2). For the cost estimation, the excavated diameter is slightly enlarged, due to a safety factor and necessary road preparation works as well as lining procedures. State-of-the-art continuous miners ensure a very accurate cross section cutting, so the calculated enlargement of the cross section is moderate. The advance speed regarding the tunnel cross section is calculated to:

- 1 m/h for larger cross sections of transport tunnel and infrastructure areas of the upper level (cross section 10.6 m x 4 m).
- 2 m/h for the remaining disposal rooms and galleries as well as ventilation and service tunnel (cross section 5.6 m x 4 m).
- 0.5 m/h for the disposal rooms with the enlarged cross section of 10.6 m x 6 m.

The calculation of the time needed for the construction of the GDF starts with the time estimation for the pure continuous miner operation needed for the excavation (see Table 4-2**:**).

Table 4-2: Excavation time upper level

Upper level [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	m³ total
Disposal gallery	5.6	4	1,900	22.4	42,560
Disposal room	10.6	6	3,960	63.6	251,856
Ventilation tunnel	5.6	4	870	22.4	19,488
Transport tunnel	10.6	4	525	42.4	22,260
Infrastructure area	70.7	4	70.7	282.8	19,994
Total					356,157

Table 4-3: Excavation time upper level (Excavation time continuous miner: #3: 2m/h; #4: 1 m/h; #5: 0.5 m/h; Infrastructure: 0.05 m/h)

Calculation of excavation time	
Total tunnel length (5,6 x 4 m)	2,770 m
Total tunnel length (10,6 x 4 m)	525 m
Total tunnel length (10,6 x 6 m)	3,960 m
Infrastructure (125 x 4 m)	70,7 m
Excavation infrastructure area	1,414 h
Excavation time #3	1,385 h
Excavation time #4	525 h
Excavation time #5	7,920 h

<u>Excavation time upper level:</u>

Infrastructure Area: 1,414 h (236 d)
Excavation time #3 (5.6 x 4 m): 1,385 h (231 d)
Excavation time #4 (10.6 x 4 m): 525 h (88 d)
Excavation time #5 (10.6 x 6 m): 7,920 h (1320 d)

Time needed to finish the excavation, maintenance interval included:

Infrastructure Area: 1.6 y
Excavation time #3: 1.5 y
Excavation time #4: 0.6 y
Excavation time #5: 8.8 y

Total: 13 y

4.3 Excavation of the lower level

The excavation time of the lower level is calculated similar to chapter 4.3. The same performance of the equipment is considered. Sizes and dimensions of the galleries vary, and thus, the excavation time is different (see Table 4-4: & Table 4-5:).

Table 4-4: Excavation time lower level

Lower level [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	m³ total
Disposal tunnel heat-generating	5.6	4	2,310	22.4	51,744
Disposal tunnel non heat-generating	5.6	6	990	22.4	22,176
Ventilation tunnel	5.6	4	1,220	22.4	27,328
Service tunnel	5.6	4	390	22.4	8,736
Transport tunnel	10.6	4	630	42.4	26,712
Infrastructure area	15.8	4	15.8	63.2	998
Total					137,694

Table 4-5: Excavation time upper level (Excavation time continuous miner: #3: 2m/h; #4: 1 m/h; #5: 0.5 m/h; Infrastructure: 0.05 m/h)

Calculation of excavation time	
Total tunnel length (5.6 x 4 m)	4,910 m
Total tunnel length (10.6 x 4 m)	630 m
Infrastructure area	15.8 m
Excavation time #1	2,455 h
Excavation time #2	630 h
Excavation infrastructure area	316 h

<u>Excavation time lower level:</u>

Excavation time #1 (5.6 x 4 m): 2,455 h (409 d)
Excavation time #2: (10.6 x 4 m): 630 h (105 d)
Infrastructure Area: 316 h (53 d)

Time needed to finish the excavation, maintenance interval included:

Excavation time #1: 2.7 y
Excavation time #2: 0.7 y
Infrastructure Area: 0.35 y

Total: 4 y

4.4 Time schedule for operation and closure period

The time schedule for the LILW disposal is limited by the time needed for shaft transport of the waste packages. The emplacement of the waste packages is done by a forklift. Because of the short transport distances, it is assumed that the forklift picks up the waste packages at the shaft landing station, transfers them to the actual disposal position, and disposes. This process is faster than the hoisting process, so the number of theoretical emplacements per shift is limited by the hoisting transport. The shaft hoisting process, including the loading and unloading of the shaft cage will take approximately 60 minutes, based on the experience in comparable DGR concepts, e.g. (ONDRAF/NIRAS 2019).

The estimated time for one emplacement cycle for the Konrad type II container is given in Table 4-6. For an average transport distance of 500 m from the shaft landing station to the emplacement drifts, the transportation time by forklift is calculated to 3 min for one way. A plane transport way with good floor conditions is assumed. The actual disposal process is assumed to be 10 min. A full transport and emplacement cycle takes 20 min, including 4 min buffer time (see Table 4-6).

Table 4-6: Disposal time for Konrad container run by forklift

Disposal time LILW container by forklift
Average distance of 500 m/one way estimated.
10 km/h maximum speed
3 min/500 m
Total for 1 process (there and back): 10 min
Nb. Of Konrad container: 13,426
Total time: 2238 h
Working days (6 h effective per day): 373 needed

Without limitations of shaft hoisting, 373 days (1 year is expected to have 220 working days) would be necessary for the emplacement process of the Konrad type II container. With the shaft hoisting limitation to six containers per shift, it will take 2,238 days for the total amount of Konrad type II containers. This would lead to a total of ten years only for the Konrad type II container. Since the emplacement processes are carried out significantly faster compared with the shaft hoisting processes, the total disposal time is set equal to the time for the shaft hoisting processes. With the maximum cage load shown in Figure 4-6, the calculated total time needed for the LLIW waste is 17 years. A safety factor set for delays during operation leads to an assumption of a total of 19 years disposal time for the LILW waste stream (see Table 4-7). All the presented durations rely on a mixed hoisting cage loading, (see Figure 4-6).

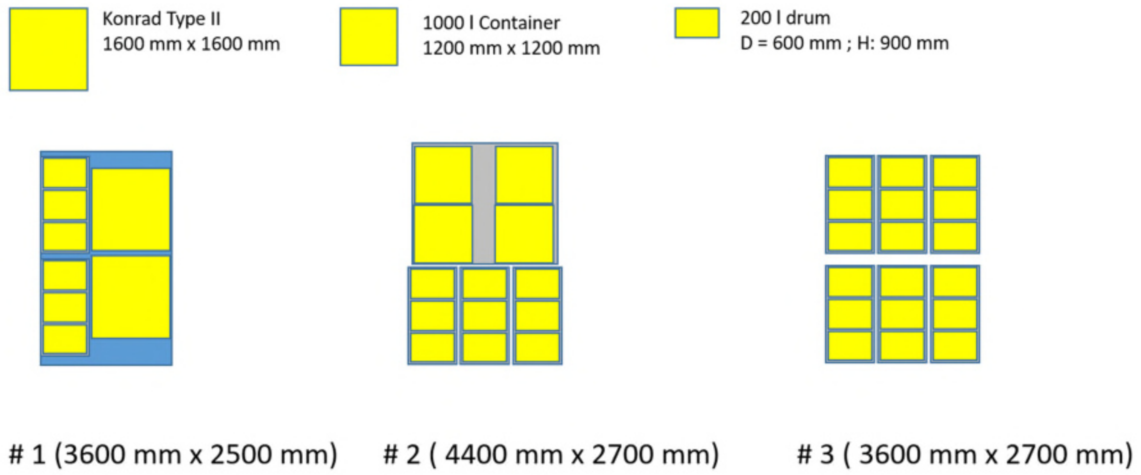

Figure 4-6: Assumed shaft cage loading configurations for a cage floor space max. 3,000 mm wide and 5,000 mm long

Table 4-7: Shaft hoisting sequences

DWP Type	Size [m]	DWP per Hoist	Shifts	Years of Operation
Konrad type II	1.6 x 1.6 x 1.6	2	2,238	10
1000 l container	1.2 x 1.2 x 1.2	4	700	3.5
200 l drums	D=0.6 ; H=0.9	6 (with Konrad container within 10 years) 9 (with 1,000 l container within 3.5 years) 18 (alone 3.5 years)	3,694 (2,238/700/756)	17 (time of combined hoist with Konrad type II & 1,000 l container included)

The estimation of the disposal time for the HLW follows the same method. 220 working days per year, 1-shift operation, 2 hoists per shift. The estimation of 3 hoists per shift goes back to (Haverkamp et al. 2017). Assuming that the shaft cage is loaded with one container per shift (A total amount of 1,224 primary waste packages of HLW result in a total DWP amount of 286), 143 working days would be needed. The transport and handling processes for the HLW container are more challenging and slower than the emplacement of the LILW. First of all, the machine load is much higher, so the transport speed is slow (less than 10 km/h according to (Wendelin & Suikki 2008)). Furthermore, the emplacement will take place at the lower level, so the ramp has to be overcome with the waste transport cart, see also section 6.2.

Table 4-8: Hoisting schedule for waste shaft operations

Group	Type	Number of primary waste packages / DWPs	DWP per hoist	Hoist per shift	Disposal shifts	Disposal shifts per day	Years
LILW	200 L drum	40,284	6	3	2,238	1	- (together with Konrad container)
LILW	200 L drum	18,900	9	3	700	1	- (together with 1000 L container)
LILW	200 L drum	40,816	18	3	756	1	3.44
LILW	1000 L magnetite	2,800	4	3	234	1	1.06
LILW	1000 concrete	5,600	4	3	467	1	2.12
LILW	Konrad type II uranium	12,600	2	3	2,100	1	9.55
LILW	Konrad type II D&D	826	2	3	138	1	0.63
SUM							**16.80**
HLW	CSD non-heat	84	1	2	42	1	0.20
HLW	CSD heat	80	1	2	40	1	0.19
HLW	ECN	122	1	2	61	1	0.28
SUM							**0.67**

Table 4-8: summarises the transportation time for the shaft hoisting processes of the waste container. The HLW containers are transported separately for safety, handling, and weight load reasons. Therefore, a total hoisting time of one year is calculated. The HLW disposal campaign assumes that emplacement and backfilling take place alternately. To estimate the total time needed for the HLW disposal campaign, time needed for the backfilling processes has to be taken into account. Table 4-9: and Table 4-10: give an overview about the calculated time for the backfilling processes.

The base assumption for the backfilling time is connected to the tunnel diameter and general experience in salt mining. Due to the early planning stage and connected uncertainties, the entire volume of the areas to be backfilled is taken into account. Volume reductions e.g. by waste packages or convergences are not considered. This leads to a pessimistic amount of material consumption. The total backfilling time is not effected by the presence of waste packages since areas were remaining spaces have to be backfilled demand a more complex and time consuming operation. 12 shifts are needed for larger diameter (10.6 m x 4 to 6 m) backfilling processes of 100 m tunnel length. 6 shifts are needed for smaller diameter (5.6 m x 4 m) backfilling of 100 m tunnel length.

Table 4-9: Backfilling sequence upper level

Upper lever [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	€/m³	m³ total	Sum [€]	Backfill time [shift]
Disposal gallery	5.6	4	1,900	22.4	244	42,560	1,0384,640	114
Disposal room	10.6	6	3,960	63.6	244	251,856	61,452,864	475.2
Ventilation tunnel	5.6	4	870	22.4	244	19,488	4,755,072	52.2
Transport tunnel	10.6	4	525	42.4	244	22,260	5,431,440	63
Infrastructure area	70.7*	4	70.7	282.8	244	19,993	4,878,526	84.84
Total						356,157	86,902,542	789.24

* - theoretical cavity volume based on reference design, see Appendix 1

Based on the calculated volumes, a duration of 589.2 shifts or 2.6 years is expected for the backfilling of the disposal galleries and disposal rooms. 200,04 shifts or 0.9 years are expected for the backfilling of the infrastructure area and transport and ventilation tunnel.

Table 4-10: Backfilling sequence lower level

Lower level [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	€/m	m³ total	Sum [€]	Backfill time [shift]
Disposal gallery heat-generating	5.6	4	2,310	22.4	244	51,744	12,625,536	277.2
Disposal gallery non heat-generating	5.6	6	990	22.4	244	22,176	5,410,944	118.8
Ventilation tunnel	5.6	4	1,220	22.4	244	27,328	6,668,032	146.4
Service tunnel	5.6	4	390	22.4	244	8,736	2,131,584	46.8
Transport tunnel	10.6	4	630	42.4	244	26,712	6,414,272	75.6
Infrastructure area	15.8	4	15.8	63.2	244	996.56	243,649	1.896
Total						136,518	33,310,529	666.70
Ramp	4	10	1,920	40	244	76,800	18,739,200	230.4

Based on the calculated volumes, a duration of 2 years is expected for the backfilling of the disposal galleries at the lower level. 1 year is expected for the backfilling of the infrastructure area and connected galleries. A small infrastructure is needed at the lower level as well to ensure a smooth operation. The backfilling of the ramp would need one additional year for the backfilling operation.

The backfilling of the emplacement areas is connected to the disposal progress due to the alternating process of emplacement and backfilling. Therefore, the time for the backfilling refers to the emplacement even though backfilling without emplacement would be much faster.

4.5 Summary

Unexpected interruptions of the operations are considered as possible risks and not included in the assumptions of the construction time. Avoidable disturbances are excluded from consideration, because a high level of quality assurance and operational monitoring is required for such a sensitive operation. This method is also used in similar cost studies, as no interruption is assumed as standard due to good advance planning. Regarding the outfitting and lining of the GDF, it is assumed that the lining runs directly after the excavation process and is not a time limiting factor. All operations regarding the outfitting are industrial standard and will run mainly parallel to the excavation process. Accordingly, they will have no great influence on the overall schedule.

5 Definition of cost items and calculation for the GDF

The item structure follows the cost breakdown structure as presented in Section 2.2 and (EURAD 2021). The estimated costs are assumed as overnight costs of 1 January 2022.

5.1 Pre-constructional activities (1)

Table 5-1: Cost assessment pre-construction activities

Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
1. Pre-constructional activities				**229,679,488 €**
1. 1. Land purchase				**62,766,688 €**
1. 1. 1 Exploration				53,180,000
1. 1. 2 Nominal cost of land purchase	345,000	m²	25	8,625,000
1. 1. 3 Notary fee	1	%	11.15%	961,688
1. 2. Site infrastructure works				**48,127,500 €**
1. 2. 1 Landscaping	345,000	m²	100	34,500,000
1. 2. 2 Roads and parking lots	10,000	m²	400	4,000,000
1. 2. 3 Green park area	15,000	m²	50	750,000
1. 2. 4 Architect/engineer fee	15	%		6,277,500
1. 2. 5 Sewage system	1,500.00	m	450	675,000
1. 2. 6 Roads (incl. temporary construction roads)	5,000.00	m	280	1,400,000
1. 2. 7 Electricity	1,500.00	m	250	375,000
1. 2. 8 Telecommunications	1,500.00	m	100	150,000
1. 3. Site facility construction				**1,920,000 €**
1. 3. 1 Utility buildings	192	unit cost/month	10,000	1,920,000
1. 4. Security installation				**1,400,000 €**
1. 4. 1 Fence including:	1,400	lfm	1,000	1,400,000
1. 5. Utility consumption				**55,462,500 €**
1. 5. 1 Utility consumption				
Electricity	9.0	year	6,000,000	54,000,000.00
Gas	9.0	year	0	0.00
Water	9.0	m³ /a	15,000	202,500.00
Consumables waste handling e.g. waste oil	9.0	€ / a	140,000	1,260,000.00
1. 6. Human resources				**60,002,800 €**
1. 6. 1 Operator	9.0	year	4,172,565	37,553,085
1. 6. 2 COVRA	9.0	year	2,494,413	22,449,715

5.1.1 Land purchase (1.1)

Exploration (1.1.1)

The cost assumption starts from the selected area, which has to be explored from the surface to get more details about the underground conditions. An estimation and breakdown of exploration costs was done by COVRA and provided for the cost estimation (see Table 3-4:). The values match the experiences that were made during conventional mining exploration operations as well as on explorations already performed in context of GDF, especially operations run by BGE.

<u>Nominal cost of land purchase (1.1.2)</u>
The overall space of the enclosed area is 385,000 m^2. The surface facilities, excluding the conditioning facilities, are estimated to take up 345,000 m^2 (compare sketch in Appendix 3). The net area for the planned buildings of the GDF is approximately 100,000 m^2. Additionally, the pathways, parking lots, dump area etc. have to be considered. Compared with similar international surface facilities, the total expansion is a reliable estimate.

The price for the land purchase is provided by COVRA and estimated to be 25 €/m^2.

<u>Notary fee (1.1.3)</u>
Acquiring real estate property is associated with notary costs and related fees. It is assumed that COVRA has to pay such common fees as well. Based on (Justlanded 2023) and (Ten-Law 2023), the following fees and average percentages are considered:

Transfer tax:	6% for industrial buildings
Real estate fee:	2% (upper level, 0.5 to 2%)
Notary fee:	1.5%
Valuation costs:	0.15%
Registration fee:	1.5%
Sum:	**11.15%**

5.1.2 Site infrastructure works (1.2)

<u>Landscaping (1.2.1)</u>
Includes surface preparation/earthworks as well as the installation of a rainwater retention basin. Estimated at 100 €/m^2.

<u>Roads and parking lots (1.2.2)</u>
This position takes into account the permanent road installations as well as the necessary parking lots for the employees and visitors. The covered space is derived from the surface facility sketch (Appendix 3) and areas for parking, belonging to the operation size. Conventional prices for road construction in the Netherlands have been taken as basis assumption, see (CBS 2011) and (Statista 2023). Estimated at 400 €/ m^2.

<u>Green park area (1.2.3)</u>
Prices were requested from a Dutch garden and landscaping company Pasahaco Landscaping (Pasahaco Landscaping 2023) through personal communication with the managing director. Estimation for pure lawn areas with the justification of a simple deconstruction. The creation of the lawn areas is estimated at costs of 20 to 50 €/m^2. The mowing works are estimated to be 5 ct/m^2. The number of mowing intervals leads to a total of 30 times per year. As the amount is relatively low, it is included here and not in the maintenance position.

The total proportion of green areas for industrial areas according to corresponding industry projects in Germany is assumed to be 2 m^2/ employee.

<u>Architect/engineer fee (1.2.4)</u>
Engineering costs are considered as extra cost item for buildings and constructions only. The engineering costs have been estimated at 15% above ground and 30% below ground by COVRA.

For the site infrastructure works covered in 1.2.1 to 1.2.3 and 1.2.5 to 1.2.8, a proportion of 15% is assumed.

<u>Sewage system (1.2.5)</u>
Fresh and waste water management installations are included in this cost item. Prices for the public connection are transferred to the owner of the land only on a pro rata basis. The community covers the difference. It is assumes that out of 1,500 €/m only 450 €/m have to paid by COVRA.

<u>Roads (incl. temporary construction roads) (1.2.6)</u>
The position includes, unlike the roads and parking lots (1.2.2) position, the temporarily needed installation of roads during the construction period. As a basis for the price estimation, conventional prices for road construction in the Netherlands are taken into account, just as in position 1.2.2.

<u>Electricity (1.2.7)</u>
The connection to the electricity net is considered in this position. Estimated connecting point for the installations is 1,500 m from site, according to the clay repository planning.

<u>Telecommunications (1.2.8)</u>
The connection to the provider including all cable connections underground in included in this position. Estimated connecting point for the installations is 1,500 m from site, similar to the clay repository planning.

5.1.3 Site facility construction (1.3)

<u>Utility buildings (1.3.1)</u>
Temporary container facilities for site preparation and construction as well as for the initial phase of shaft sinking.

5.1.4 Utility consumption (1.5)

<u>Electricity (1.5.1)</u>
The annual consumption is assumed to stay at the same level throughout all project phases. Ventilation accounts for the highest percentage of the total energy consumption. Therefore, the changes in operating phases as e.g. excavation or disposal have no relevant influence on the total amount. Reduced energy consumptions during site selection and monitoring serve as a safety factor.

<u>Gas (1.5.2)</u>
Gas prices according to Dutch market prices are estimated at 25 ct/kWh. At the planned beginning of construction, only electrically driven vehicles will be in use. Furthermore, there will

be no gas needed for heating. Therefore, the consumption of gas and diesel is estimated to be zero. The possibility of keeping a diesel-powered emergency generator on hand is not considered in this calculation.

Water (1.5.3)
Water price according to Dutch market prices estimated at 1.50 €/m³. The consumption is estimated based on the average consumption rates of the facilities of BGE. Special operations with more water consumption (e.g. concrete work for foundations) are considered with a mark-up (Waternet 2023).

Consumables waste handling (1.5.4)
The consumables waste handling cost item includes the fees for the disposal of e.g. waste oil. The prices for the purchase of the consumables are included in the acquisition prices for the belonging items and the maintenance position. E.g., a mine car delivery includes the assembly and commissioning on site and therefore, the consumable already on board.

5.1.5 Security installation construction (1.4)

Fence (1.4.1)
Including perimeter gate, monitoring system, access control system, and automatic entrance detection system. The fence system is a state-of-the-art fully equipped fence & detection system. Prices were requested from HAVERKAMP GmbH (HAVERKAMP GmbH 2023) in a personal communication. The total length of the fence, derived from the surface facility planning, corresponds to the dimensions of the opera clay planning.

5.1.6 Human resources (1.6)

See chapter 3.2.4 for the human resources estimation. Total amounts per year and phase were calculated there and are multiplied by the duration per phase here.

5.2 Repository construction (2)

Table 5-2: Repository construction cost assesment

2. Repository construction				**1,228,397,684 €**
2. 1. Construction and outfitting shafts				**408,200,000 €**
2. 1. 1 Personnel shaft construction	850	m	70,000	59,500,000
2. 1. 2 Personnel shaft hoisting system		unit		40,000,000
2. 1. 3 Waste shaft construction	750	m	100,000	75,000,000
2. 1. 4 Waste shaft hoisting system		unit		60,000,000
2. 1. 5 Ventilation shaft construction	850	m	70,000	59,500,000
2. 1. 6 Ventilation shaft hoisting system		unit		20,000,000
2. 1. 7 Architect/engineer fee	30	%	314,000,000.00 €	94,200,000
2. 2. Construction and outfitting upper level main area				**6,969,052 €**
2. 2. 1 Excavation cost CM	19,994	m³	3	59,982
2. 2. 2 Continous Miner	1	piece	2,500,000	2,500,000
2. 2. 3 Continous miner maintenance & other vehicles maintenance	2	a	300,000	600,000
2. 2. 4 Roof bolting machine	1	piece	450,000	450,000
	10	n/100m	20	2,000
2. 2. 5 Scaler	1	piece	500,000	500,000
2. 2. 6 LHD	1	piece	600,000	600,000
2. 2. 7 Dumper	1	piece	450,000	450,000
2. 2. 8 Working platform	1	piece	200,000	200,000
2. 2. 9 Mine car	4	piece	150,000	600,000
2. 2. 10 Outfitting (electricity, fire protection)	71	m	100	7,070
2. 2. 11 Infrastructure area equipment	1	piece	1,000,000	1,000,000
Incl. workshop, drill core storage, charging stations, rescue room, decontamination & monitoring room, parking area, group room		m³		
2. 3. Construction and outfitting HLW main area				**5,946,847 €**
2. 3. 1 Ramp construction inc. hoisting system	1,920	m	2,300	4,416,000
2. 3. 2 Excavation cost CM	77,799	m³	3	233,396
2. 3. 3 Continous miner		piece	2,500,000	
2. 3. 4 Continous miner maintenance & other vehicles maintenance	2.0	a	300,000	600,000
2. 3. 5 Roof bolting machine		piece		
	10	n/100m	20	3,872
2. 3. 6 Scaler		piece		
2. 3. 7 LHD		piece		
2. 3. 8 Dumper		piece		
2. 3. 9 Working platform		piece		
2. 3. 10 Mine car		piece		
2. 3. 11 Outfitting (electricity, fire protection)	1,936	m	100	193,580
2. 3. 12 Infrastructure area equipment	1	piece	500,000	500,000
Incl. workshop, drill core storage, charging stations, rescue room, decontamination & monitoring room, parking area, group room		m³		
2. 4. Construction and outfitting HLW disposal area				**2,181,568 €**
2. 4. 1 Excavation cost CM	144,496	m³	3	433,488
2. 4. 2 Continous miner		piece	2,500,000	
2. 4. 3 Continous miner maintenance & other vehicles maintenance	4.0	a	300,000	1,200,000
2. 4. 4 Roof bolting machine		piece		
	10	n/100m	20	11,080
2. 4. 5 Scaler		piece		
2. 4. 6 LHD		piece		
2. 4. 7 Dumper		piece		
2. 4. 8 Working platform		piece		
2. 4. 9 Mine car		piece		
2. 4. 10 Outfitting (electricity, fire protection)	5,370	m	100	537,000
2. 4. 11 Infrastructure area equipment		piece	100,000	
Incl. workshop, drill core storage, charging stations, rescue room, decontamination & monitoring room, parking area, group room		m³		

Table 5-3: Repository construction cost assesment

2. 5. Construction and outfitting LILW and (TE)NORM disposal galleries				**5,048,502 €**
2. 5. 1 Excavation cost CM	336,164	m³	3	1,008,492
2. 5. 2 Continous miner		piece		
2. 5. 3 Continous miner maintenance & other vehicles maintenance	11	a	300,000	3,300,000
2. 5. 4 Roof bolting machine		piece		
	10	n/100m	20	14,510
2. 5. 5 Scaler		piece		
2. 5. 6 LHD		piece		
2. 5. 7 Dumper		piece		
2. 5. 8 Working platform		piece		
2. 5. 9 Mine car		piece		
2. 5. 10 Outfitting (electricity, fire protection)	7,255	m	100	725,500
2. 5. 11 Infrastructure area equipment		piece	100,000	
Incl. workshop, drill core storage, charging stations, rescue room, decontamination & monitoring room, parking area, group room		m³		
2. 6. Site facility construction				**289,258,350 €**
2. 6. 1 Transformer station		unit	126,000	126,000
2. 6. 2 Emergency power system station		unit	3,375,000	3,375,000
2. 6. 3 Fuel tank building		unit	412,500	412,500
2. 6. 4 Ventilation building		unit	6,450,000	16,450,000
Main fan, technical equipment		unit	10,000,000	
2. 6. 5 Administration building (incl. central control)		unit	17,331,500	17,331,500
2. 6. 6 Visitors centre		unit	3,264,000	3,264,000
2. 6. 7 Handling facility (incl. entrance, drying, hot cell, decontamination, transport- and supplying hall)		unit	97,200,000	97,200,000
2. 6. 8 Shaft tower waste shaft		unit	30,000,000	30,000,000
2. 6. 9 Shaft hall access shaft		unit	6,000,000	6,000,000
2. 6. 10 Shaft tower access shaft		unit	20,000,000	20,000,000
2. 6. 11 Locker room access		unit	2,975,000	2,975,000
2. 6. 12 Engine building access shaft		unit	1,500,000	1,500,000
2. 6. 13 Ventilation shaft building incl. equipment		unit	10,000,000	10,000,000
2. 6. 14 Workshops, vehicle storage		unit	9,000,000	9,000,000
2. 6. 15 Guardhouse		unit	510,000	510,000
2. 6. 16 Water supply / waste water		unit	2,700,000	2,700,000
2. 6. 17 Weather station		unit	1,785,000	1,785,000
2. 6. 18 Laboratory / drill core storage		unit	12,750,000	12,750,000
2. 6. 19 Washing place vehicles		unit	200,000	200,000
2. 6. 20 Dump		m³		0
2. 6. 21 Engine building ventilation (transformer station & emergency power station)		unit	3,000,000	3,000,000
2. 6. 22 Collection and treatment of radioactive waste		unit	450,000	450,000
2. 6. 23 Fire station		unit	7,500,000	7,500,000
6. 24 Backfill processing plant		unit	5,000,000	5,000,000
2. 6. 25 Architect/engineer fee	15	%		37,729,350
		Total	251,529,000.00	
2. 7. Maintenance surface				**124,730,840 €**
2. 7. 1 Maintenance surface facilities	5,030,580.00	%	2.00	115,703,340
2. 7. 2 Maintenance surface areas	392,500.00	%	1.00	9,027,500
2. 8. Insurance				**34,372,000 €**
2. 8. 1 Combined construction/assembly insurance incl. assembly equipment		year	200,000	4,600,000
2. 8. 2 Builder's liability insurance		total	3,000,000	3,000,000
2. 8. 3 Public liability insurance conventional		year	14,000	322,000
2. 8. 4 Public liability insurance nuclear		year	600,000	13,800,000
2. 8. 5 Nuclear insurance		year	550,000	12,650,000
2. 8. 6 Further insurance (visitors etc.)		year		0
2. 9. Utility consumption				**141,737,500 €**
2. 9. 1 Utility consumption				
Electricity	23.00	year	6,000,000	138,000,000.00
Water	23.00	m³ /a	15,000	517,500.00
Consumables waste handling e.g. waste oil	23.00	€ / a	140,000	3,220,000.00
2. 10 Human resources				**209,953,025 €**
2. 10 1 Operator	23	year	6,331,036	145,613,828
2. 10 2 COVRA	23	year	2,797,356	64,339,197

5.2.1 Construction below ground

5.2.1.1 Construction and outfitting shafts and ramp (2.1)

Personnel shaft construction (2.1.1)
The personnel shaft as well as the ventilation shaft are estimated to have a diameter of 5 m each. The shaft sinking and lining will be done by a shaft sinking company. The shaft sinking platform is a customised construction for the shaft sinking and lining process itself and will be replaced by the final hoisting equipment after finishing the shaft construction. The lining method for the cost estimation is a sliding shaft lining. The main components are concrete moulded blocks, an asphalt layer, steel sealing layer, and a concrete layer. All prices estimated for the surface connection construction are based on experience gained during BGE operations, mainly run by sub-contractor operations.

Personnel shaft hoisting system (2.1.2)
The personnel shaft is supplied with fresh air intake to ensure a safe air quality without any risk of contamination. The hoisting cage for the employee transport is installed here. The transportation of conventional material will also be done here to separate the conventional processes from the waste handling processes. Shaft hoisting system for construction operation, payload approximately 30 tons, including auxiliary hoisting device and complete hoisting tower included.

Waste shaft construction (2.1.3)
The transport shaft is planned with a diameter of 8 m to provide enough space for the disposal container transport from the surface to the deep geological facility. The dimensions as well as the costing are based on the experience and planning of similar projects. The construction costs of the shaft, including the lining but excluding further installations, especially the hoisting system, is estimated to be 100,000 € / m. This value also includes the additional costs for the ventilation works during the construction process.

Waste shaft hoisting system (2.1.4)
The hoisting system for the waste transport sets higher requirements for the construction due to the weight load, the special handling process of the waste containers, and the high standard safety requirements. Shaft hoisting system for waste transport operation, payload approximately 100 tons, including auxiliary hoisting device and complete hoisting tower.

Ventilation shaft construction (2.1.5)
The ventilation shaft has the same diameter as the personnel shaft. Even though a smaller diameter for the ventilation shaft would be cheaper and would reduce the cavity that needs to be backfilled, the ventilation shaft is also used as emergency shaft and therefore planned with the same dimension as the personnel shaft. Therefore, it has to be equipped with a hoisting system or at least a mobile hoisting equipment to ensure a fast evacuation of the miners in case of emergency.

Ventilation shaft hoisting system (2.1.6)
The hoisting system can either be a permanently installed system or a mobile hoisting system that is stored nearby. Whatever will eventually be decided, at this planning state, the costs will be estimated to be equal. The equipment needed for the ventilation is considered in the surface facility construction phase.

Architect/engineer fee (2.1.7)
See 1.2.4.

5.2.1.2 Construction and outfitting upper level main area (2.2)

The cost estimation of the vehicles requires electrical drive. Therefore, a battery package that covers the 1-shift system is included in the price assumption. Underground mining equipment is supposed to have a lifetime of up to 20 years of operation. Electrically driven equipment needs less maintenance compared with conventional mining equipment and its lifetime is estimated to be much longer, except wear parts. The battery pack is also considered as a wear part. The estimated lifetime for a battery pack is already between 8-10 years and will be enhanced until the planned beginning of the COVRA operations. Therefore, a renewal of the battery pack or a complete machine is not part of the main calculation in this cost study. The renewal of a machine or a battery pack will be considered as a risk.

Excavation cost continuous miner (2.2.1)
Prices taken from industry experience gained in operating processes in rock salt mines. Estimated at 3 €/m³. The unit costs include only the excavation process without personnel cost and maintenance.

Continuous Miner (2.2.2)
Price assumption is based on the market price for standard Continuous Miners.

Continuous Miner maintenance & other vehicles maintenance (2.2.3)
Prices for Continuous Miner maintenance based on experience during operation at Heilbronn salt mine (10% of acquisition costs). 50,000 € (approximately 2%) additional for other vehicles in total is estimated based on expert judgement and experience from similar conventional mining operations. Personnel costs for the maintenance operations are included in the total personnel costs per period.

Roof bolting machine (2.2.4)
Prices taken from industry standard. Number of roof anchors estimated at 10 anchors per 100-m-excavation. Due to homogeneous conditions, anchor bolts are only necessary for supply lining. 18 € for each anchor is estimated according to average price given by (DSI Underground 2023) by phone correspondence. Another offer given by Bochumer Eisenhütte GmbH & Co. KG (BE-TH 2023) includes expanding sleeve anchors (d=18m, L= 1,800 mm), smooth steel E360, standard anchor with thread length 140/120mm, 5-winged expansion anchor, anchor nut SW36, plate, cutting tolerance bar +/-100 mm, weight approximately 4.1 kg =18.30 €/piece. Including a safety factor for installation work, 20 €/anchor is estimated.

Scaler (2.2.5)
The scaler is especially used in salt mines for smooth preparations of the roof, after the excavation processes. The continuous miner already creates a smooth surface but in case of disturbances and risks of falling rocks, re-cutting is needed. Scalers are also used for re-cutting due to processes caused by convergence. Prices taken from industry standard.

LHD (2.2.6)
An LHD (Load, Haul, and Dump Machine) is used for the loading and transportation of bulk material in a one-vehicle operation. Therefore, the LHD has a shovel in front to dump the material and has a compact and shallow design for operations in narrow tunnel systems. Remote control is state of the art and in use for unprotected mining areas. Remote control in use for GDFs offers the chance to reduce the duration of stay in areas close to the disposal areas. Prices taken from industry standard.

Dumper (2.2.7)
A dumper is used to support the LHD during the material removing operations. Especially for longer driving distances, it is more efficient to use a dumper instead of an LHD. Prices taken from industry standard.

Working platform (2.2.8)
Working platforms are needed for roof operations and others. Prices taken from industry standard.

Mine car (2.2.9)
Mine cars are compact vehicles for underground mining operations with multiple possible functions. Most common is the passenger transport underground. As basic assumption, 4 mine cars are estimated. The vehicles can be equipped as rescue cars, fire trucks, or maintenance trucks. Prices taken from industry standard.

Outfitting (electricity, fire protection) (2.2.10)
The outfitting position covers the installation of the supplying equipment within the drifts. This includes fire protection installations, the ventilation lining (further equipment like additional doors are also included here), electricity, water, and compressed air supply.

According to standard underground mining operations in salt mines, one electricity station every 300 m is needed.

Architect/engineer fee (2.2.11)
See 1.2.4.

5.2.1.3 Construction and outfitting LILW and (TE)NORM disposal galleries (2.3)

Ramp construction including hoisting system (2.3.1)
The ramp construction is also done by the continuous miner that is already available on site. The slope of the ramp can easily be handled by the continuous miner. The outfitting of the ramp is similar to the outfitting of the other tunnels and included in the outfitting cost item. The length of the ramp of 1,920 m leads to a long construction period.

5.2.1.4 Construction and outfitting HAW main area (2.4)

Cost items identical to *Construction and outfitting upper level main area 5.2.2*.

5.2.1.5 Construction and outfitting HAW disposal area (2.5)

Cost items identical to *Construction and outfitting upper level main area 5.2.2*.

5.2.2 Construction above ground

5.2.2.1 Surface facilities (2.6)

For the calculation of the surface facilities, an exemplary planning of the surface area including all building dimensions was done. The planning is based on planning experience for BGE site facilities as well as comparable international planning for surface facilities. The calculation is based on the estimation of unit prices per m³ for enclosed space (see Table 5-4:). Since the height of buildings at a mine surface facility varies a lot (e.g. shaft building), the cubic meter unit prices consider the cost impact of varying height better than square meter prizes. Six categories of building types regarding the complexity and function were set based on industry standards and comparable projects for planning of surface facilities in conventional mines and waste disposal facilities. The unit prices include the basic technical installations like e.g. electrical wiring, sanitary installations. The dimensions of the buildings are given in the surface facility sketch see Appendix 3.

Table 5-4: Building unit prices

Category	Unit prices for object categories	Description and explanation	Unit price €/m³
I	Administration buildings (limited technical function)	E.g. office building, garage, workshop (including technical installations like sanitary, heating, cooling, electrical installation, communication)	850
II	Industrial building, technical operating buildings (conventional)	E.g. ventilation building, electrical building (including technical installations like sanitary, heating, cooling, electrical installation, communication)	500
III	Industrial building, technical operating buildings (nuclear low level simple)	E.g. buffer (storage) hall (including technical installations like sanitary, heating, cooling, electrical installation, communication)	750
IV	Industrial building, technical operating buildings (nuclear high level complex)	E.g. handling facilities for nuclear waste (including technical installations like sanitary, heating, cooling, electrical installation, communication)	1000

Category	Unit prices for object categories	Description and explanation	Unit price €/m³
V	Paved areas	Roads, parking areas, operating areas complete with substructure, cover layer incl. edgings, drainage facilities, furnishing according to their usage	400/m²
VI	Protection / safety	Incl. access doors without technical equipment e.g. monitoring, detection, drive-through protection, access control	1000/m

Transformer station (2.6.1)
The transformer station building hosts the equipment to generate, transmit, and distribute the electricity of the repository. Voltage is transformed to high or low voltage.

Emergency power system station (2.6.2)
Emergency power systems provide automatic backup power in the event of normal power loss.

Fuel tank building (2.6.3)
Even though there will only be electrically driven vehicles on site, consumables like lubricating greases, engine oil, and optional diesel for the emergency generator system have to be kept in stock. The fuel tank building is also used for the collection of used consumables.

Ventilation building (2.6.4)
The acquisition costs for the main fan, additional supporting and backup fans as well as the related technical equipment above surface are included in this position. The software and further IT equipment for a ventilation on demand system is also included. Since the energy consumption of the mine ventilation has the highest impact on the total energy consumption, ventilation on demand systems are state of the art in new mining projects.

Administration building (incl. central control) (2.6.5)
The administration building hosts the space needed for the office staff. The central control of the repository is also located here. The locker rooms for the mine visitors are part of the administration building and are directly connected to the access shaft building.

Visitor centre (2.6.6)
The visitor centre outside of the security area is part of the public relations work.

Handling facility (incl. entrance, drying, hot cell, decontamination, transport- and supplying hall) (2.6.7)
The handling facility is the most sensitive part of the surface facilities (beside the conditioning facility). The handling of the waste containers from the incoming inspection to the loading of the hoisting cage is done here. The building has a separate locker room for the staff to separate the conventional mining operations from the waste handling.

Shaft tower waste shaft (2.6.8)
The cost item shaft tower includes the building construction as well as the technical equipment, excluding the hoisting system itself. The shaft hall for the waste shaft is connected to the handling facility and imputed there, since the containers are transported inside the handling facility building directly to the waste shaft loading.

Shaft hall access shaft (2.6.9)
The access shaft hall is connected to the administration building. The mine workers locker room is also connected to the shaft hall. From the administration building, visitors are also able to enter the access shaft hall.

Shaft tower access shaft (2.6.10)
The cost item shaft tower includes the technical equipment, excluding the hoisting system itself.

Locker room access (2.6.11)
The locker room is connected to the access shaft hall and the administration building. It is used for all employees of non-nuclear areas above – and underground.

Engine building access shaft (2.6.12)
The engine building hosts all technical equipment for the operations of the surface facility. It includes e.g. turbines and generators. On the ceiling of the building, there are one or two bridge cranes to move heavy machine parts. The control could also be located here.

Ventilation shaft building, including equipment (2.6.13)
The cost item ventilation shaft building estimates not only the construction costs but also the outfitting of the shaft hall, including the related ventilation equipment.

Workshops, vehicle storage (2.6.14)
Conventional building for vehicle storage and workshops. Mobile hoisting equipment can be also stored here.

Guardhouse (2.6.15)
The guardhouse is located at the entrance gate for entrance control of employees, visitors, and deliveries.

Water supply / waste water (2.6.16)
Fresh water supply and waste water treatment or storage.

Weather station (2.6.17)
Conventional weather station for monitoring of the environment.

Laboratory / drill core storage (2.6.18)
During the excavation processes, a continuous exploration is needed to get more detailed data about the underground conditions. Drill cores will be extracted and need to be investigated.

The storage as well as further conventional laboratory tests will be done at the laboratory / drill core building.

Washing place vehicles (2.6.19)
Mining operations, especially at the surface facility during the construction phase but also during normal operations, cause a pollution of the vehicles. In the sense of maintenance and lifecycle extension, the vehicles have to be cleaned regularly.

Dump (2.6.20)
The planning concept for this cost study assumes a dump area included in the surface facility of the GDF. Therefore, no fees for the storage of the excavated material will be charged. Costs for dumping of the material are included in the transportation/movement of the material and the operator personnel costs. Remaining material can be handled in the course of re-cultivation after site closure.

Engine building ventilation (transformer station & emergency power station) (2.6.21)
The ventilation shaft building is connected to the engine building, where all the equipment for the ventilation and power supply from ventilation shaft site is hosted. An emergency system for a continuous power supply in case of a lock down is also placed here to ensure a safe operation in emergency cases.

Facility for the collection and treatment of radioactive waste (2.6.22)
The collection and treatment of radioactive waste is a nuclear facility necessary for the collection of e.g. used contaminated water or other waste from nuclear handling processes in special containers. A separated ventilation circuit is needed to avoid contaminations of the environment.

Fire station (2.6.23)
For safety reasons and rapid intervention in the event of fire on site, a fire station is provided. Equipment for the mine rescue team and, if required, a fire truck are stored here. A first aid station can also be included, in addition to the one necessary at the administration building.

Backfill processing plant (2.6.24)
Silo plants for storage of mortar, cement, sand, bentonite, complete including feeding, unloading equipment.

Preparation plant for dry mortar/concrete/sand/bentonite mixes.

Architect/engineer fee (2.6.25)
See 1.2.4.

5.2.3 Maintenance surface (2.7)

Maintenance surface facility (2.7.1)
Two percent of the acquisition price are estimated as maintenance costs for buildings. The order of magnitude matches to market standard maintenance amounts. The maintenance is

estimated to 23 years, even though the construction of the surface buildings is within the first 10 years still ongoing. This covers the accumulation of reserves.

Maintenance surface areas (2.7.2)
One percent of acquisition costs for surface areas are estimated for this cost item. Covered are e.g. small repairs, winter service, and landscape maintenance. The amount is verified by market prices among others with Pasahaco Landscaping (Pasahaco Landscaping 2023), (telephone correspondence with the managing director).

5.2.4 Insurance (2.8)

For covering the risks during operation, there are two options available that have to be weighted. On the one hand there is the option of self-carrying. If the operator assumes that the risk can be pushed to a minimum due to a risk minimisation programme, it may be an option to carry the risk by himself and save the high costs for the insurance cover. On the other hand, some risks have to be covered and/or cannot be put to self-carrying. These risks have to be transferred to an insurance company by insurance coverage. Experience has shown that insurers have strong reservations against risks related to the field of radioactive waste disposal. Therefore, the number of companies offering an insurance cover is limited and the prices are above the average market prices for similar insurances. Typical self-carrying risks are damage due to faulty planning, damage during excavation (it can be assumed that the underground conditions are known well enough to avoid major damage), storage and dumping of excavated material (planning avoids major risks), business interruption damage (no risk assumed, but considerable additional costs with increased operation time).

The imputed consideration of the insurance item starts within the second phase, since the amount for Phase 1 is negligibly small at this planning point and the insurances are instead considered a little longer than probably needed in that dimension.

Combined construction/assembly insurance, incl. assembly equipment (2.8.1)
For all projects, the operations of construction and assembly risks have to be covered by the operator. The sub-operators assigned by COVRA will have their own insurance and charge COVRA with the related fee. Nevertheless COVRA as the overall operator has to cover all processes by themselves. What will be covered in detail has to be negotiated with the insurance companies. The estimated amounts are offered market prices for similar operations. Due to the early state of the GDF project and a rapidly changing insurance market, the prices are subject to a high degree of uncertainty.

Builder's liability insurance (2.8.2)
The insurance includes the environmental liability as well as seismic damage induced by excavation operations that are demanded by law. Offers by insurers for similar projects have been taken into account for estimating the costs. Dutch law does not require parties involved in construction projects to take out insurances. Over the years, however, it has become common practice to take out insurances to cover a number of construction-related risks.

Public liability insurance conventional (2.8.3)

Conventional insurance, depending on market prices. Offers by insurers for similar projects have been taken into account for estimating the costs.

<u>Public liability insurance nuclear (2.8.4)</u>
A very specific insurance for nuclear operations. The providers on the market are few and the prices due to the uncertainty on insurers side high. Therefore, the prices are significantly higher than conventional insurances. Offers by insurers for similar projects have been taken into account for estimating the costs.

<u>Nuclear insurance (2.8.5)</u>
Annual costs given by COVRA.

<u>Further insurance (visitors etc.) (2.8.6)</u>
Further insurance covering the personnel and visitors' insurances. Offers by insurers for similar projects have been taken into account for estimating the costs.

5.2.5 Utility consumption (2.9)

Cost items identical to Utility Consumption (1.5)

5.2.6 Human resources (2.10)

See chapter 3.2.4 for the human resources estimation. Total amounts per year and phase were calculated there and are multiplied by the duration per phase here.

5.3 Operation HLW (3)

Table 5-5: HLW disposal campaign cost assessment

3 HLW disposal campaign				**47,339,669 €**
3. 1. Disposal				**1,850,000 €**
3. 1. 1 Waste transport cart	1	unit	1,500,000	1,500,000
3. 1. 2 Waste transport cart maintenance	1	a	150,000	150,000
3. 1. 3 Backfilling equipment maintenance	1	a	200,000	200,000
3. 2 Backfilling and sealing				**18,036,480 €**
3. 2. 1 Disposal gallery heat-generating				12,625,536
3. 2. 2 Disposal gallery non heat-generating				5,410,944
3. 3. Maintenance surface				**5,423,080 €**
3. 3. 1 Maintenance surface facilities	5,030,580.00	%	2.00	5,030,580
3. 3. 2 Maintenance surface areas	392,500.00	%	1.00	392,500
3. 4. Insurance				**4,364,000 €**
3. 4. 1 Combined construction/assembly insurance incl. assembly equipment		year	200,000	200,000
3. 4. 2 Builder's liability insurance		total	3,000,000	3,000,000
3. 4. 3 Public liability insurance conventional		year	14,000	14,000
3. 4. 4 Public liability insurance nuclear		year	600,000	600,000
3. 4. 5 Nuclear insurance		year	550,000	550,000
3. 4. 6 Further insurance (visitors etc.)		year		0
3. 5. Utility consumption				**6,162,500 €**
3. 5. 1 Utility consumption				
Electricity	1	year	6,000,000	6,000,000
Water	1	m³ /a	15,000	22,500
Consumables waste handling e.g. waste oil	1	€ / a	140,000	140,000
3. 6. Human resources				**11,503,609 €**
3. 6. 1 Operator	1	year	8,056,076	8,056,076
3. 6. 2 COVRA	1	year	3,447,534	3,447,534

5.3.1 Disposal (3.1)

Waste transport cart (3.1.1)
The price estimation for a waste transport cart for the disposal processes underground were already done by Posiva for the disposal operations at Olkilouto: *"The total cost estimate for completing the system came to 1 500 000 Euros, of which 400 000 Euros were planning costs and 1 100 000 Euros were installation as well as manufacturing costs."* - Posiva Working Report 2008-38 (Wendelin & Suikki 2008).

Waste transport cart maintenance (3.1.2)
The disposal processes are subject to sensitive safety regulations due to the handling of high level waste material. Therefore, the effort for maintenance is high to ensure a safe operation and avoid downtimes and incidents. 10 percent of the acquisition costs per year are assumed for the maintenance processes.

Backfilling equipment maintenance (3.1.3)
The high stress on the machine leads to a high maintenance intensity. Therefore, the amount is set to 10 percent of the acquisition cost analogous to the continuous miner, which is also exposed to a high stress load. Furthermore, the immediate backfilling supports a safe operation during the disposal campaign of high-level waste.

5.3.2 Closure (3.2)

According to the general arrangement drawings of the GDF layout provided by COVRA, the following assumptions for the backfilling operation were made (see Table 5-6:):

Table 5-6: Assumptions for the backfilling operation

Lower level [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	€/m³	m³ total	Sum [€]
Disposal gallery heat-generating	5.6	4	2,310	22.4	244	51,744	12,625,536
Disposal gallery non heat-generating	5.6	4	990	22.4	244	22,176	5,410,944

5.3.3 Maintenance surface (3.3)

See (2.7)

5.3.4 Insurance (3.4)

Cost items identical to insurance (2.8)

5.3.5 Utility consumption (3.5)

Cost items identically to Utility Consumption (1.5)

5.3.6 Human resources (3.6)

See chapter 3.2.4 for the human resources estimation. Total amounts per year and phase were calculated there and are multiplied by the duration per phase here.

5.4 Operation LILW and (TE)NORM (4)

Table 5-7: LILW and (TE)NORM waste disposal campaign cost assessment

4 LILW and (TE)NORM waste disposal campaign				**496,561,720 €**
4. 1. Disposal				**6,020,000 €**
4. 1. 1 Waste transport cart / forklift	2	unit	300,000	600,000
4. 1. 2 Waste transport cart maintenance	17	a	60,000	1,020,000
4. 1. 3 Backfilling equipment	1	unit	1,000,000	1,000,000
4. 1. 4 Backfilling equipment maintenance	17	a	200,000	3,400,000
4. 2. Backfilling and sealing				**71,837,504 €**
4. 2. 1 Disposal gallery				10,384,640
4. 2. 2 Disposal room				61,452,864
4. 3. Utility consumption				**104,762,500 €**
4. 3. 1 Utility consumption				
Electricity	17	year	6,000,000	102,000,000
Water	17	m³ /a	15,000	382,500
Consumables waste handling e.g. waste oil	17	€ / a	140,000	2,380,000
4. 4. Maintenance surface				**92,192,360 €**
4. 4. 1 Maintenance surface facilities	5,030,580.00	%	2.00	85,519,860
4. 4. 2 Maintenance surface areas	392,500.00	%	1.00	6,672,500
4. 5. Insurance				**26,188,000 €**
4. 5. 1 Combined construction/assembly insurance incl. assembly equipment		year	200,000	3,400,000
4. 5. 2 Builder's liability insurance		total	3,000,000	3,000,000
4. 5. 3 Public liability insurance conventional		year	14,000	238,000
4. 5. 4 Public liability insurance nuclear		year	600,000	10,200,000
4. 5. 5 Nuclear insurance		year	550,000	9,350,000
4. 5. 6 Further insurance (visitors etc.)		year		0
4. 6. Human resources				**195,561,356 €**
4. 6. 1 Operator	17	year	8,056,076	136,953,285
4. 6. 2 COVRA	17	year	3,447,534	58,608,071

5.4.1 Disposal (4.1)

Waste transport cart (4.1.1)

For the emplacement of LILW and (TE)NORM waste, an electrically driven conventional heavy weight forklift is taken as basis for the price estimation. To cover maintenance and charging operations, an amount of two carts is calculated. Due to the long time horizon for the emplacement of the LILW and (TE)NORM waste during a 1-shift operation, a complete replacement during the operating time is probable and covered within the maintenance position.

Waste transport cart maintenance (4.1.2)

For the maintenance of the emplacement equipment, an amount of 10 percent of the acquisition price per year is calculated.

Backfilling equipment (4.1.3)

The price estimation is based on the assumption of a conventional machine for centrifugal backfilling operations. Backfilling operations with crushed salt are state of the art in the salt mining industry. Due to the high stress on the machine during operation, it is assumed that at least one replacement will be necessary during the project time.

Backfilling equipment maintenance (4.1.4)
The high stress on the machine leads to a high maintenance intensity. Therefore, the amount is set to 10 percent of the acquisition costs analogous to the continuous miner, which is also exposed to a high stress load.

5.4.2 Closure (4.2)

Market prices for construction material are subject to daily fluctuation. Therefore, an average price based on purchasing experience was set to: 232 €/t for rock salt, 667 €/t for MgO, and 81 €/t for $MgCl_2$ (based on BGE TECHNOLOGY operations in 2020). As reference mixture, the so-called A1 concrete is considered. The mixture includes 63.7% rock salt, 11.3% MgO, and 25.0% $MgCl_2$-solution. In total and inflation-adjusted, a price of 244 €/t for MgO-concrete is assumed.

The rock salt price covers the processing costs for the excavation material with the necessary quality grade. Even though the disposal areas will be backfilled with the MgO-concrete composition and the areas outside the waste disposal are only backfilled with excavated crushed rock salt material, the price assumption stays the same due to the high percentage of rock salt in the composition. Since the processing of the excavation material causes also costs and the assumption of the market prices for backfill material are subject to a great deal of uncertainty, the price of 244 €/t is also assumed for the backfilling with processed excavation material. The material for sealing elements planned for the backfilling and closure operations is also covered by the average price of 244 €/m³. The additional manpower effort for the construction of the sealing elements is covered by the human resources and the timeframe for the backfilling and sealing operations.

According to the general arrangement drawings of the GDF layout provided by COVRA, the following assumptions for the backfilling operation were made (see Table 5-8:):

Table 5-8: Upper level backfilling cost assessment

Upper level [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	€/m³	m³ total	Sum [€]
Disposal gallery	5.6	4	1,900	22.4	244	42,560	10,384,640
Disposal room	10.6	6	3,960	63.6	244	251,856	61,452,864

5.4.3 Utility consumption (4.3)

Cost items identically to Utility Consumption (1.5)

5.4.4 Maintenance surface (4.4)

See (2.7)

5.4.5 Insurance (4.5)

Cost items identically to Insurance (2.8)

5.4.6 Human resources (4.6)

See chapter 3.2.4 for the human resources estimation. Total amounts per year and phase were calculated there and are multiplied by the duration per phase here.

5.4.7 Observation (5)

Table 5-9: Underground observation cost assessment

5. Underground observation				**134,585,102 €**
5. 1. Maintenance surface				**54,230,800 €**
5. 5. 1 Maintenance surface facilities	5,030,580.00	%	2.00	50,305,800
5. 5. 2 Maintenance surface areas	392,500.00	%	1.00	3,925,000
5. 2. Insurance				**16,640,000 €**
5. 2. 1 Combined construction/assembly insurance incl. assembly equipment		year	200,000	2,000,000
5. 2. 2 Builder's liability insurance		total	3,000,000	3,000,000
5. 2. 3 Public liability insurance conventional		year	14,000	140,000
5. 2. 4 Public liability insurance nuclear		year	600,000	6,000,000
5. 2. 5 Nuclear insurance		year	550,000	5,500,000
5. 2. 6 Further insurance (visitors etc.)		year		0
5. 3. Utility consumption				**20,425,000 €**
4. 3. 1 Utility consumption				
Electricity	10	year	2,000,000	20,000,000
Water	10	m³ /a	5,000	75,000
Consumables waste handling e.g. waste oil	10	€ / a	35,000	350,000
5. 4. Human resources				**43,289,302 €**
5. 4. 1 Operator	10	year	1,823,002	18,230,020
5. 4. 2 COVRA	10	year	2,505,928	25,059,282

5.4.8 Maintenance surface (5.1)

See (2.7)

5.4.9 Insurance (5.2)

Cost items identical to insurance (2.8)

The amount is considered to stay as high as during the disposal phase to cover the dismantling as well within this position. In general, as already mentioned, the estimation of the insurance costs contains a high degree of uncertainty.

5.4.10 Utility consumption (5.3)

Cost items identical to utility consumption (1.5)

5.4.11 Human resources (5.4)

See chapter 3.2.4 for the human resources estimation. Total amounts per year and phase were calculated there and are multiplied by the duration per phase here.

5.5 Post Closure (6)

Table 5-10: Repository closure cost assessment

6			**Repository closure**				**780,898,727 €**
6.	**1.**		**Backfilling and sealing galleries and ramp**				**49,365,231 €**
6.	1.	1	Ventilation tunnel lower level				6,668,032
6.	1.	2	Service tunnel lower level				2,131,584
6.	1.	3	Transport tunnel lower level				6,517,728
6.	1.	4	Infrastructure area lower level				243,649
6.	1.	5	Ramp				18,739,200
6.	1.	6	Ventilation tunnel upper level				4,755,072
6.	1.	7	Transport tunnel upper level				5,431,440
6.	1.	8	Infrastructure upper level				4,878,526
6.	**2.**		**Backfilling and sealing shafts**				**450,000,000 €**
6.	2.	1	Dismantling of the underground plant technology		total		50,000,000
6.	2.	2	Dismantling hoisting systems and rent of 2 temporary hoisting systems		total		200,000,000
6.	2.	3	Dismantling and removal of the shaft interior		total		50,000,000
6.	2.	4	Shaft backfill & closure structure (3 times)	3	€	50,000,000	150,000,000
6.	**3.**		**Dismantling and decommissioning nuclear facilities**				**100,000,000 €**
6.	3.	1	Clearance measurement of nuclear facilities inkl. hoisting systems and buildings control and monitoring area	5	year	20,000,000	100,000,000 €
6.	**4.**		**Site dismantling and clearance**				**50,000,000 €**
6.	4.	1	Dismatling of conventional surface facilities		total		50,000,000
6.	**5.**		**Insurance**				**13,912,000 €**
6.	5.	1	Combined construction/assembly insurance incl. assembly equipment		year	200,000	1,600,000
6.	5.	2	Builder's liability insurance		total	3,000,000	3,000,000
6.	5.	3	Public liability insurance conventional		year	14,000	112,000
6.	5.	4	Public liability insurance nuclear		year	600,000	4,800,000
6.	5.	5	Nuclear insurance		year	550,000	4,400,000
6.	5.	6	Further insurance (visitors etc.)		year		0
6.	**6.**		**Utility consumption**				**49,300,000 €**
6.	6.	1	Utility consumption				
			Electricity	8	year	6,000,000	48,000,000
			Water	8	m³ /a	15,000	180,000
			Consumables waste handling e.g. waste oil	8	€ / a	140,000	1,120,000
6.	**7.**		**Human resources**				**68,321,496 €**
6.	7.	1	Operator	8	year	6,511,705	52,093,640
6.	7.	2	COVRA	8	year	2,028,482	16,227,856
7			**Post operational phase**				**0 €**
7.	1.		Operator		year	524,951	0
7.	2.		COVRA		year	1,559,291	0

5.5.1 Backfilling and sealing galleries and ramp (6.1)

Backfilling lower level

Table 5-11: Backfilling lower level cost assessment

Lower level [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	€ / m³	m³ total	Sum [€]
Ventilation tunnel	5.6	4	1,220	22.4	244	27,328	6,668,032
Service tunnel	5.6	4	390	22.4	244	8,736	2,131,584
Transport tunnel	10.6	4	630	42.4	244	26,712	6,517,728
Infrastructure	15.8	4	15.8	63.2	244	3,600	243,649

Ramp

Table 5-12: Ramp backfilling cost assessment

Lower level [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	€ / m³	m³ total	Sum [€]
Ramp	4	10	1,920	40	244	76,800	18,739,200

Infrastructure upper level

Table 5-13: Infrastructure backfilling upper level cost assessment

Upper lever [m]	Width [m]	Height [m]	Length total [m]	m³ each 1 m tunnel length	€ / m³	m³ total	Sum [€]
Ventilation tunnel	5.6	4	870	22.4	244	19,488	4,755,072
Transport tunnel	10.6	4	525	42.4	244	22,260	5,431,440
Infrastructure area	70.7	4	70.7	282.8	244	19,993	4,878,526

5.5.2 Backfilling and sealing shafts (6.2)

Examples of a closure concept are given in Chapter 3.2.3.

5.5.3 Dismantling and decommissioning nuclear facilities (6.3)

The amount has the same dimension as estimated for other disposal concepts and projects.

5.5.4 Site dismantling and clearance (6.4)

The amount has the same dimension as estimated for other disposal concepts and projects.

5.5.5 Insurance

Cost items identical to insurance (2.8)

5.5.6 Utility consumption (6.5)

Cost items identical to utility consumption (1.5)

5.5.7 Human resources (6.6)

See chapter 3.2.4 for the human resources estimation. Total amounts per year and phase were calculated there and are multiplied by the duration per phase here.

6 Boundary conditions for the cost estimate – conditioning facility

(Wunderlich et al. 2023) developed a conceptual design of a DWP for heat-generating waste. As part of the conceptual design, a first cost estimation had to be prepared. The aim was to define the order of magnitude of the expected costs. Because of the early planning stage and the far distant implementation after the year 2100, the cost estimate is connected to a high uncertainty. In the cost estimation, the technology available today has been taken into account. All costs are considered as overnight costs.

The costing discusses the costs for the Disposal Waste Package (DWP) production itself, the construction and operation of the conditioning facility, and the design and construction of the DWP disposal vehicle.

The following sub sections summarise the main assumptions and requirements for the costing and discuss the calculated numbers.

6.1 DWP production and cost estimation

6.1.1 Brief description of the production process

The preferred material for the DWP is steel TStE355, which cannot be casted. Thus, a DWP manufacturing by forging is assumed. The conceptual design of the DWP gives a volume of 3.8 m^3 for the DWP for ECN-canisters and 4.5 m^3 for the DWP for CSD-V canisters. The forging process leads to several interim steps in the DWP production. The lid and the DWP body represent the end products.

The body consists of a tube with a ring and a bottom. It is assumed that the tube and bottom will be forged from one piece. The ring is cut of the tube in a further process step. As a result, a much higher volume is needed for the interim step as for the final tube with the ring. For the DWP-ECN, a material volume of 4.7 m^3 is required before cutting. For the DWP-CSD, a material volume of 5.5 m^3 is required before cutting.

6.1.2 DWP cost estimation

At the current development stage, it is usually very hard to make detailed cost estimates. Therefore, the German VDI (Verein Deutscher Ingenieure/ Association of German Engineers) designed a method for cost estimates at early development stages based on comparative material costs and the volume of product parts. The method was published in the VDI guideline 2225 (VDI Richtlinie 2225)

As price basis for forged steel (comparable to TStE355), material costs between 4,000 € and 5,000 € per ton can be estimated for 2022. For the calculation, material costs of 4,500 €/ton are assumed. This equals a price of 35,325 € per cubic metre of steel. TStE355 cannot be casted. For the DWP production, forging is assumed. Cost factors considering the forge work related to the material price can be found e.g. in (Wittel et al. 2013). For the manufacturing of forged steel, a factor of 3 is assumed. The material costs M can then be calculated with the following equation:

$$M = V * k_{v0} * k_v \quad (1)$$

M Material costs [€]
V Material volume of the product [m^3]
k_{v0} Basic material costs [€/m^3]
k_v Factor for comparative material costs [-]

This leads to total costs of 499,000 € for the waste package for ECN-canisters and 583,000 € for the waste package for CSD-V canisters. The costs include the manufacturing costs as well.

A further consideration of additional factors for the manufacturing is not included in the cost estimation. The manufacturing process is covered by the volume, the basic material costs, and the factor k_{v0}.

6.2 Cost estimation for the disposal technology

The development of special transportation and disposal equipment tailored to the DWP concept is not part of this study. However, in order to be able to make a statement about the expected costs of such transport and disposal equipment, a basic knowledge of its design must be available. This basic knowledge is gained by analogues to comparable devices.

The main functions of the device is the transport and emplacement of the DWP. It is assumed that both functions can be combined in one device. This also includes the transfer of the DWP from the shaft transport system to the device at the shaft landing station. Furthermore, an automotive and wheel-based device is assumed to pass the ramp between upper and lower level. The needs in regard to the emplacement are defined by the disposal concept. The DWP will be placed inside shallow boreholes at the floor of the disposal galleries. A detailed description of the emplacement concept can be found in (Bartol et al. 2025).

The so-called canister installation vehicle developed by Posiva Oy (Finland) has to fulfil similar functions and is comparable to the needs of the Dutch concept. Figure 6-1 illustrates the conceptual design of the canister installation vehicle.

Figure 6-1: Left: Canister installation vehicle, right: canister installation vehicle's chassis in a view obliquely from the rear. The radiation shield and the canister are missing from the picture. Both pictures based on (Wendelin & Suikki 2008)

The Finish canister installation vehicle captures the DWP at the shaft landing station, transports it towards the actual disposal position, and emplaces the DWP. The conceptual design as presented in Figure 6-1 is designed as crawler type vehicle. Latest designs consider a wheeled vehicle as seen in Figure 6-2. For the Dutch canister installation vehicle, a radiation shield similar to the Finnish design would not be required. The DWPs are shielded. However, for the cost estimation, this sub system is considered.

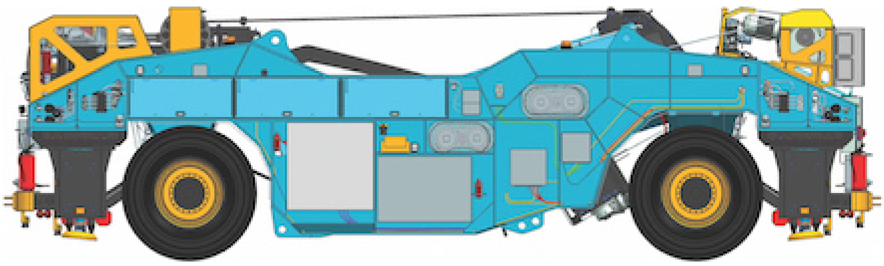

Figure 6-2: Updated design of the canister installation vehicle, based on (NEI 2023)

(Wendelin & Suikki 2008) gives a preliminary cost estimation for the design and construction of the device (see Table 6-1:). Taking into account the average inflation rate, the costs can be extrapolated to the price base 2021. Between 2008 and 2014, an average inflation rate of 1.7% is assumed, see (Worlddata 2023). The costs for the vehicle are not included in the conditioning facility cost estimation.

Table 6-1: Cost estimation for the canister installation vehicle based on (Wendelin & Suikki 2008) and extrapolated to price level 2021 with an average inflation rate of 1.7%

Sub System	Price base 2008 [T€]	Price base 2021 [T€]
Radiation shield handling equipment	320	405
Canister lifting gear	205	260
Control lifting gear	77	98
Control system for canister handling	156	198
Vehicle`s chassis	735	931
Sum	1,493	1,892

6.3 Cost estimation for the conditioning facility

The development of a conditioning facility (CF) tailored to the developed DWP is not part of the study in hand. However, to give a preliminary estimation of the costs, basic knowledge about the design of the CF is required, and a rough concept of the main processes has to be defined. Figure 6-3 illustrates the main working steps in a flow chart. The colour code indicates the actual place inside the CF. Figure 6-4 illustrates a preliminary design of the CF in top and side view with the same colour code of the main rooms. The CF consists of the following main rooms:

- Canister reception hall
- Storage area
- Decontamination room
- Hot cell

- Welding cell
- Inspection room
- Transfer cell
- HVAC
- Buffer storage

The conditioning process starts with the delivery of the primary waste package, the empty DWP, and the lid of the DWP. The empty DWP and the lid arrive at the storage area. The primary waste package, placed inside a not yet defined transport cask, arrives at the canister reception hall. The transport cask is moved from the truck and placed on a transfer trolley. The trolley is used for the internal transport inside the CF. In the next step, the trolley moves into the transfer cell. Below the hot cell, the trolley arrives at the first parking position. The trolley lifts the canister onto the docking station 1 of the hot cell. In parallel, the empty DWP is transferred to the docking station 2 of the hot cell in the same way.

The next working steps take place inside the hot cell. The canister is opened and the transport cap of the DWP is removed. Afterwards, the primary waste package (ECN or CSD) is removed from the canister and placed into the DWP. The process is repeated as long as primary waste packages can be taken from the canister or placed inside the DWP. Once a DWP is filled, the lid is placed on the top of the DWP. The temporarily closed DWP is lowered and the trolley moves the DWP to below the welding cell. At the parking position, the DWP is lifted and connected to the docking station of the welding cell. After welding, the DWP will be transferred to the inspection cell. After a successful inspection, the DWP can be transferred to the buffer storage. The buffer storage allows a short-term storage of the DWPs if a DWP cannot be emplaced directly. It is assumed that the buffer storage has a capacity for up to 20 DWPs.

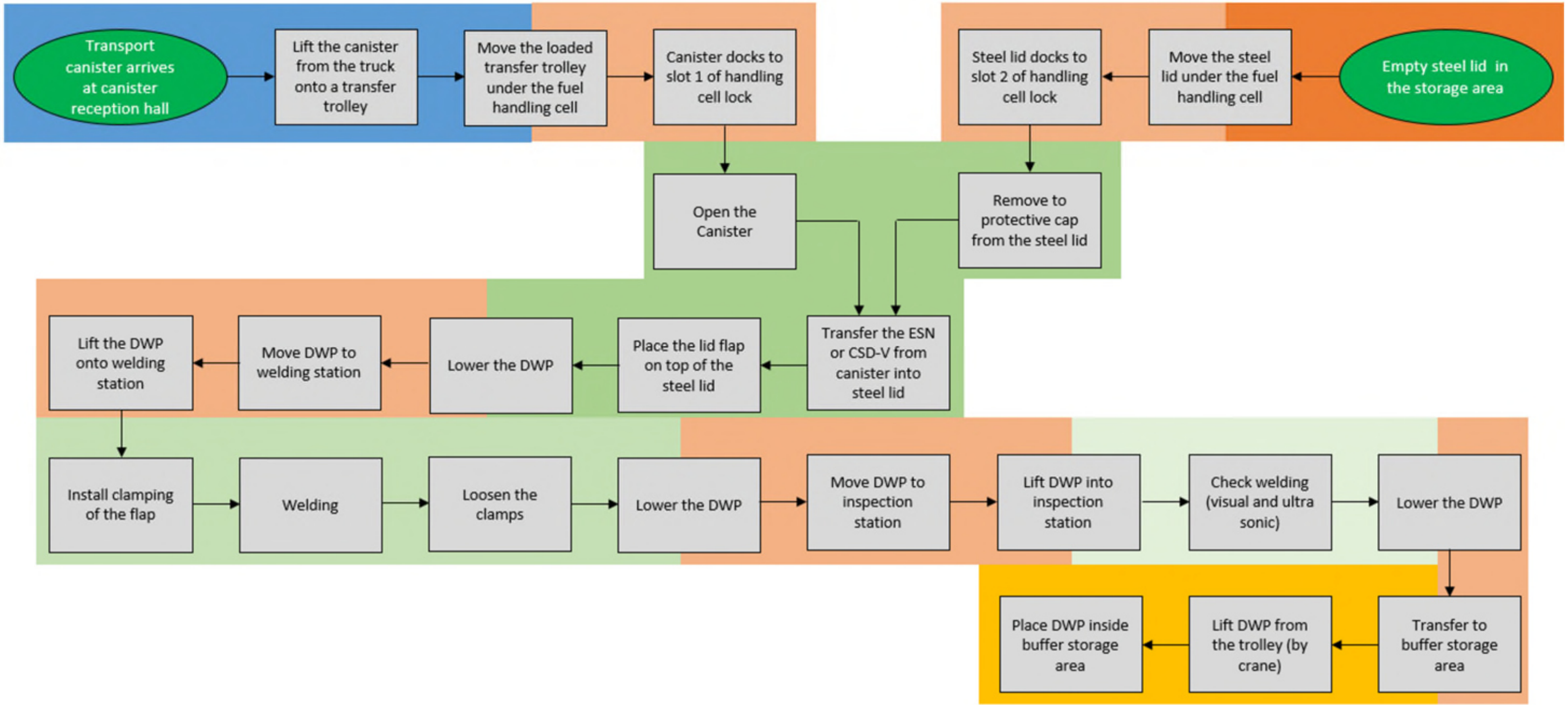

Figure 6-3: **Flow chart of the main working steps during conditioning and DWP closure**

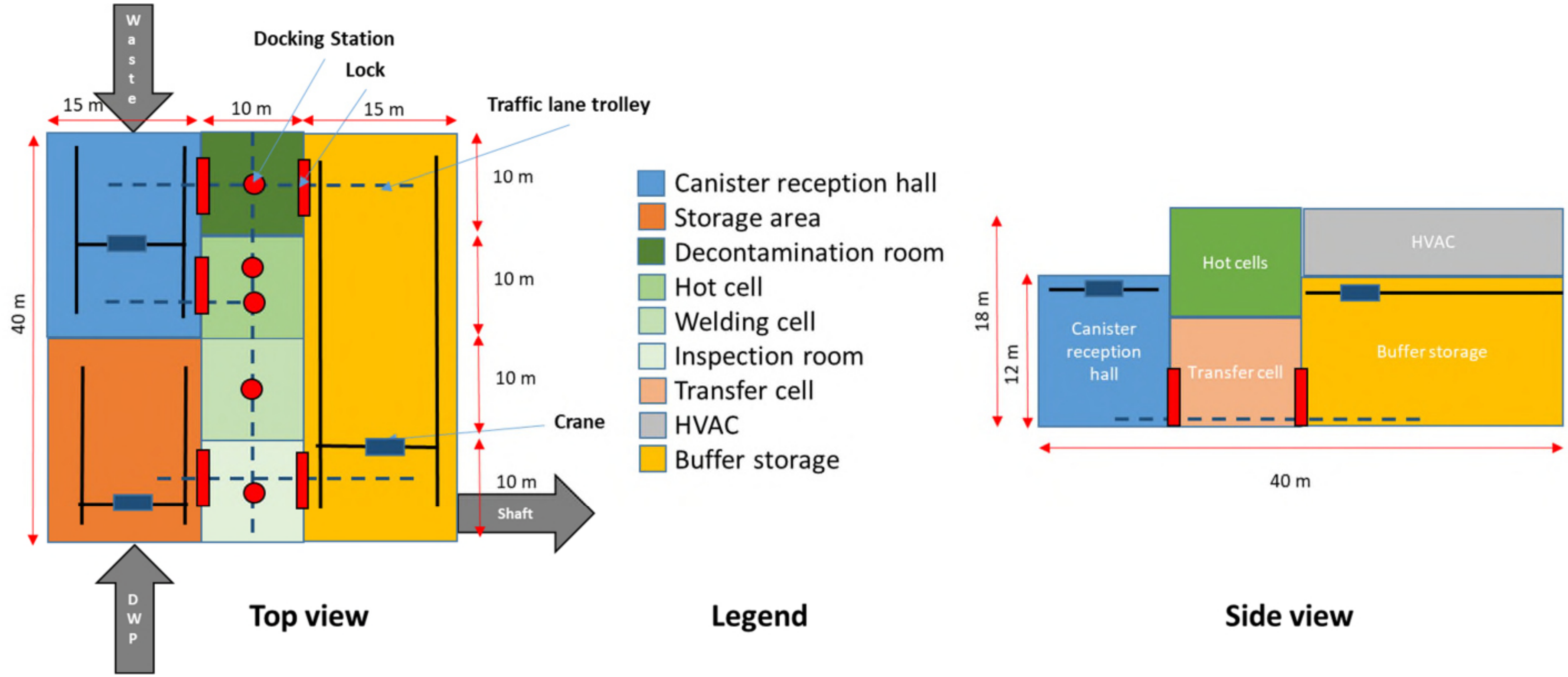

Figure 6-4: **Illustrative top and side view of the CF including rooms and main components**

The costs for the construction of the CF as well as the costs for the internals are estimated based on analogues from comparable concepts of other radioactive waste management projects. References for CF construction and preliminary costing can be found e.g. in (Saanio et al. 2021) and (Kukkola 2021).

The cost estimation follows a simplified cost breakdown structure. The costs are separated into three main phases:

1. Site preparation
2. CF Construction and operation
3. Closure and decommissioning

Every phase is further divided into general cost groups specific to the phase. General cost groups are investment costs, human resources, maintenance costs, consumables, and insurance. The specific cost groups are phase-specific variants of the general cost groups. The third level of the breakdown structure is represented by cost items (see Table 6-2:). A cost item represents the lowest level of the breakdown structure.

Table 6-2: Cost breakdown structure for the CF cost estimation, including phases, cost groups and cost items

1. Site preparation
1.1.Investment - Land purchase
1.1.1 Nominal cost of the land purchase
1.1.2 Notary fee
1.2 Investment - Site infrastructure works
1.2.1 Landscaping
1.2.2 Roads and parking
1.2.3 Green park area
1.2.4 Sewage system
1.2.5 Connection to utilities network and sewage
1.2.6 Architect/engineering fee
1.3 Human resources site preparation
1.3.1 Operator
1.3.2 COVRA
2.1 Investment - Site facility construction
2.1.1 CF building
2.1.2 Architect/engineering fee
2.2 Investment - CF internals/construction and installation
2.2.1 Fuel handling systems, cranes and lifts, trolley
2.2.2 Process systems
2.2.3 Automation and telecommunications
2.2.4 Electric power system
2.2.5 HVAC
2.2.6 Radiation protection and monitoring
2.2.7 Architect/engineering fee
2.3. Human resources CF construction
2.3.1 Operator

2.3.2 COVRA
2.4 Maintenance during HLW disposal campaign
2.4.1 CF building
2.4.2 CF internals/construction and installation, incl. replacement
2.5 Insurance during HLW disposal campaign
2.5.1 CF building
2.5.2 CF internals/construction and installation
2.6 Material for DWP and consumables
2.6.1 DWP lid and flap ECN "hot and cold"
2.6.2 DWP lid and flap CSD "hot and cold"
2.6.3 Transport cap
2.6.4 CF utility consumption
2.6.5 Operational waste management
2.7 Human resources
2.7.1 Operator
2.7.2 COVRA
3. Closure and decommissioning
3.1 Investment - Dismantling and decommissioning nuclear facilities
3.1.1 CF
3.1.2 Internals
3.2 Human resources during dismantling
3.2.1 Operator
3.2.2 COVRA

6.4 Cost estimation for processing and disposal of (TE)NORM

The cost estimation of the TE(NORM) processing and disposal is part of the report (van Oudenaren & Browning 2023). Details regarding the cost estimation for buildings and operations are described there.

	Levenscycluskosten (rekenhorizon 115 jaar, reële kosten)	
Deelraming Gebouw en installatie	€	12,369,654
Deelraming Operationeel	€	314,117,220
Kosten inclusief BTW	**€**	**326,486,873**

Figure 6-5: Summary of total costs based on SSK Method including 21% VAT (van Oudenaren & Browning 2023)

6.5 Definition of cost items CF

6.5.1 Site preparation (1)

Table 6-3: Overview of the estimated costs for the CF

	Quantity	Unit	Unit cost [Eur]	Total cost [Eur]
1. Site preparation				**612,375.00 €**
1. 1. Investment - Land purchase				**71,875.00 €**
1. 1. 1 Nominal costs of land purchase	2,500	m²	25.00 €	62,500
1. 1. 2 Notary fee	15.00%	%	4.00 €	9,375
1. 2. Investment - Site infrastructure works				**540,500.00 €**
1. 2. 1 Landscaping	2,500	m²	100.00 €	250,000
1. 2. 2 Roads and parking lots	100	m²	400.00 €	40,000
1. 2. 3 Green park area	800	m²	50.00 €	40,000
1. 2. 4 Sewage system	200.00	m²	450.00 €	90,000
1. 2. 5 Connection to utilities networks and sewage		ff	50,000.00 €	50,000
1. 2. 6 Architect/engineer fee	15%	%		70,500
2. CF construction and operation				**360,991,000 €**
2. 1. Investment - Site facility construction				**20,286,000 €**
2. 1. 1 CF building	25,200	m³	700.00 €	17,640,000
2. 1. 2 Architect/engineer fee	15%	%		2,646,000
2. 2. Investment - CF internals/construction and installation				**111,800,000 €**
2. 2. 1 Fuel handling systems, cranes and lifts	2	unit	16,000,000.00 €	32,000,000
2. 2. 2 Process systems	2	unit	9,000,000.00 €	18,000,000
2. 2. 3 Automatisation and telecommunication	2	unit	6,000,000.00 €	12,000,000
2. 2. 4 Electric power system	2	unit	5,000,000.00 €	10,000,000
2. 2. 5 HVAC	2	unit	5,000,000.00 €	10,000,000
2. 2. 6 Radiationprotection and monitoring	2	unit	2,000,000.00 €	4,000,000
2. 2. 7 Architect/engineer fee	30%	%		25,800,000
2. 4. Maintenance during HLW disposal campaign				**41,599,600 €**
2. 4. 1 CF building	7	year	352,800.00 €	2,469,600
2. 4. 2 CF internals/construction and installation, incl. replacement	7	year	5,590,000.00 €	39,130,000
2. 5. Insurance during HLW disposal campaign				**6,670,400 €**
2. 5. 1 CF building	11	year	176,400	1,940,400
2. 5. 2 CF internals/construction and installation	11	year	430,000	4,730,000
2. 6. Material for DWP and consumables				**180,635,000 €**
2. 6. 1 DWP lid and flap ECN "hot"	122	pieces	499,000.00 €	60,878,000
2. 6. 2 DWP lid and flap CSD "hot and cold"	164	pieces	583,000.00 €	95,612,000
2. 6. 3 Transport cap	286	pieces	7,500.00 €	2,145,000
2. 6. 4 CF utility consumtion (electricity, HVAC)	11	year	1,500,000.00 €	16,500,000
2. 6. 5 Operational waste management	11	years	500,000.00 €	5,500,000
3. Closure and decommissioning				**31,092,000 €**
3. 1. Investment - Dismantling and decommissioning nuclear facilities				**31,092,000 €**
3. 1. 1 Conditioning facility	1	unit	5,292,000.00 €	5,292,000
3. 1. 1 Internals	1	unit	25,800,000.00 €	25,800,000

6.5.2 Land purchase, infrastructure, and construction

It is assumed what the CF is located next to or within the surface facility of the repository. Thus, the CF can participate in the basic infrastructure of the repository. Therefore, power supply, utility services etc. are not considered in the cost estimation of the CF. Those costs are part of the cost estimation of the repository.

The CF as described in Figure 6-4 covers 1,600 m² of ground. It is assumed that 5 m of additional land around the CF is used as green park area. The total land use covers 2,500 m^2. The total volume of the CF is 25,200 m^3. Based on (Saanio et al. 2021), construction costs of 700 €/m³ can be assumed.

The investment for the internals inside the rooms is summarised in Table 6-4:.

Table 6-4: Cost items for investment of CF internals/construction and installation

Internals	Costs as lump sum [k€]
Fuel handling systems, cranes and lifts	16,000
Process systems	9,000
Automation and telecommunications	6,000
Electric power system	5,000
HVAC	5,000
Radiation protection and monitoring	2,000

6.5.3 Architect and engineering fee

The cost item architect and engineering fee is considered in every cost group related to investment. The fee is assumed as 15% for non-nuclear activities, e.g. the site infrastructure works, and 30% for all nuclear related activities.

6.5.4 Notary fee

For the purchase of land, a notary fee is required. It is assumed that COVRA, as the owner of the land and the facility, have to pay the notary fee. The fee consists of the following parts:

Transfer tax:	6% for industrial buildings
Real estate fee:	2% (upper level, 0.5 to 2%)
Notary fee:	1.5%
Valuation costs:	0.15%
Registration fee:	1.5%
Sum:	**11.15%**

6.5.5 Maintenance and consumables

For the maintenance of the CF building, an annual demand of 2% of the investment costs is assumed. The assumption is in line with the experience of BGE and the German repository sites.

For the maintenance of the green park area and roads, 1% of the investment costs is assumed.

The maintenance of the internals includes repair work and replacement as well as workforce. The workforce is included in the cost group human resources. The maintenance of the CF internals requires 5% of the investment costs per year.

Electricity represents the most important item of the consumables. It is assumed that 1.5 Mio. € of electricity costs occur per year.

The operational waste of the CF has to be treated. It is assumed that 0.5 Mio. € of waste handling costs occur per year of operation.

6.5.6 Human resources site preparation

The human resources estimated for the CF are included in the GDF calculation and follow the same assumption. It is assumed that construction, operation, and dismantling is done by an operator. COVRA acts as a supervisor. For both, the same categories and rates for salary are assumed, see section 3.2.4 and Table 3-1.

6.5.7 Insurance

The annual insurance fee amounts to 1% of the investment costs.

6.5.8 Dismantling

For the dismantling and decommissioning of the CF including all internals, a rate of 30% of the investment costs is assumed.

6.6 Summary CF cost estimation

The costs of the construction, operation, and dismantling of the conditioning facility are estimated at 393 Mio. € in total. 0.6 Mio. € are linked to the site preparation. The main share of 361 Mio. € of the costs is linked to CF construction and operation. Closure and decommissioning cover 31.09 Mio. €.

Separated into characteristic cost groups, 38% or 164 Mio. € are linked to investment costs, 51% or 180 Mio. € are linked to material (DWP) and consumables, and 11% or 48 Mio. € are linked to maintenance and insurance. Figure 6-6 and Figure 6-7 illustrate the ratios of the main cost groups.

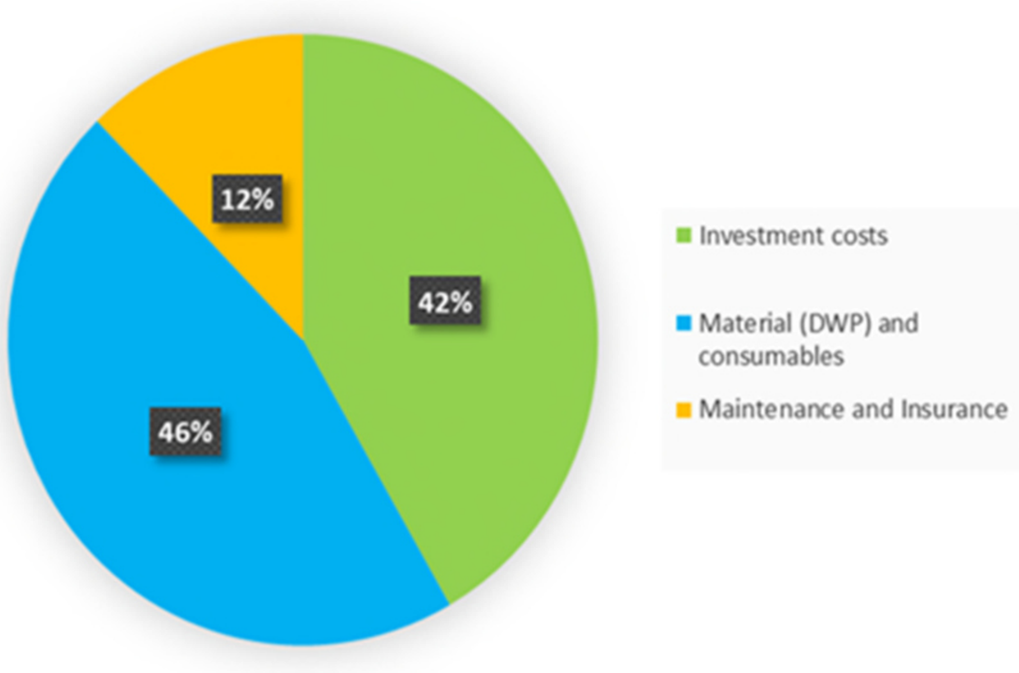

Figure 6-6: **Proportion of total costs accounted for by the four main cost groups investment, human resources, material and consumables, and maintenance and insurance**

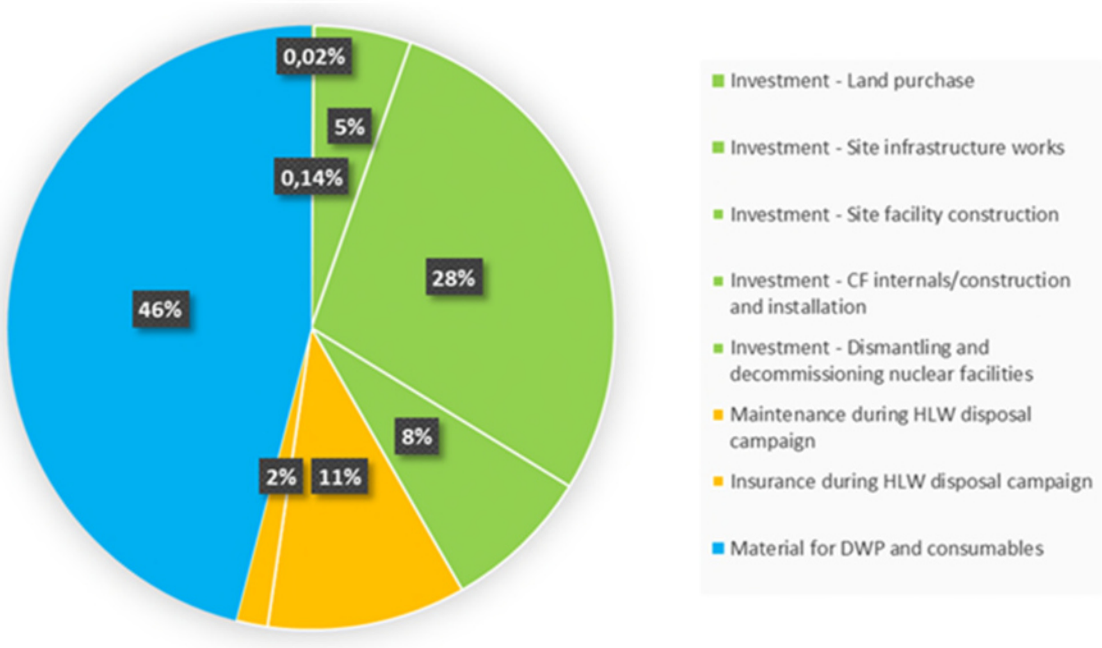

Figure 6-7: **Proportion of total costs accounted for by the cost groups of Phase 1, 2 and 3**

7 Overview of total estimated costs and SSK Method excel sheet import

The costs for the planning, construction, operation and closure of a Dutch GDF in a domal salt formation are estimated at 2,917,462 k€. Further costs of 392,695 k€ are expected for the construction, operation, and dismantling of the HLW conditioning facility. (van Oudenaren & Browning 2023) estimated the costs for the (TE)NORM conditioning at 270,000 k€.

For the GDF, the costs are unevenly distributed across the phases. The construction of the surface and underground facilities are connected to one third of the expected costs. In contrast to this, the HLW disposal phase is connected to the lowest amount of costs, in total 2%. Figure 7-1 illustrates the cost distribution between the phases graphically. Table 7-1 summarises the costs for the different phases. Table 7-3: gives a more detailed overview of the distribution of costs between the different cost groups for the repository phases.

Table 7-1: Expected costs for different GDF lifetime phases, without CF costs

Category	Sum [k€]
Pre-constructional activities	229,679
Repository construction	1,228,398
HLW waste disposal campaign	47,340
LILW and (TE)NORM waste disposal campaign	496,562
Underground observation	134,585
Repository closure	780,899
Total GDF	2,917,462

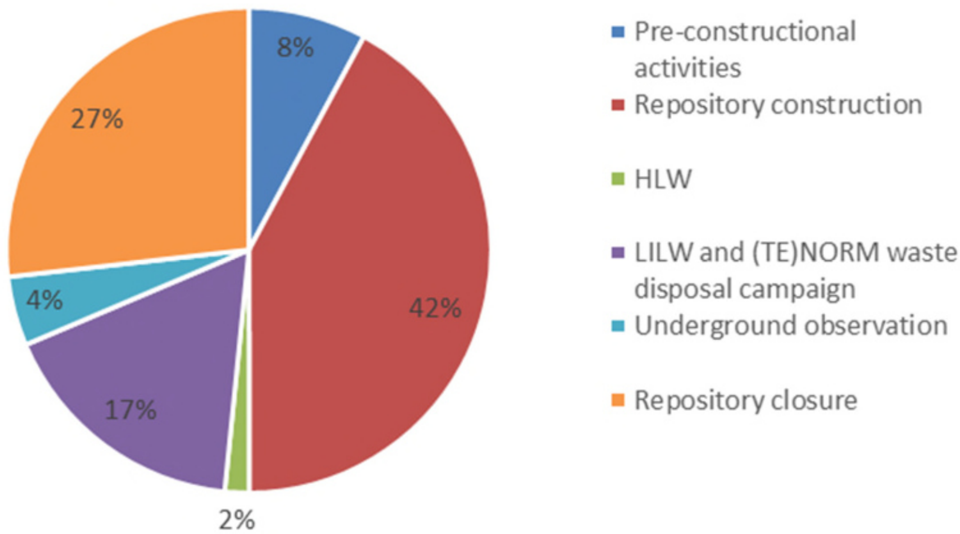

Figure 7-1: Grafic illustration of the costs for different phases of the GDF lifetime, without conditioning facilities

Sorted by cost types, the Investments, such as the building or equipment, cover 28% of the total costs. Human resources are 21 %. Table 7-2 summarises the costs for the different cost types. Figure 7-2 illustrates the cost distribution between the cost types graphically.

Table 7-2: **Expected costs grouped according to cost types, without CF costs.**

Category	Sum [k€]
Investments	782,151
Human resources	585,300
Consumables	377,850
Insurance	95,476
Maintenance	221,693
Closure	724,557
Total GDF	2,790,360

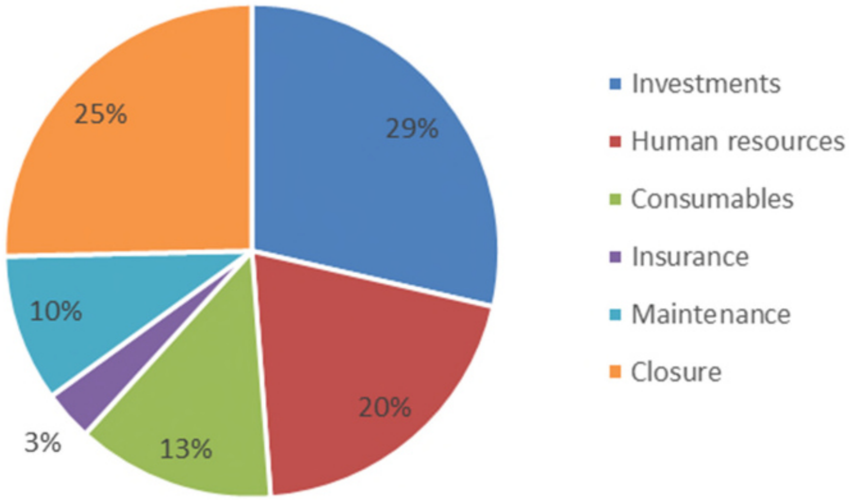

Figure 7-2: **Grafic illustration of the costs for characteristic cost types of the GDF, without conditioning facilities**

The bottom-up cost item estimations from Chapter 5 were imported into the Rekenmodel SSK 2018 Versie 2.3.000. The resulting cost overview is shown in Table 7-4: to Table 7-7:.

Table 7-3: Summary GDF cost estimation according to GDF lifetime phases and main cost groups, without CF costs.

Category	Sum
Pre-constructional activities	**229,679,488 €**
Land purchase	62,766,688 €
Site infrastructure works	48,127,500 €
Site facility construction	1,920,000 €
Security installation	1,400,000 €
Utility consumption	55,462,500 €
Human resources	60,002,800 €
Repository construction	**1,228,397,684 €**
Construction and outfitting shafts	408,200,000 €
Construction and outfitting upper level main area	6,969,052 €
Construction and outfitting HLW main area	5,946,847 €
Construction and outfitting HLW disposal area	2,181,568 €
Construction and outfitting LILW and (TE)NORM disposal galleries	5,048,502 €
Site facility construction	289,258,350 €
Maintenance surface	124,730,840 €
Insurance	34,372,000 €
Utility consumption	141,737,500 €
Human resources	209,953,025 €
HLW	**47,339,669 €**
Disposal	1,850,000 €
Backfilling and sealing	18,036,480 €
Maintenance surface	5,423,080 €
Insurance	4,364,000 €
Utility consumption	6,162,500 €
Human resources	11,503,609 €
LILW and (TE)NORM waste disposal campaign	**496,561,720 €**
Disposal	6,020,000 €
Backfilling and sealing	71,837,504 €
Utility consumption	104,762,500 €
Maintenance surface	92,192,360 €
Insurance	26,188,000 €
Human resources	195,561,356 €
Underground observation	**134,585,102 €**
Maintenance surface	54,230,800 €
Insurance	16,640,000 €
Utility consumption	20,425,000 €
Human resources	43,289,302 €
Repository closure	**780,898,727 €**
Backfilling and sealing galleries and ramp	49,365,231 €
Backfilling and sealing shafts	450,000,000 €
Dismantling and decommissioning nuclear facilities	100,000,000 €
Site dismantling and clearance	50,000,000 €
Insurance	13,912,000 €
Utility consumption	49,300,000 €
Human resources	68,321,496 €

Table 7-4: Cost Overview SSK Export, 1 of 2

Kostenoverzicht SSK2018							*Rekenmodel SSK2018 versie 2.3.000*
	Directe kosten - benoemd	*Directe kosten - nader te detailleren*	*Directe kosten*	*Indirecte kosten*	*Voorziene kosten*	*Risicoreservering*	*Totaal*
Investeringskosten:							
Bouwkosten Deelraming Site Prep incl A&F Fee	€ 41,850,000	€ -	€ 41,850,000	€ -	€ 41,850,000	€ -	€ 41,850,000
Bouwkosten Deelraming Site Prep excl. A&F Fee	€ 81,086,688	€ -	€ 81,086,688	€ -	€ 81,086,688	€ -	€ 81,086,688
Bouwkosten Deelraming Surface	€ 251,529,000	€ -	€ 251,529,000	€ -	€ 251,529,000	€ -	€ 251,529,000
Bouwkosten Deelraming Shaft Sinking	€ 314,000,000	€ -	€ 314,000,000	€ -	€ 314,000,000	€ -	€ 314,000,000
Bouwkosten Deelraming Repository construction	€ 14,439,571	€ -	€ 14,439,571	€ -	€ 14,439,571	€ -	€ 14,439,571
Bouwkosten Deelraming HLW Disposal	€ 19,536,480	€ -	€ 19,536,480	€ -	€ 19,536,480	€ -	€ 19,536,480
Bouwkosten Deelraming LILW (TE)NORM Disposal	€ 73,437,504	€ -	€ 73,437,504	€ -	€ 73,437,504	€ -	€ 73,437,504
Bouwkosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Repository Closure	€ 549,365,231	€ -	€ 549,365,231	€ -	€ 549,365,231	€ -	€ 549,365,231
Bouwkosten Deelraming CF arch	€ 71,875	€ -	€ 71,875	€ -	€ 71,875	€ -	€ 71,875
Bouwkosten Deelraming Cf Building	€ 17,640,000	€ -	€ 17,640,000	€ -	€ 17,640,000	€ -	€ 17,640,000
Bouwkosten Deelraming CF Installation	€ 86,000,000	€ -	€ 86,000,000	€ -	€ 86,000,000	€ -	€ 86,000,000
Bouwkosten Deelraming Cf Materials Decommissiong	€ 189,727,000	€ -	€ 189,727,000	€ -	€ 189,727,000	€ -	€ 189,727,000
Bouwkosten Deelraming TENORM Conditioning	€ 269,976,632	€ -	€ 269,976,632	€ -	€ 269,976,632	€ -	€ 269,976,632
Bouwkosten Deelraming CF incl archi	€ 470,000	€ -	€ 470,000	€ -	€ 470,000	€ -	€ 470,000
Bouwkosten	**€ 1,909,129,981**	**€ -**	**€ 1,909,129,981**	**€ -**	**€ 1,909,129,981**	**€ -**	**€ 1,909,129,981**
Engineeringskosten Deelraming Site Prep incl A&F Fee	€ 6,277,500	€ -	€ 6,277,500	€ -	€ 6,277,500	€ -	€ 6,277,500
Engineeringskosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Surface	€ 37,729,350	€ -	€ 37,729,350	€ -	€ 37,729,350	€ -	€ 37,729,350
Engineeringskosten Deelraming Shaft Sinking	€ 94,200,000	€ -	€ 94,200,000	€ -	€ 94,200,000	€ -	€ 94,200,000
Engineeringskosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Cf Building	€ 2,646,000	€ -	€ 2,646,000	€ -	€ 2,646,000	€ -	€ 2,646,000
Engineeringskosten Deelraming CF Installation	€ 25,800,000	€ -	€ 25,800,000	€ -	€ 25,800,000	€ -	€ 25,800,000
Engineeringskosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF incl archi	€ 70,500	€ -	€ 70,500	€ -	€ 70,500	€ -	€ 70,500
Engineeringskosten	**€ 166,723,350**	**€ -**	**€ 166,723,350**	**€ -**	**€ 166,723,350**	**€ -**	**€ 166,723,350**

Table 7-5: Cost Overview SSK Export, 2 of 2

Vastgoedkosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Objectoverstijgende risicoreservering						€ -	€ -
Verschuiving						€ 2,340,134	€ 2,340,134
Investeringskosten exclusief BTW	€ **2,075,853,331**	€ -	€ **2,075,853,331**	€ -	€ **2,075,853,331**	€ **2,340,134**	€ **2,078,193,464**
BTW	€ 435,929,199	€ -	€ 435,929,199	€ -	€ 435,929,199	€ 491,428	€ 436,420,628
Investeringskosten inclusief BTW (reële kosten)	€ **2,511,782,530**	€ -	€ **2,511,782,530**	€ -	€ **2,511,782,530**	€ **2,831,562**	€ **2,514,614,092**
Investeringskosten inclusief BTW (contante waarde), discontovoet van 02% en rekenhorizon van 68 jaar							€ *906,759,527*

Bandbreedte : met een 70%-betrouwbaarheidsinterval liggen de investeringskosten inclusief BTW (reële kosten) tussen € 1668866974.4 en € 3358286031.2
De variatiecoëfficiënt bedraagt ± 30.1%

Geraamde Investeringskosten inclusief BTW (reële kosten)	€ 2,514,614,092
Organisatiegebonden reservering investeringen (opgave financier)	€ -
Onzekerheidsreserve investeringen (opgave financier)	€ -
Reservering scope wijzigingen investeringen (opgave financier)	€ -
Gerealiseerde investeringskosten buiten de raming maar binnen budget (opgave financier)	€ -
Aan te houden budget investeringskosten inclusief BTW	€ **2,514,614,092**

Table 7-6: Maintenance Cost Overview SSK Export, 1 of 2

Instandhoudingskosten:							
Bouwkosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Site Prep excl. A&F Fee	€ 123,427,800	€ -	€ 123,427,800	€ -	€ 123,427,800	€ -	€ 123,427,800
Bouwkosten Deelraming Surface	€ 651,053,080	€ -	€ 651,053,080	€ -	€ 651,053,080	€ -	€ 651,053,080
Bouwkosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Repository construction	€ 215,653,025	€ -	€ 215,653,025	€ -	€ 215,653,025	€ -	€ 215,653,025
Bouwkosten Deelraming HLW Disposal	€ 15,253,609	€ -	€ 15,253,609	€ -	€ 15,253,609	€ -	€ 15,253,609
Bouwkosten Deelraming LILW (TE)NORM Disposal	€ 196,581,356	€ -	€ 196,581,356	€ -	€ 196,581,356	€ -	€ 196,581,356
Bouwkosten Deelraming Underground Observation	€ 63,714,302	€ -	€ 63,714,302	€ -	€ 63,714,302	€ -	€ 63,714,302
Bouwkosten Deelraming Repository Closure	€ 168,321,494	€ -	€ 168,321,494	€ -	€ 168,321,494	€ -	€ 168,321,494
Bouwkosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Cf Materials Decommissiong	€ 70,270,000	€ -	€ 70,270,000	€ -	€ 70,270,000	€ -	€ 70,270,000
Bouwkosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten	**€ 1,504,274,667**	€ -	**€ 1,504,274,667**	€ -	**€ 1,504,274,667**	€ -	**€ 1,504,274,667**
Engineeringskosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -

Table 7-7: Maintenance Cost Overview SSK Export, 2 of 2

Vastgoedkosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Objectoverstijgende risicoreservering						€ -	€ -
Verschuiving						€ 1,695,786	€ 1,695,786
Instandhoudingskosten exclusief BTW	**€ 1,504,274,667**	**€ -**	**€ 1,504,274,667**	**€ -**	**€ 1,504,274,667**	**€ 1,695,786**	**€ 1,505,970,454**
BTW	€ 315,897,680	€ -	€ 315,897,680	€ -	€ 315,897,680	€ 356,115	€ 316,253,795
Instandhoudingskosten inclusief BTW (reële kosten)	**€ 1,820,172,348**	**€ -**	**€ 1,820,172,348**	**€ -**	**€ 1,820,172,348**	**€ 2,051,901**	**€ 1,822,224,249**
Instandhoudingskosten inclusief BTW (contante waarde), discontovoet van 02% en rekenhorizon van 105 jaar							*€ 1,096,275,344*

Bandbreedte : met een 70%-betrouwbaarheidsinterval liggen de instandhoudingskosten inclusief BTW (reële kosten) tussen € 1209350523.7 en € 2433594188.9

De variatiecoëfficiënt bedraagt ± 30.1%

Geraamde Instandhoudingskosten inclusief BTW (reële kosten)	€ 1,822,224,249
Organisatiegebonden reservering instandhoudingen (opgave financier)	€ -
Onzekerheidsreserve instandhoudingen (opgave financier)	€ -
Reservering scope wijzigingen instandhoudingen (opgave financier)	€ -
Gerealiseerde instandhoudingskosten buiten de raming maar binnen budget (opgave financier)	€ -
Aan te houden budget instandhoudingskosten inclusief BTW	**€ 1,822,224,249**

Levenscycluskosten inclusief BTW (reële kosten)	**€ 4,331,954,878**	**€ -**	**€ 4,331,954,878**	**€ -**	**€ 4,331,954,878**	**€ 4,883,463**	**€ 4,336,838,341**
Levenscycluskosten inclusief BTW (contante waarde), discontovoet van 02% en rekenhorizon van 105 jaar							*€ 2,003,034,871*
Equivalente jaarlijkse kosten inclusief BTW van de gehele levenscyclus							*€ 39,658,702*

Bandbreedte : met een 70%-betrouwbaarheidsinterval liggen de levenscycluskosten inclusief BTW (reële kosten) tussen € 2878217498.1 en € 5791880220.1

De variatiecoëfficiënt bedraagt ± 30.1%

Geraamde Levenscycluskosten inclusief BTW (reële kosten)	€ 4,336,838,341
Organisatiegebonden reserveringen (opgave financier)	€ -
Onzekerheidsreserve (opgave financier)	€ -
Reservering scope wijzigingen (opgave financier)	€ -
Gerealiseerde kosten buiten de raming maar binnen budget (opgave financier)	€ -
Aan te houden budget levenscycluskosten inclusief BTW	**€ 4,336,838,341**

8 Risks and opportunities

The cost estimation in hand is connected to an early stage in the planning phase in regard to technical maturity as well as to time until planned realisation. In disposal programmes and connected cost estimations, it is an inherent risk that data and assumptions are associated with numerous uncertainties. (EURAD 2021) highlights the *"…complex and often not fully defined scope, the number of assumptions that have to be used in place of gaps in the information or data available, the societally sensitive nature of the programme with the large number of stakeholders involved, and long implementation periods."* In the current conceptual design, several technical aspects are not yet defined or described in detail. Some aspects are covered by assumptions. During the actual work of the cost estimation at different points of the conceptual design, technical risks or opportunities were identified. In this context, risks and opportunities vary from uncertainties (see section 9). Risk are defined as potential future developments or events with negative (financial) impact on the project. Opportunities are defined as potential future developments or events with positive (financial) impact on the project. The following sub-sections discuss the risks and opportunities connected to potential technical changes of the conceptual design that could influence the costing.

All sub-sections focus on the deep geological disposal in a rock salt formation. They represent technical adaptations to the conceptual design, assuming that the general concept will be implemented. More global risks and opportunities, influencing the general Dutch disposal programme are not considered. Such general risks and opportunities could be the use of alternative disposal options or a significant change of the inventory.

8.1 Risks

8.1.1 Surface facilities

Shafts represent the direct connection between the surface and the underground facilities. The current reference concept assumes that the surface facilities can be placed directly above the underground facility. The position is defined by the geological conditions in the salt formation. The concept is based on a generic geological model. A site is currently not selected. There is a risk of restricted usability of the surface. The population density of the Netherlands is one of the highest in the EU. Conflicts of land use or geographical restrictions are possible. If so, the surface facilities have to be placed at a larger distance to the underground facilities. The distance has to be covered by additional mine openings or other surface connections. In any case, a changed design of the surface connection is connected to higher costs for the excavation. A quantification of the costs is not possible because the actual local conditions are not known. However, in addition to increased investments for the larger mine openings, the longer transport way will have an impact on the operating period and the duration. Indirectly, the operational costs will increase as well.

8.1.2 Additional exploration drilling

The concept considers a specific amount ("as many as necessary, as few as possible") of large exploration boreholes along each shaft axis to prevent the creation of additional potential pathways between host rock and surface. One additional drilling of a large exploration borehole, in case the first 3 exploration drillings do not provide the needed results, is assumed as a risk. The associated additional costs on the drilling campaign can be assumed as approximately 1 Mio €.

8.1.3 Disposal concept for heat-generating waste

Deep geological disposal concepts all over the world consider a horizontal or vertical emplacement of DWP. A typical horizontal disposal option is the drift disposal. The borehole disposal is done vertically. The current Dutch reference concept of shallow boreholes in a drift represents a somehow unique concept, combining both drift and borehole disposal. Advantages of the concept are e.g. the avoidance of tilting processes of the DWP. However, compared with a pure drift disposal, the shallow borehole concept is characterised by a more complex excavation process. The construction of the shallow boreholes represents an additional working process in the disposal campaign. If boreholes are constructed directly before the disposal of a DWP, the alternating working mode of excavating and emplacement may lead to an extended period of the HLW disposal campaign.

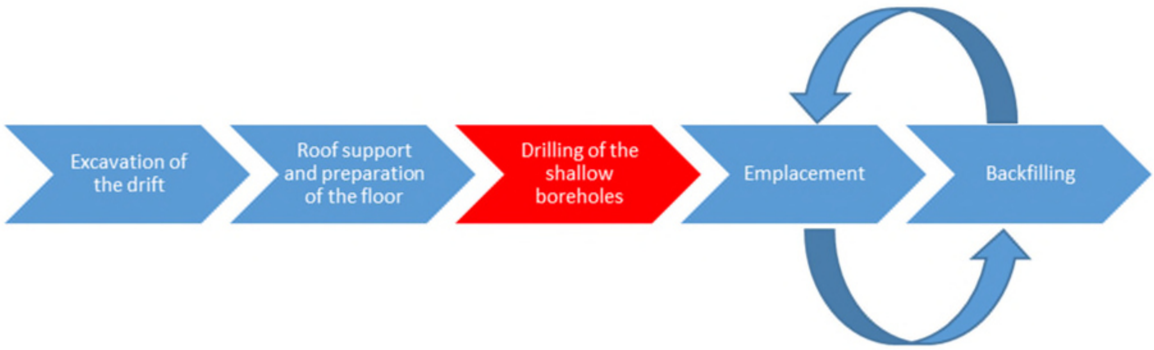

Figure 8-1: Workflow of the emplacement

The backfilling with crushed rock salt has to be done immediately after the disposal of a DWP. Known slinger truck techniques or pneumatic backfilling techniques cannot be used for backfilling a whole disposal drift in one step. The range of these technologies is limited to a few metres. As the heat output of the DWPs is limited, a defined distance between the DWPs for thermal reasons does not determine the design. The slope of the backfill and the size of the emplacement device will be the most relevant parameters for the minimum distance between two DWPs, see Figure 8-2. The size of the backfilling slope is defined by the friction angle, the height of the DWP, and the required covering of the DWP. The size of the emplacement device depends on the actual technical design. Currently, no conceptual design is available. If both design-determining parameters become too large, additional emplacement drifts will be required. A significant increase of the distance between two DWPs – compared with the reference assumptions – would lead to an extension of the layout and of the operating period.

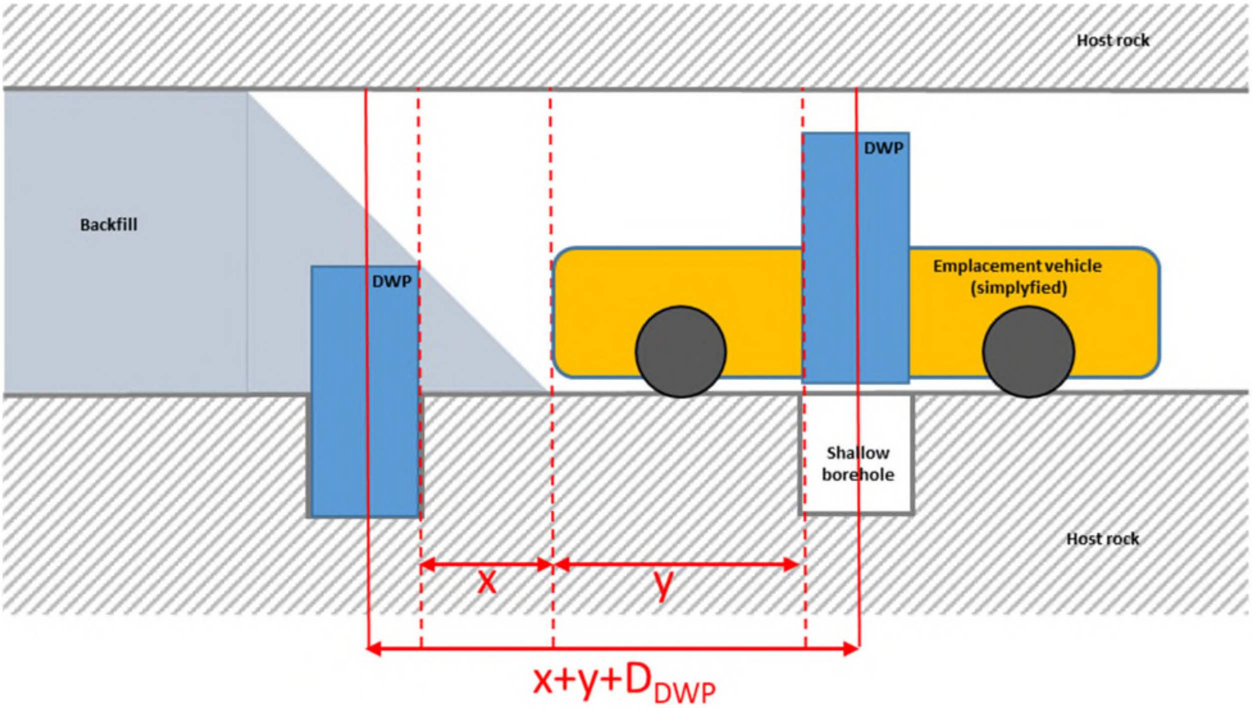

Figure 8-2: **Illustration of the minimum technically needed borehole distance**

8.1.4 Unfavourable geology at underground level

Despite extensive exploration, there is always a risk that actual geological conditions may differ from those assumed on the basis of the exploration results. This may lead to an expansion or a relocation of the service tunnel or disposal areas. This results not only in an extension of the space needed for the underground disposal facility but also in a time and cost extension.

8.1.5 Insurance costs

The insurance coverage involves a high risk due to a high degree of uncertainty in estimating the costs. The start of construction work is far in the future and insurance costs are subject to high fluctuations.

8.1.6 Land acquisition costs

Land acquisition costs are estimated on the basis of current land prices. It is difficult to estimate the development of costs until the actual acquisition of the land. In addition, the financial levies to the region are difficult to estimate, as it is not possible to predict the level of acceptance among the general public and, in particular, among landowners.

8.1.7 Project delays

Project delays due to delays in the approval process, requests for changes, or the influence of the public are common risks in construction projects. As the size of the project increases, so does the risk of problems in approval and implementation. Further possible project delays are induced through delays in the construction progress above ground and underground as well as in the backfilling and closure phase.

8.2 Opportunities

8.2.1 Synergies with the conditioning facilities

The considered Dutch inventory of radioactive waste can be classified into heat-generating and non-heat-generating waste. Heat-generating waste represents HLW in the form of CSD canisters and ECN canisters. The non-heat-generating waste represents LILW in different types of waste. LILW constitutes the largest volume of the waste. LILW is generated by activities using radioactive materials or radioisotopes in different industries, research institutes but also medicine. Another significant group of this waste type is the TE(NORM) waste. (TE(NORM)) represent uranium ores or other natural radioactive material that are generated in industrial processes and cover a significant inventory. The mentioned main groups of waste (HLW and LILW) are characterised by different volumes and inventories.

In the current reference design, it is assumed that at least two separate conditioning facilities have to be used. One facility is designed for the encapsulation of the HLW. A second facility is planned for the TE(NORM). Both facilities will be operated independently from each other and in a staggered operation. The HLW will be encapsulated and disposed at the lower level in a first campaign. After excavation of the upper level, the LILW and TE(NORM) will be encapsulated and subsequently disposed.

The planned construction, operation, and dismantling of two separate condition facilities includes the opportunity to combine both and reduce the technical as well as financial effort. The facilities handle different waste streams with different properties. However, the basic processes during the encapsulation processes are the same:

- Canister reception hall
- Storage area
- Decontamination room
- Hot cell
- Welding cell/grouting cell
- Inspection room
- Transfer cell
- Heating, Ventilation and Air Conditioning (HVAC)
- Buffer storage

The combination of both conditioning facilities into one promises the reduction of doubled structures and costs. If a complete dual use option cannot be realised, a refurbishment after the first encapsulation campaign may still offer significant savings compared with decommissioning and new construction. A parallel use of both facilities is not intended and thus, the facility could be adapted to the needs of the second encapsulation campaign.

The opportunity of combining both conditioning facilities promises a cost reduction of some tens to hundreds of million Euro. The construction, operation and dismantling of the HLW CF is estimated to cost approximately 370 Mio. €. Savings are expected especially during construction and dismantling. If costs for construction and decommissioning of one facility can be saved, a cost reduction of up to 130 Mio. € could be achieved. However, this represents just a rough estimation. More reliable estimations have to be based on a more detailed technical planning of both options.

8.2.2 Working mode/Shift regime

The duration of both disposal campaigns is defined by the amount of DWPs (see Figure 8-3) and the required time to dispose of them. The HLW DWPs will be disposed in a drift disposal concept. The LILW DWPs will be disposed in large chambers. Transport and disposal of the DWPs will be adjusted to the time actually needed. Per shift or working day, just as many DWPs will be transported as can be disposed. An additional buffer storage underground is not planned. The shaft transport represents the bottleneck of the transport and emplacement process.

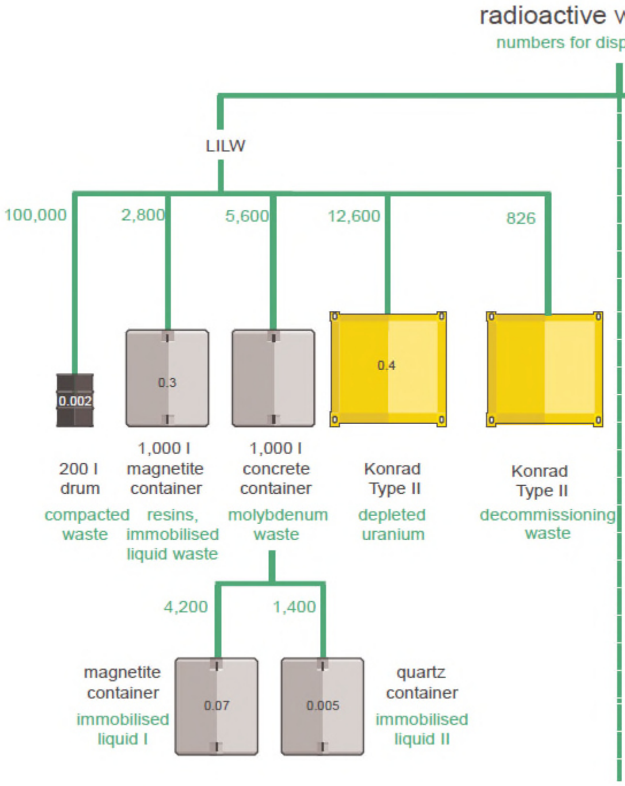

Figure 8-3: **Overview radioactive waste families and number of expected primary waste packages, based on (Bartol et al. 2025)**

Especially the LILW waste families include a large number of waste packages. Overall, 123,050 DWPs of different sizes have to be disposed. Table 8-1: and Table 8-2: summarise the assumed transport capacities. With an assumed useable cage size of 2 m width and 4 m length, up to nine 200 L drums, three 1,000 L canisters, or two Konrad type II canisters could be transported in one hoist. Operating the GDF in a one shift mode would result in approximately 18 years of pure disposal operation. Changing the shift regime, the net disposal time would remain the same, but the period would be shortened to around 10 years, because there would be more DWPs per day.

Table 8-1: Hoisting time for 1-shift operation

Group	Type	Number of primary waste packages / DWPs	DWP per hoist	Hoist per shift	Disposal shifts	Disposal shifts per day	Years
LILW	200 L drum	40,284	6	3	2,238	1	- (together with Konrad container)
LILW	200 L drum	18,900	9	3	700	1	- (together with 1000 L container)
LILW	200 L drum	40,816	18	3	756	1	3.44
LILW	1000 L magnetite	2,800	4	3	234	1	1.06
LILW	1000 concrete	5,600	4	3	467	1	2.12
LILW	Konrad type II uranium	12,600	2	3	2,100	1	9.55
LILW	Konrad type II D&D	826	2	3	138	1	0.63
SUM							**16.08**
HLW	CSD non-heat	84	1	2	42	1	0.20
HLW	CSD heat	80	1	2	40	1	0.19
HLW	ECN	122	1	2	61	1	0.28
SUM							**0.67**

Table 8-2: Hoisting time for 2-shift operation

Group	Type	Number of primary waste packages / DWPs	DWP per hoist	Hoist per shift	Disposal shifts	Disposal shifts per day	Years
LILW	200 L drum	40,284	6	3	2,238	2	- (together with Konrad container)
LILW	200 L drum	18,900	9	3	700	2	- (together with 1000 L container)
LILW	200 L drum	40,816	18	3	756	2	1.72
LILW	1000 L magnetite	2,800	4	3	234	2	0.53
LILW	1000 concrete	5,600	4	3	467	2	1.06
LILW	Konrad type II uranium	12,600	2	3	2,100	2	4.77
LILW	Konrad type II D&D	826	2	3	138	2	0.31
SUM							**8.39**
HLW	CSD non-heat	84	1	2	42	2	0.10
HLW	CSD heat	80	1	2	40	2	0.09
HLW	ECN	122	1	2	61	2	0.14
SUM							**0.33**

For the disposal campaign of the upper level, each year of disposal operation is connected to approximately 25.0 Mio. €. The costs include 6.2 Mio. € utility consumption, 5.4 Mio. € maintenance costs, 1.5 Mio. € insurance, and 11.5 Mio. € human resources.

If the number of disposal shifts is increased, the duration of the disposal campaign will be shortened and at least some of the costs can be reduced.

The following changes of the mentioned cost items are expected:

- A second disposal shift requires additional human resources. 2.8 Mio. € are assumed as additional costs for the underground operations. It is assumed that no additional human resources for COVRA are needed.
- Utility consumption increases by one quarter. 1.5 Mio. € are assumed as additional costs for the second disposal shift.
- It is assumed that maintenance for both shifts in covered in the mentioned costs.
- It is assumed that costs for insurance cover the whole facility and all activities.

For two disposal shifts, annual costs of approximately 29.0 Mio. € are expected. The duration could be reduced from 17 years to a maximum of 8.5 years. This reduced operational period corresponds to a maximum cost reduction of approximately 180 Mio. €. This represents a first, rough estimation. However, it can be highlighted that the implementation of a second disposal shift offers the opportunity to reduce the costs for up to several hundreds of million Euros.

8.2.3 Cooperation in research and development with other countries

For a relatively small country like the Netherlands, cooperation in research and development with other countries offers a great opportunity to save costs for its own research work. The Netherlands is already involved in an intensive international exchange of knowledge and benefits from the late start of the project. At this point, there is a chance that a lot of knowledge has already been built up in other countries and can be accessed.

8.2.4 Land sale after project completion

This opportunity covers the possibility that the land purchased for the deep geological repositories can be resold after closure of the repository.

9 Uncertainties

The cost estimate carried out in the course of this study is based on a rather low level of detail because of the low degree of maturity of the project. For both, the GDF and the CF, first conceptual plans are available. Assumptions had to be made to define boundary conditions and to identify unit costs for a significant number of cost items as well as for the duration of construction steps and operation. Consequently, most estimated costs are based on expert knowledge. Accordingly, the estimation is connected to a certain level of uncertainty.

In the context of cost estimations for disposal programmes of radioactive waste, uncertainties are defined as those *"…that can be reasonably expected to occur within the defined scope of the programme although they cannot be predicted. Such uncertainties are known as in-scope uncertainties."* (EURAD 2021)

For the evaluation of uncertainties in the study in hand, two major steps are necessary. First, uncertainties have to be identified and second, the potential impact on the cost evolution has to be evaluated. Later on, a management or uncertainty treatment would be necessary to monitor the uncertainties and address them in the following iterations of the cost assessments. Further information can be found e.g. in (IAEA 2020) and partly (NEA 2017). However, such an uncertainty management is not part of the assessment in hand.

Within the current cost estimation, it is assumed that in general all cost items are connected to an uncertainty. A detailed identification of the level of uncertainty has to be done. Significant technical uncertainties are discussed in section 8 as so-called risks and opportunities. The actual challenge is the evaluation of the uncertainties related to the current level of detail of the planning. This evaluation includes an assessment of probability and potential consequences. Between the different cost items both, probability and potential consequences, can vary.

The estimated costs for the different cost items have been given as base costs. No safety margins have been included in the costs for potential complications or additional technical or regulatory requirements that may turn up in the future course of the project. Therefore, base costs are also referred to as optimistic costs. Obviously, the consequence of optimistic assumptions is that the real costs of a project are usually higher.

The Association for the Advancement of Cost Engineering (AACE) has developed a methodology for estimating project costs based on experience from the execution of large-scale industrial projects (AACE 2005, 2019). According to this methodology, the potential increase or decrease of final project costs resulting from a cost assessment is estimated by considering the kind of costs that have been calculated (optimistic, most probable, or pessimistic), the character of the project, and the technical maturity of the project.

Considering the time scales of the different project phases: planning, construction, operation, closure, and post-closure monitoring period and some of the boundary conditions, geological disposal facility projects are certainly no typical large-scale engineering projects. Still, the

AACE methodology is considered to be a reasonable approach to get an idea about the final total costs based on the present first cost estimate of expected base costs.

It has to be taken into account that currently, the concept of a geological disposal facility for the Netherlands in rock salt environment is at a very early stage and future development of the project may lead to unforeseen changes with significant impact on the costs. Accordingly, the uncertainty range of total final costs resulting from the application of the AACE methodology will not cover all eventualities.

According to the AACE methodology, the uncertainty of projects or sub-projects has to be classified. The AACE provides guidelines for applying general principles to assign uncertainty classes to project cost estimates. This includes a cost estimate classification system to assess the typical uncertainties or expected level of accuracy. The AACE classification system divides the project or sub-systems into five characteristic classes (see Table 9-1:). Each class represents a specific level of maturity. Thus, a characteristic uncertainty level or level of accuracy can be defined. Class 5 represents the first and earliest stage. This class corresponds to a first concept screening or strategic planning. With decreasing class number, the maturity increases. Class 1 represents cost calculations based on tendering processes, actual project controlling, or change management tasks. At this class level, the project and the costs are nearly completely defined.

(AACE 2005) and (AACE 2019) give the same methodology and almost the identical table. However, there is a slight difference in the table. (AACE 2005) uses percentages to characterise the uncertainties. (AACE 2019) uses an index to characterise the uncertainties. The index 1 represents the expected costs and class 1. The higher the uncertainty or class, the higher the index is. The index represents the factor by which the expected costs are to be multiplied. To allow a better comparison with the SSK method (see section 7), the old system of (AACE 2005) is used for the further analysis.

The AACE method (see Table 9-1:) assumes the given costs as most likely costs, including base costs plus the “Estimating uncertainties”. Estimating Uncertainty (EU) addresses uncertainties related to the degree of technological advancement and the project maturity (level of development). Accordingly, the expected accuracy ranges cover potential savings as well as cost increases.

Due to the early stage of the repository concept, the step to define EUs has not been performed separately. Instead, as mentioned above, the costs calculated for the cost assessment in hand are given as base costs or optimistic costs. This means that it is expected that all assumptions are true, the full project is managed under the ideal schedule etc. Uncertainties, therefore, will essentially result in a cost increase.

Table 9-1: AACE classification system, based on (AACE 2005)

	Primary Characteristic	Secondary Characteristic			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

Notes: [a] The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.
[b] If the range index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

In addition to calculating the disposal costs in rock salt using a deterministic method, as applied in OPERA, the SSK (Standaard Systematiek Kostenramingen) method is also utilized here. The SSK is a standardized cost estimation framework widely used in the Netherlands for infrastructure and construction projects. It provides a structured and transparent approach by breaking down costs into direct and indirect components using a Work Breakdown Structure (WBS). With this method, probabilistic cost estimates can be calculated using a Monte Carlo simulation to improve cost reliability. A Monte Carlo simulation was conducted for a cost estimate of a repository in rock salt. In total, 10,000 simulations were performed using a triangular distribution. Two uncertainty distributions are considered. In the first, uncertainties range between -50% and +50%. In the second, the AACE classification system is applied.

Class 5 corresponds to the earliest project stage, covering initial concept screening or strategic planning. As the class number decreases, project maturity increases. Class 1 represents cost calculations based on tendering processes, actual project control, or change management, where project scope and costs are nearly fully defined. For broadly defined cost items, Class 5 is applied, representing initial concept screenings. For specific systems or cost items comparable to other repository projects, Class 4 is used, reflecting feasibility study stages, or potentially Class 3. However, Class 3 typically applies to cost estimates prepared for budget authorizations or funding requests. Given the current level of detail, even with experience from other repository projects, applying Class 3 would likely be too optimistic. Therefore, apart from the costs for land acquisition (Class 3), only Classes 4 and 5 have been applied in this cost estimation. Furthermore, the lowest and the highest are uncertainty are selected. For example, in class 5, the uncertainty ranges between -50% and +100%.

Simulation using an uncertainty range of -50% to +50% shows that a repository in rock salt will likely cost around 4.3 billion euros including VAT but thus about 3.5 billion euros, which is like the estimate calculated using the deterministic method (see Figure 9-1). This is likely a result of the symmetric uncertainty distribution used and that no one single item represents a significant large part of the cost. There is a probability of 5% that the repository will cost less than 1.8 billion euros (excluding VAT) and a 5% chance that it will cost more than 5.3 billion euros (excluding VAT).

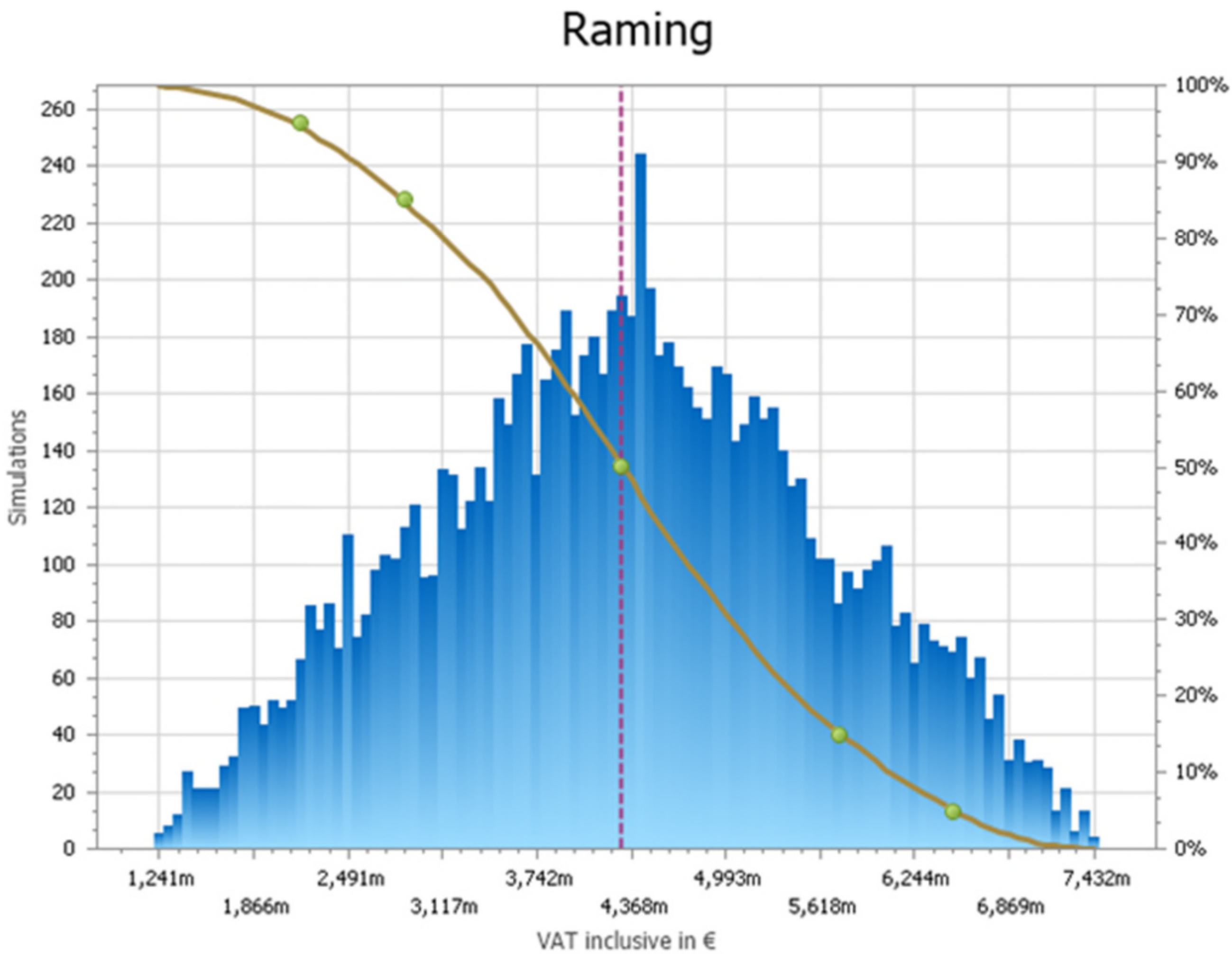

Figure 9-1: **Monte Carlo simulation of the expected cost using the -50% – 50% uncertainty in the prices. Note that the prices shown here includes VAT**

Using the uncertainties from the AACE classification, a repository in rock salt is estimated to cost around 4.8 billion euros including VAT and 3.9 excluding VAT (see Figure 9-2). In the AACE classification, there is a higher probability that the price will increase, leading to an overall higher cost. There is a probability of 5% that the repository will cost less than 1.3 billion euros (excluding VAT) and a 5% chance that it will cost more than 6 billion euros (excluding VAT).

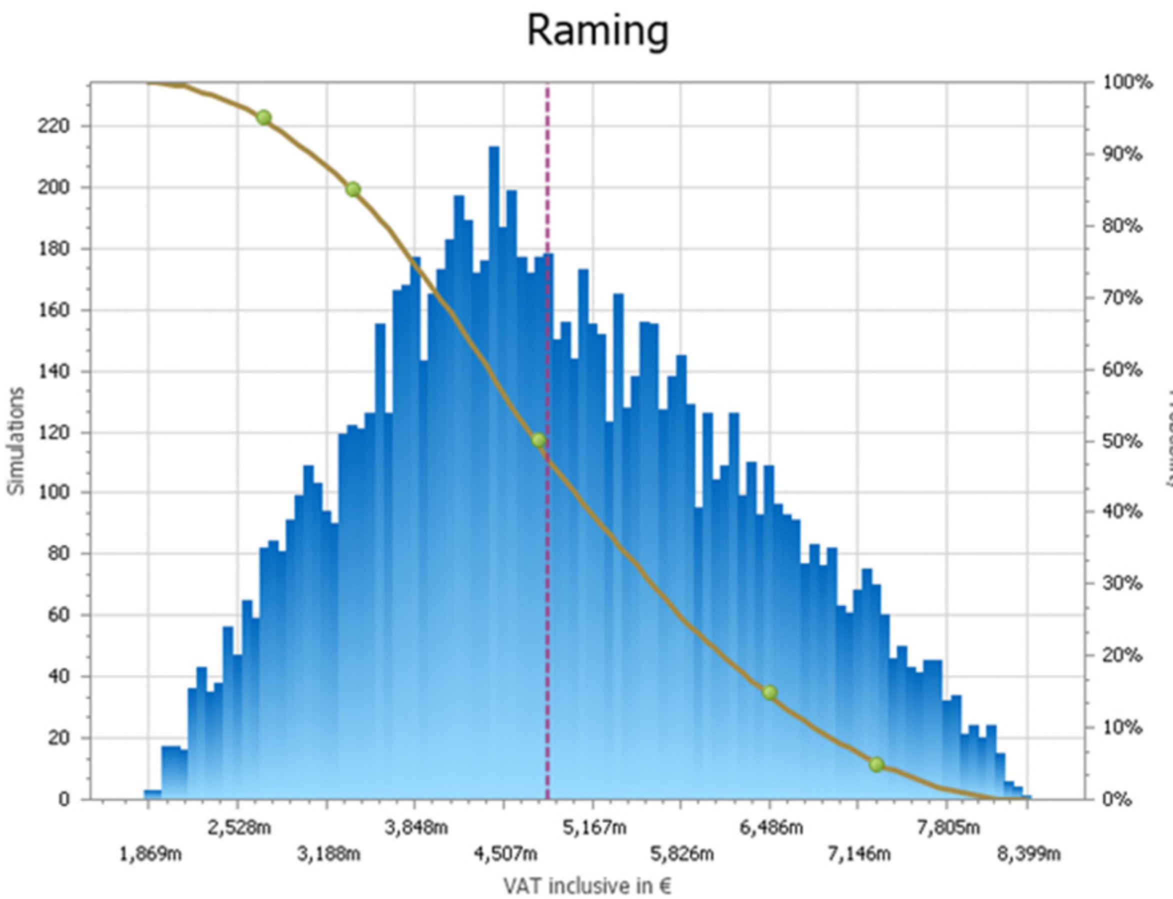

Figure 9-2: **Monte Carlo simulation of the expected cost using the AACE classification for the uncertainty in the prices. Note that the distribution shown here includes VAT**

While a significant increase in costs between the expected total final costs compared with the total base costs was to be expected, the upper boundary seems rather high. On the other hand, looking at the cost evolution of a variety of large-scale projects in the past, even larger cost increases do not seem to be that unusual. As an example: A 2014 study on systematically planned and real budgets for 170 large infrastructure projects in Germany, from the building, transportation, defence, energy, and ICT sectors showed that 119 of them, which were finished between 1960 and 2014, had an average cost overrun of 73% (Kostka & Anzinger 2014).

10 Summary

With regard to deep geological disposal, there are potentially two different host rocks available in the Netherlands, clay formations and rock salt. The latest cost estimate for a GDF in rock salt in the Netherlands goes back to 1999 and has to be updated in 2023, not only because of the time that has passed since then, but also because of changes in the conceptual design. In contrast to the 1999 costing, the disposal of other waste streams than high-level waste shall be taken into account as well. BGE TECHNOLOGY GmbH has been commissioned to perform the 2023 cost estimation for such a GDF in a domal salt formation based on the boundary conditions given by the Dutch radioactive waste management strategy. In between several assumptions related to the inventory and the GDF design have changed. Thus an additional update of the cost estimation was performed.

Based on the current reference concept and the chosen assumptions, total base costs of 2,790 Mio. € are expected. These costs cover the detailed site investigation, the design and planning phase, the construction, the operation as well as the observation, closure, and dismantling of the GDF. Within each phase, costs for the investment and the operation itself are considered. Typical investments are for example the construction of surface buildings. Typical operational costs are for example human resources. The costs include 393 Mio. € for construction, operation, and dismantling of the conditioning facility for HLW disposal waste packages. It is assumed that this facility is located at site and operated in parallel to the GDF.

Based on the internationally excepted standards, the costing followed a breakdown structure to allow a clear and transparent traceability of the costs. All costs are expected to be overnight costs. The price base is set to the start of 2022.

It has to be kept in mind that at the present stage of the project for the disposal of radioactive waste in a geological disposal facility in the Netherlands, the uncertainties are still very high. The estimated base costs assume an optimistic development of the project without any margins for delays or unexpected difficulties. Accordingly, the estimated total final costs and the associated uncertainty bandwidth have to be taken as a first indication of the total costs, which may change significantly during the further development of the conceptual planning.

In order to estimate more realistic total costs for the facility, the AAEC methodology for cost assessment of large-scale projects has been applied roughly. This method assigns uncertainty margins depending on the maturity level of the respective planning. Considering the early stage of the project and the character of the estimated base costs, this increased total cost value is considered as a far more realistic estimate of the future final costs than the total base cost. Still, as discussed above, the future development of the project can still lead to significant changes of these expected total costs.

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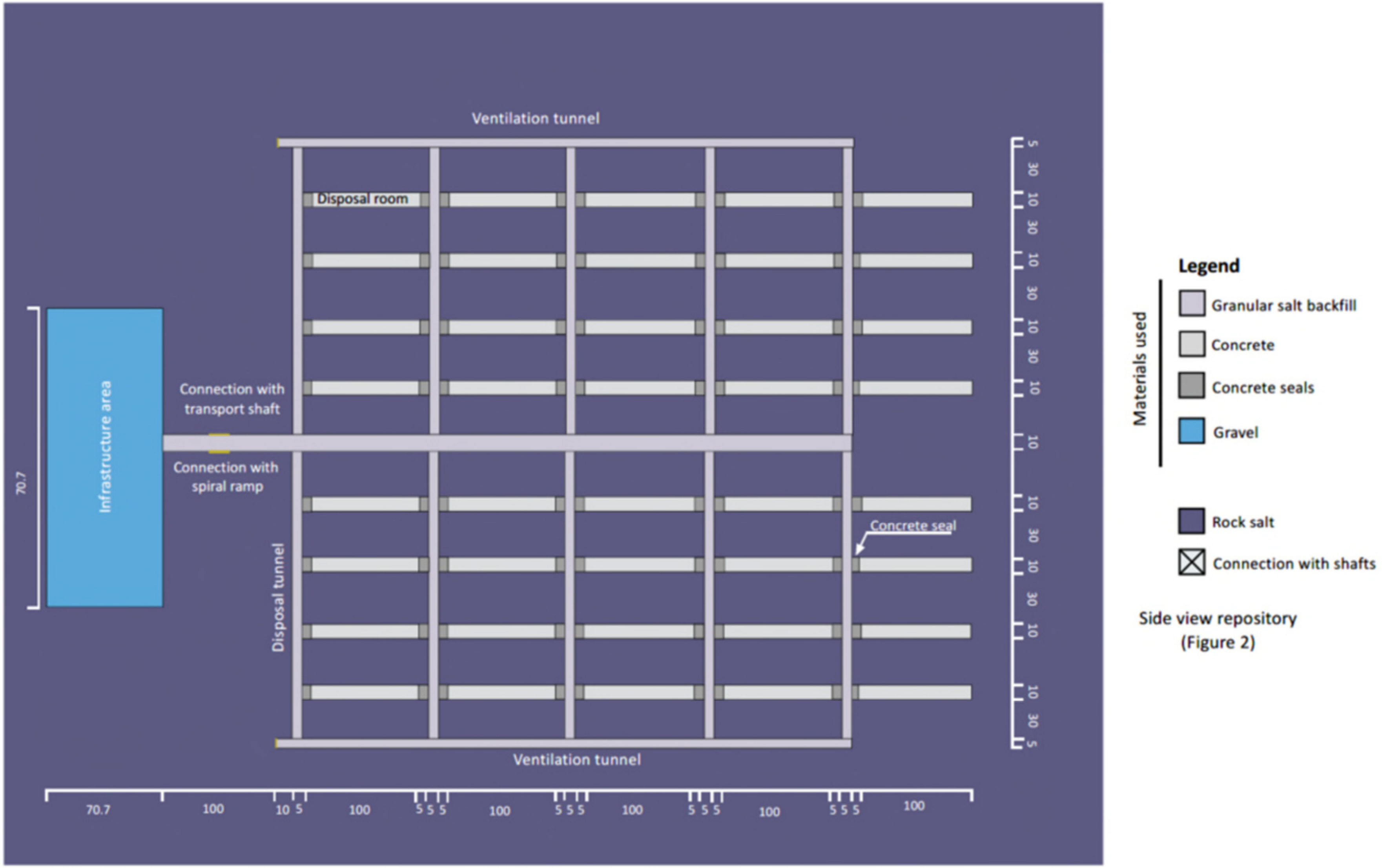
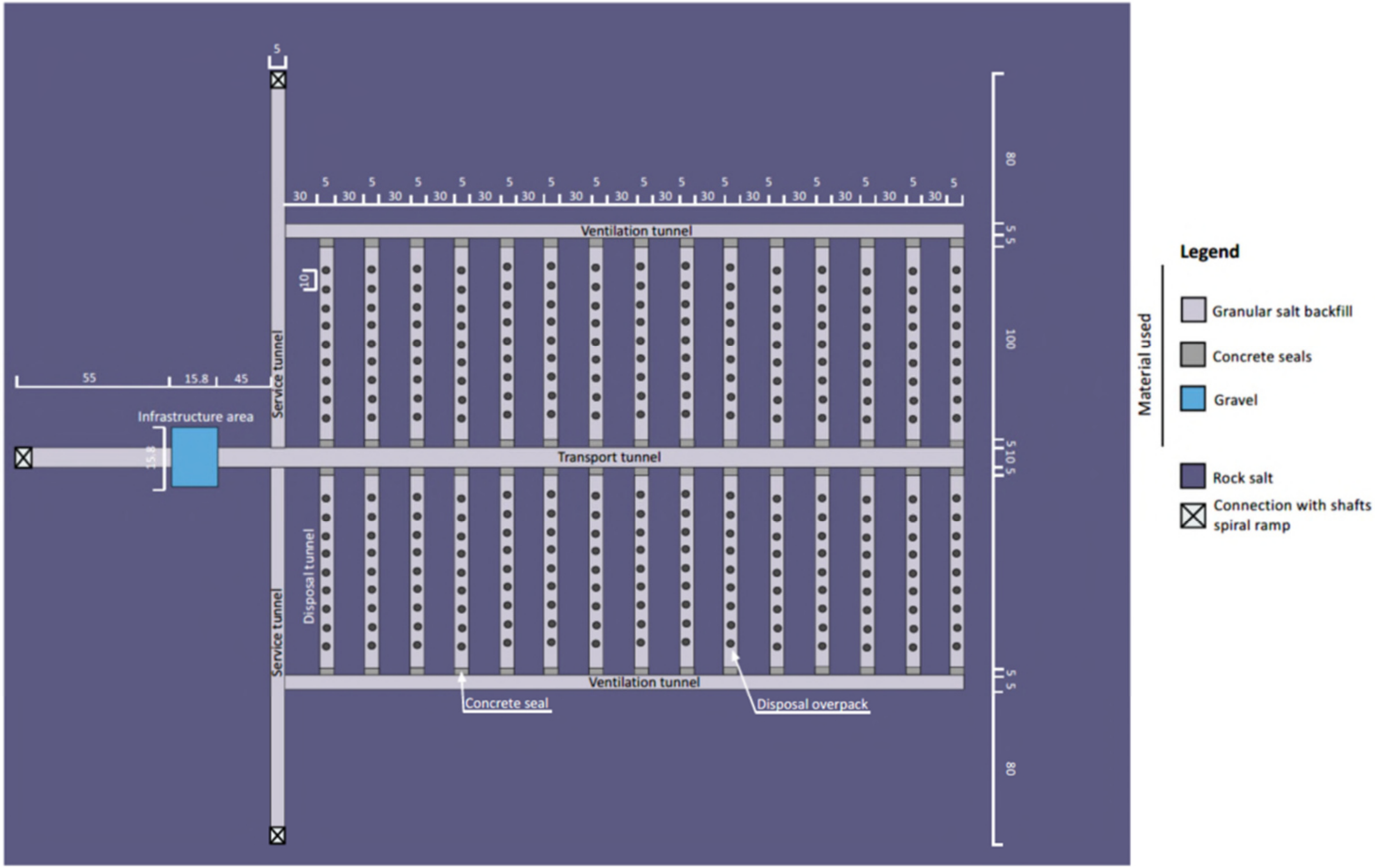
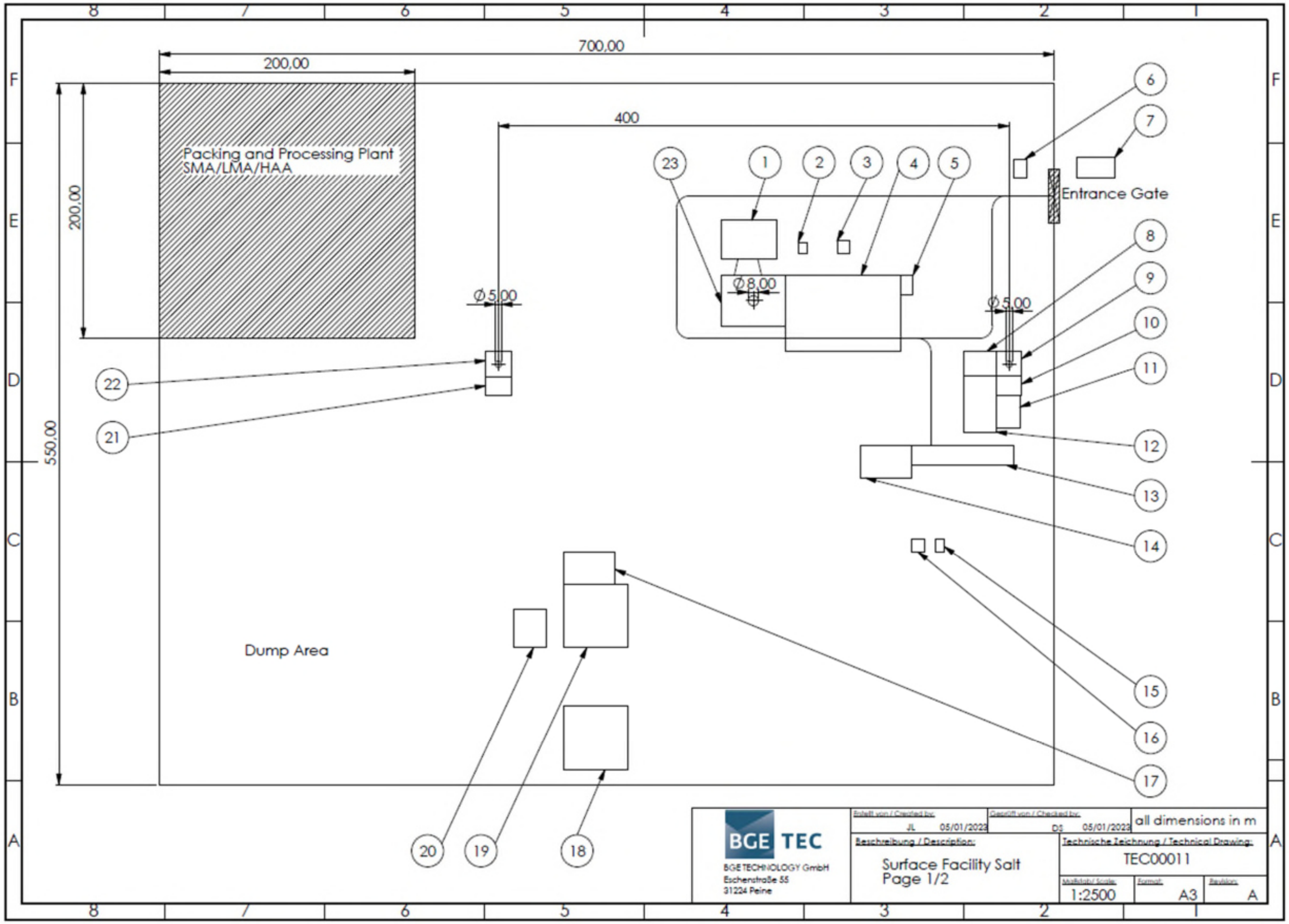
Appendix 1 Layout Upper Level



Appendix 2 Layout Lower Level



Appendix 3 Surface Facility Sketch



Pos.	Name	Length	Width	Height
1	Ventilation Building	43	30	10
2	Transformer Station	9	7	4
3	Weather Station	10	10	21
4	Handling Facility (incl. Entrance, Drying, Hot Cell, Decontamination, Transport and Supply Hall)	90	60	18
5	Collection and Treatment of Radioactive Waste	15	10	4
6	Guardhouse	15	10	4
7	Visitors Centre	30	16	8
8	Locker Room Access	25	20	7
9	Shaft Hall Access	20	20	15
10	Engine Building Access Shaft	20	15	10
11	Emergency Power System Station	25	15	18
12	Administration Building incl. Central Control	43.5	25	15
13	Workshop, Garage	80	15	15
14	Fire Station	40	25	15
15	Fuel Tank Building	11	7.5	5
16	Washing Area	10	10	4
17	Laboratory / Drill Core Storage	40	25	15
18	Backfill Processing Plant	50	50	8
19	Construction Material Storage	50	50	8
20	Water Supply / Waste Water	30	25	6
21	Engine Building Ventilation Shaft	20	15	10
22	Ventilation Shaft Hall	20	20	15
23	Shaft Hall Waste Shaft	50	40	20

BGE TEC
BGE TECHNOLOGY GmbH
Eschenstraße 55
31224 Peine

Erstellt von / Created by: JL 05/01/2023
Geprüft von / Checked by: DS 05/01/2023

Beschreibung / Description:
Surface Facility Salt
Page 2/2

Technische Zeichnung / Technical Drawing: TEC00011
Maßstab/ Scale:
Format: A3
Revision: A

Appendix 4 SSK Costing Structure

	GDF
10	**Pre-constructional activities**
11	**Land purchase**
11,01	Exploration
11,02	nominal cost of land purchase
11,03	notary fee
12	**Site infrastructure works**
12,01	landscaping
12,02	roads and parking lots
12,03	green park area
12,04	architect/engineer fee
12,05	sewage system
12,06	Roads (incl. temporary construction roads)
12,07	Electricity
12,08	Telecommunications
13	**Site facility construction**
13,01	utility buildings
14	**Security installation**
14,01	fence including:
15	**Utility consumption**
	Utility consumption
15,01	electricity
15,02	Gas
15,03	water
15,04	consumables waste handling e.g. waste oil
16	**Human resources**
16,01	Operator
16,02	COVRA
20	**Repository construction**
21	**Construction and outfitting shafts**
21,01	personal shaft construction
21,02	personal shaft hoisting system
21,03	waste shaft construction
21,04	waste shaft hoisting system
21,05	Ventilation shaft construction
21,06	Ventilation shaft hoisting system
21,07	architect/engineer fee

22	**Construction and outfitting upper level main area**
22,01	Excavation cost CM
22,02	Continous Miner
22,03	Continous Miner Maintenance & other vehicles maintenance
22,04	Roof Bolting Machine
22,05	Rock Bolts
22,06	Scaler
22,07	LHD
22,08	Dumper
22,09	Working Platform
22,10	Mine Car
22,11	outfitting (electricity, fire protection)
22,12	Infrastructure Area Equipment
23	**Construction and outfitting HAW main area & bunker**
23,01	Ramp construction inc. hoisting system
22,01	Excavation cost CM
22,02	Continous Miner
22,03	Continous Miner Maintenance & other vehicles maintenance
22,04	Roof Bolting Machine
22,05	Rock Bolts
22,06	Scaler
22,07	LHD
22,08	Dumper
22,09	Working Platform
22,10	Mine Car
22,11	outfitting (electricity, fire protection)
22,12	Infrastructure Area Equipment

24	**Construction and outfitting HAW disposal area**
22,01	Excavation cost CM
22,02	Continous Miner
22,03	Continous Miner Maintenance & other vehicles maintenance
22,04	Roof Bolting Machine
22,05	Rock Bolts
22,06	Scaler
22,07	LHD
22,08	Dumper
22,09	Working Platform
22,10	Mine Car
22,11	outfitting (electricity, fire protection)
22,12	Infrastructure Area Equipment
25	**Construction and outfitting LILW and (TE)NORM disposal galleries**
22,01	Excavation cost CM
22,02	Continous Miner
22,03	Continous Miner Maintenance & other vehicles maintenance
22,04	Roof Bolting Machine
22,05	Rock Bolts
22,06	Scaler
22,07	LHD
22,08	Dumper
22,09	Working Platform
22,10	Mine Car
22,11	outfitting (electricity, fire protection)
22,12	Infrastructure Area Equipment

26	**Site facility construction**
26,01	Transformer station
26,02	Emergency power system station
26,03	Fuel Tank Building
26,04	Ventilation Building
26,05	Main Fan, Technical Equipment
26,06	Administration Building (incl. Central control)
26,07	Visitors centre
26,08	Handling Facility (incl. Entrance, Drying, hot cell, decontamination, transport- and supplying hall)
26,09	Shaft Tower Waste Shaft
26,10	Shaft hall Access Shaft
26,11	Shaft Tower Access Shaft
26,12	Locker room Access
26,13	Engine Building Access shaft
26,14	Ventilation Shaft Building incl. Equipment
26,15	Workshops, Vehicle Storage
26,16	Guard Building
26,17	Water Supply / Waste Water
26,18	Weather Station
26,19	Laboratory / Drill Core Storage
26,20	Washing place vehicles
26,21	Dump
26,22	Engine Building Ventilation (transformer station & Emergency power station)
26,23	collection and treatment of radioactive waste
26,24	Fire Station
26,25	Backfill Processing Plant
26,26	Artwork for Building design
26,27	architect/engineer fee
27	**Maintenance surface**
27,01	Maintenance surface facilities
27,02	Maintenance surface areas

28	**Insurance**
28,01	Combined construction/assembly insurance incl. assembly equipment
28,02	Builder's liability insurance
28,03	Public liability insurance conventional Public liability insurance nuclear
28,04	Nuclear insurance
28,05	Further insurance (visitors etc.)
15	**Utility consumption**
	Utility consumption
15,01	electricity
15,03	water
15,04	consumables waste handling e.g. waste oil
29	**Human resources**
29,01	Operator
29,02	COVRA
30	**HLW disposal campaign**
31	**Disposal**
31,01	Waste transport cart
31,02	Waste transport cart maintenance
31,03	Backfilling Equipment Maintenance
32	**Backfilling and Sealing**
32,01	Disposal Tunnel heat-generating
32,02	Disposal Tunnel non heat-generating
27	**Maintenance surface**
27,01	Maintenance surface facilities
27,02	Maintenance surface areas

28	**Insurance**
28,01	Combined construction/assembly insurance incl. assembly equipment
28,02	Builder's liability insurance
28,03	Public liability insurance conventional Public liability insurance nuclear
28,04	Nuclear insurance
28,05	Further insurance (visitors etc.)
15	**Utility consumption**
	Utility consumption
15,01	electricity
15,03	water
15,04	consumables waste handling e.g. waste oil
33	**Human resources**
33,01	Operator
33,02	COVRA
40	**LILW and (TE)NORM waste disposal campaign**
41	**Disposal**
41,01	Waste transport cart / Forklift
41,02	Waste transport cart maintenance
41,03	Backfilling Equipment
41,04	Backfilling Equipment Maintenance
42	**Backfilling and sealing**
42,01	Disposal Gallery
42,02	Disposal Room
15	**Utility consumption**

	Utility consumption
15,01	electricity
15,03	water
15,04	consumables waste handling e.g. waste oil
27	**Maintenance surface**
27,01	Maintenance surface facilities
27,02	Maintenance surface areas
28	**Insurance**
28,01	Combined construction/assembly insurance incl. assembly equipment
28,02	Builder's liability insurance
28,03	Public liability insurance conventional
28,04	Public liability insurance nuclear Nuclear insurance
28,05	Further insurance (visitors etc.)
43	**Human resources**
43,01	Operator
43,02	COVRA
50	**Underground observation**
27	**Maintenance surface**
27,01	Maintenance surface facilities
27,02	Maintenance surface areas
28	**Insurance**
28,01	Combined construction/assembly insurance incl. assembly equipment
28,02	Builder's liability insurance
28,03	Public liability insurance conventional
	Public liability insurance nuclear
28,04	Nuclear insurance
28,05	Further insurance (visitors etc.)

51	**Utility consumption**
	Utility consumption
51,01	electricity
51,02	water
51,03	consumables waste handling e.g. waste oil
52	**Human resources**
52,01	Operator
52,02	COVRA
60	**Repository closure**
61	**Backfilling and sealing galleries and ramp**
61,01	Ventilation Tunnel lower level
61,02	Service Tunnel lower level
61,03	Transport Tunnel lower level
61,04	Infrastructure area lower level
61,05	Ramp
61,06	Ventilation Tunnel upper level
61,07	Service Tunnel upper level
61,08	Transport Tunnel upper level
61,09	Salt bunker
61,10	Infrastructure upper level
62	**Backfilling and sealing shafts**
62,01	Dismantling of the underground plant technology
62,02	Dismantling hoisting systems and rent of 2 temporary hoisting systems
62,03	Dismantling and removal of the shaft interior
62,04	Shaft backfill & closure structure (3 times)

63	**Dismantling and decommissioning nuclear facilities**
63,01	Clearance measurement of nuclear facilities inkl. Hoisting systems and buildings control and monitoring area
64	**Site dismantling and clearance**
64,01	Dismatling of conventional surface facilities
28	**Insurance**
28,01	Combined construction/assembly insurance incl. assembly equipment
28,02	Builder's liability insurance
28,03	Public liability insurance conventional Public liability insurance nuclear
28,04	Nuclear insurance
28,05	Further insurance (visitors etc.)
15	**Utility consumption**
	Utility consumption
15,01	electricity
15,03	water
15,04	consumables waste handling e.g. waste oil
65	**Human resources**
65,01	Operator
65,02	COVRA
70	**Post Operational Phase**
71,01	Operator
71,02	COVRA

80	**Maintenance Equipment**
80.01	Continous Miner Maintenance
80.02	Roof Bolting Machine Maintenance, 10 % of aquisition cost
80.03	Scaler Maintenance, 10 % of aquisition cost
80.04	LHD Maintenance, 10 % of aquisition cost
80.05	Dumper Maintenance, 10 % of aquisition cost
80.06	Working Platform Maintenance, 10 % of aquisition cost
80.07	Mine Car Maintenance, 10 % of aquisition cost
80.08	Maintenance transformer station
80.09	Maintenance emergency power system station
80.10	Maintenance Fuel Tank Building
80.11	Maintenance Ventilation Building
80.12	Maintenance Administration Building (incl. Central control)
80.13	Maintenance Visitors centre
80.14	Maintenance Handling Facility (incl. Entrance, Dryiing, hot cell, decontamination, transport- and suppliing hall)
80.15	Maintenance Shaft Tower Waste Shaft
80.16	Maintenance Shaft hall Access Shaft
80.17	Maintenance Shaft Tower Access Shaft
80.18	Maintenance Locker room Access
80.19	Maintenance Engine Building Access shaft
80.20	Maintenance Workshops, Garage locomotive, Cart
80.21	Maintenance Guard Building
80.22	Maintenance Water Supply / Waste Water
80.23	Maintenance Weather Station
80.24	Maintenance Laboratory / Drill Core Storage
80.25	Maintenance Washing place vehicles
80.26	Maintenance Energy Supply: (transformer station & Emergency power station)
80.27	Maintenance collection and treatment of radioactive waste
80.28	Maintenance Fire Station

	CF
90	**Site preparation**
91	Investment - Land purchase
91.01	nominal cost of land purchase
91.02	notary fee
92	Investment - Site infrastructure works
92.01	landscaping
92.02	roads and parking lots
92.03	green park area
92.04	sewage system
92.05	connection to utilities networks and sewage
92.06	architect/engineer fee
93	Human resources site preparation
93.01	Operator
93.02	COVRA
93.03	control of the construction license
90	CF construction and operation
94	Investment - Site facility construction
94.01	CF building
94.02	architect/engineer fee
95	Investment - CF internals/construction and installation
95.01	Fuel handling systems, cranes and lifts
95.02	process systems
95.03	Automatisation and telecommunication
95.04	Electric power system
95.05	HVAC
95.06	Radiationprotection and monitoring
95.07	architect/engineer fee

96	Human resources CF construction
96.01	Operator
96.02	COVRA
96.03	control of the construction license
97	Maintenance during HLW disposal campaign
97.01	CF building
97.02	CF internals/construction and installation, incl. Replacement
98	Insurance during HLW disposal campaign
98.01	CF building
98.02	CF internals/construction and installation
99	Material for DWP and consumables
99.01	DWP lid and flap ECN "hot"
99.02	DWP lid and flap CSD "hot and cold"
99.03	Transport Cap
99.04	CF utility consumtion (electricity, HVAC)
99.05	Operational waste management
100	Human resources during HLW disposal campaign
100.01	Operator
100.02	COVRA
100.03	control of the operation license
90	Closure and decommissioning
101	Investment - Dismantling and decommissioning nuclear facilities
101.01	conditioning facility
101.02	internals
101.03	Operator
101.04	COVRA
101.05	control of the dismantling and decommissioning license

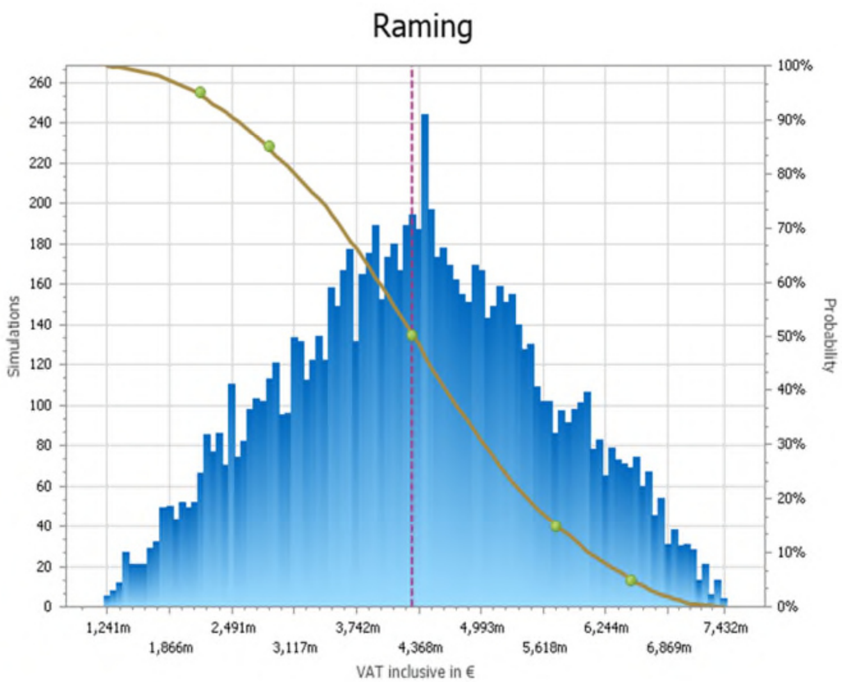
Appendix 5 The estimated cost distribution using a Monte Carlo simulation using the -50% - 50% uncertainty in the prices

Probabilistische resultaten levenscycluskosten

Deterministische levenscycluskosten inclusief BTW = modus (T_waarde)	€	4,331,954,878
Verschuiving levenscycluskosten inclusief BTW	€	4,883,463
Probabilistische levenscycluskosten inclusief BTW = gemiddelde (Mu_waarde)	**€**	**4,336,838,341**
Variatiecoëfficiënt levenscycluskosten		**30%**
Standaardafwijking levenscycluskosten	€	1,303,582,264
Scheefheid		0.00
Minimum waarde	€	1,209,347,452
Maximum waarde	€	7,463,286,709
5% onderschrijdingskans	€	2,179,722,145
Ondergrens 70% interval	**€**	**2,878,217,498**
50% overschrijdingskans	€	4,348,251,205
Bovengrens 70% interval	**€**	**5,791,880,220**
5% overschrijdingskans	€	6,540,587,062

[All] Electricity , 0.85 kW/h, (object: Surface, oorzaak: price)	19.5%
[TE]Conrad container, (object: TENORM Conditioning, oorzaak: price)	15.2%
[All] Maintenance surface facilities, (object: Surface, oorzaak: price)	14.9%
[Post closure] Dismantling hoisting systems and rent of 2 temporary hoisting systems, (object: Repository Clc	9.5%
[Post closure] Shaft backfill & closure structure (3 times), (object: Repository Closure, oorzaak: price)	5.3%
[Construction] Operator Construction, (object: Repository construction, oorzaak: price)	4.9%
[LILW disposal] Operator LILW Disposal Campaign, (object: LILW (TE)NORM Disposal, oorzaak: price)	4.0%
[Construction] Handling Facility (incl. Entrance, Drying, hot cell, decontamination, transport- and supplying hall), (object: Surface, oorzaak: price)	3.3%
Other	23.5%
Total	100.0%

Hierboven staan de risicobijdragen levenscycluskosten (kostenposten die de grootte van de standaardafwijking bepalen)



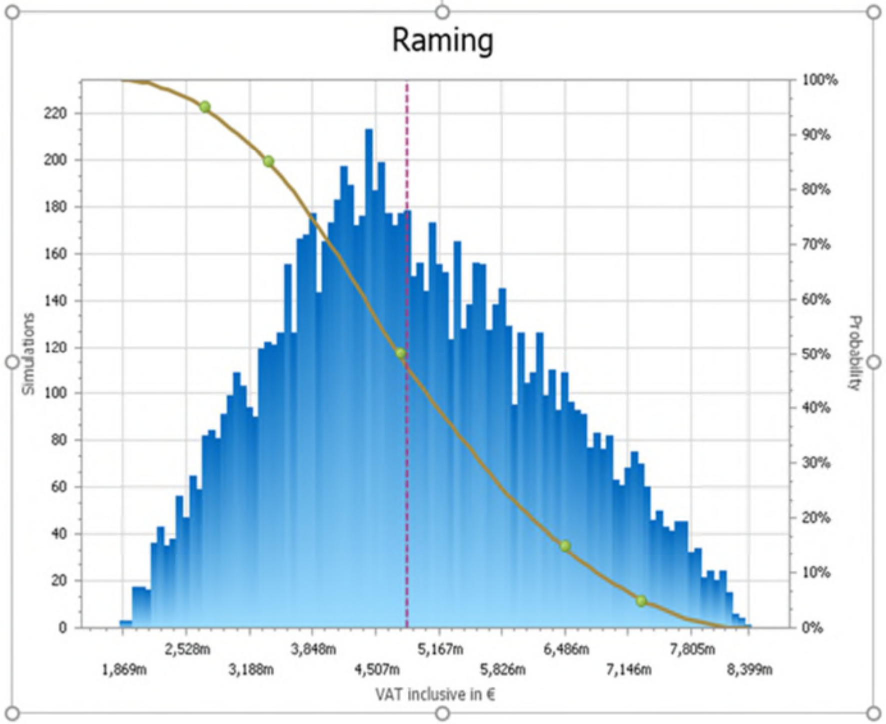
Appendix 6 The estimated cost distribution using a Monte Carlo simulation using the AACE classification uncertainty in the prices

Probabilistische resultaten levenscycluskosten

Deterministische levenscycluskosten inclusief BTW = modus (T_waarde)	€	4,331,954,878
Verschuiving levenscycluskosten inclusief BTW	€	566,021,521
Probabilistische levenscycluskosten inclusief BTW = gemiddelde (Mu_waarde)	€	**4,897,976,398**
Variatiecoëfficiënt levenscycluskosten		**28%**
Standaardafwijking levenscycluskosten	€	1,382,808,959
Scheefheid		0.22
Minimum waarde	€	1,835,875,607
Maximum waarde	€	8,431,825,301
5% onderschrijdingskans	€	2,740,447,177
Ondergrens 70% interval	€	**3,414,821,166**
50% overschrijdingskans	€	4,775,787,409
Bovengrens 70% interval	€	**6,488,457,112**
5% overschrijdingskans	€	7,324,122,663

[All] Maintenance surface facilities, (object: Surface, oorzaak: price)	26.7%
[Post closure] Dismantling hoisting systems and rent of 2 temporary hoisting systems, (object: Repository Closure, oorzaak: price)	17.2%
[All] Electricity , 0.85 kW/h, (object: Surface, oorzaak: price)	9.7%
[Post closure] Shaft backfill & closure structure (3 times), (object: Repository Closure, oorzaak: price)	9.3%
[TE]Conrad container, (object: TENORM Conditioning, oorzaak: price)	7.9%
[Construction] waste shaft construction, (object: Shaft Sinking, oorzaak: price)	3.6%
[Construction] ventilation shaft construction, (object: Shaft Sinking, oorzaak: price)	2.5%
[Construction] Personel shaft construction, (object: Shaft Sinking, oorzaak: price)	2.4%
Other	20.8%
Total	100.0%

Hierboven staan de risicobijdragen levenscycluskosten (kostenposten die de grootte van de standaardafwijking bepalen)



Appendix 7 Updated Waste Scenario – Cost Estimation by COVRA

The waste inventory as presented in section 3 of the main report represents the basis for the reference design, the basis for the cost estimation performed by Herold and Leonhard (2024), as well as the updated cost estimation summarised in the main report. However, other scenarios with a significantly increased waste volume and inventory might be realistic in the future. To determine the cost effects of such an increased inventory, COVRA performed an upscaling based on the cost estimation presented in the main report. This appendix, appendix 6, summarises the upscaling based on the alternative scenario.

1 Introduction

In the Netherlands, COVRA is the organisation responsible for managing radioactive waste, from collection through to disposal in a Geological Disposal Facility (GDF). While a GDF should be operational in the Netherlands in 2130 (Environment Ministry of Infrastructure and Water Management, 2017), research into geological disposal in the Netherlands is already underway (Verhoef et al., 2021). This includes estimating the costs of a repository to ensure adequate funding for the construction, operation, and final closure of the GDF.

A cost estimate for a GDF in rock salt was conducted during the OPLA programme (1982-1992), which projected that the development of a GDF would cost about 454 million Dutch Guilders (approximately 206 million Euros) based on 1985 prices. A more recent estimate was made in 1999, suggested a total cost of 280 million Euros for a GDF in rock salt, with an additional 1.8 million Euros per year required for its operation (Grupa and Jansma, 1999). This estimate only accounted for the disposal of High-Level Waste (HLW) and not Low- and Intermediate-Level Waste (LILW) which is the largest volume of waste. The most recent cost estimate was made in 2023 by Herold and Leonhard (2024). They showed that a repository in rock salt will cost about 3.5 billion Euros when using the deterministic method as in OPERA (Verhoef et al., 2017) and the probabilistic SSK method.

The cost estimate by Herold and Leonhard (2024) is a based on waste Scenario 1 of Burggraaff et al. (2022) This waste scenario assumes that the current nuclear facilities will remain open as planned, while only one new research reactor will be constructed (Pallas). However, this scenario does not account for the opening of new nuclear power plants, as currently considered by the Dutch government (Erkens, 2024). Here, we present an updated cost estimate, based on the cost estimate by Herold and Leonhard (2024) that takes the opening of new nuclear power plants, as currently considered by the Dutch government.

2 Waste scenario BASIS scenario

In the update waste scenario, also referred to as the BASIS scenario, it is based on the most recent masterplan and accounts for the construction of two new nuclear power plants and an extended operating period of URENCO. Together, they will significantly increase the expected waste for disposal, especially the HLW and (TE)NORM, for disposal as shown in Figure A7-1.

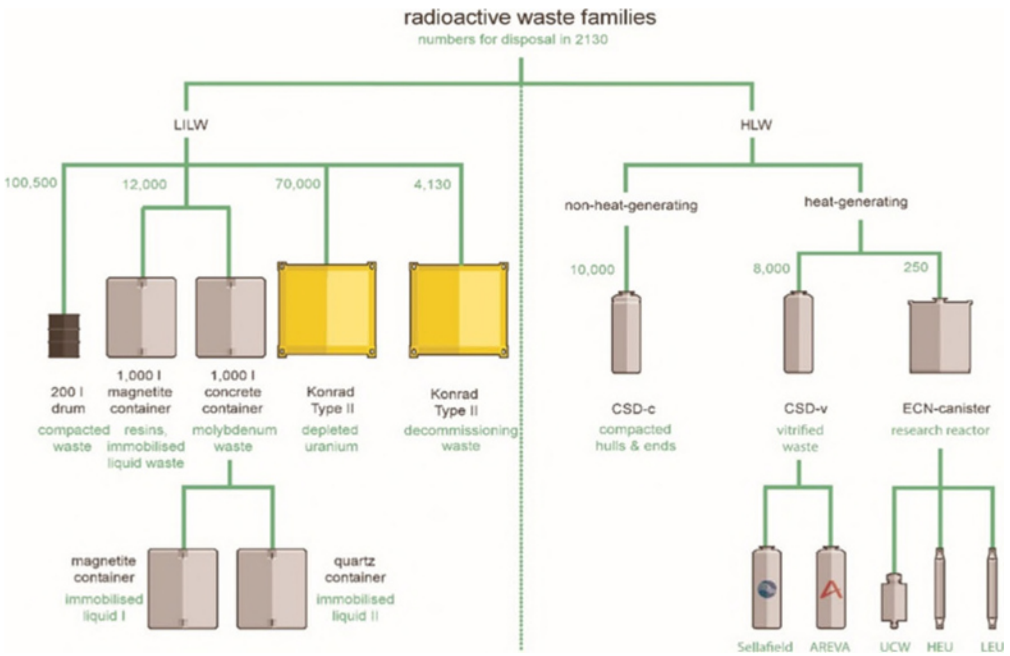


Figure A7-1: **Total waste expected for disposal when taking into account opening of new nuclear power plants, as currently considered by the Dutch government (Erkens, 2024)**

3 Method

To calculate the total costs of a repository in rock salt for the extended waste scenario, the cost estimate by Herold and Leonhard (2024) is used as a basis. Therefore, all unit costs per item remain the same, but the total number of required items changes. For example, a continuous miner costs 2,500,000 € in both cost estimates. However, while only one was required in Herold and Leonhard (2024), four are needed in the updated disposal concept to account for the larger repository required for the waste. Similarly, the type of personnel required (job) for each phase remains the same in both cost estimates, but the number of personnel needed differs. For example, more personnel are required to operate the repository when the number of continuous miners increases from one to four. Likewise, the construction speed per continuous miner remains unchanged, but the overall construction speed can be increased by adding more continuous miners. It is also assumed that no additional HLW facility is needed, and that the existing facility does not require expansion. Furthermore, the number of 200 L and 1000 L drums per disposal room is optimised (increased), while the same room dimensions remain. Lastly, the increase in electricity required for ventilation because of the larger repository is calculated based on the increase in the geological disposal facility volume. Table A7-1 presents the assumptions made in this cost estimate and the number of disposal rooms and tunnels needed to dispose all the waste for each cost estimate.

Table A7-1: Assumptions made in this cost estimate compared to that of Herold and Leonhard (2024)

Item	Herold and Leonhard (2024)	This cost estimate
Shafts	1	2
Continues miners	1	4
Backfilling equipment	1	4
Number of 100 L drums in a disposal room	9,000	13,635
Number of 1000 L drums in a disposal room	2,376	2,403
Factor increase electricity	1	4.95

4 Cost per phase

4.1 Pre-constructional activities

For the surface constructions, we assume that no additional buildings are required, and that the area designated for the repository does not need to be expanded. Therefore, both the duration (see Table A7-2) and the cost of pre-construction activities remain unchanged from the previous cost estimate. This includes electricity, as the expected usage is not expected to change: no electricity for ventilation is required yet. This phase is projected to cost approximately 230 million Euros and will last 9 years. For a detailed cost estimate, we refer to the tables given at the end of this appendix.

Table A7-2 Time (years) needed for and total cost (euros) of each phase

Item	Herold and Leonhard (2024)		This cost estimate	
Pre-constructional activities	9	€ 230,291,863	9	€ 230,291,863
Construction	23	€ 1,227,949,480	23	€ 2,224,881,530
Operation HLW including conditioning facility	1	€ 395,815,669	4	€ 2,684,878,252
Operation LILW - (TE)NORM including conditioning facility	17	€ 766,538,352	31	€ 3,351,386,091
Observation period	10	€ 134,585,102	10	€ 219,791,084
Closure	8	€ 784,062,581	11	€ 1,316,864,093
Total	68	€ 3,539,243,048	88	€ 10,028,092,914

4.2 Repository Construction

4.2.1 Shafts

Since more waste is expected to be disposed of, the time required to lower it into the repository increases significantly. Hence, with only one transport shaft operational, approximately 68 years will be needed to complete the process, assuming the same number of waste packages can be transported per shift and the same number of shifts as in Herold and Leonhard (2024). Specifically, about 7 years will be required for HLW and over 61 years for LILW. To reduce this, an additional transport shaft will be constructed. Under this assumptions, the total disposal time decreases to 33 years—approximately 4 years for HLW and 31 years for LILW. It is assumed that all the shafts, both ventilation and transport, are constructed contemporarily and since their length will remain the same, the total construction time will remain the same although the costs will increase: the total length of the shafts increases. Having more shafts, the number of workers needed for maintenance increases as well and is doubled compared to the cost estimate of Herold and Leonhard (2024) for the operating phase, (see Table Table A7-3).

Table A7-3: Workers needed for the shaft and ramp operation and maintenance

Shaft and ramp operation and maintenance department	Headcount in Herold and Leonhard (2024)	Headcount in this cost estimate
supervisor (mechanical)	1	2
supervisor (electrical)	1	2
maintenance electrician	5	10
maintenance mechanic	5	10

4.2.2 Size lower level

For this updated cost estimate, a few assumptions were made for the construction of the lower level. First, it is assumed that the existing lower level can be extended. For the lower level designated for HLW disposal, additional disposal tunnels will be constructed similarly to the current disposal concept for waste scenario 1. Thus, the number of disposal tunnels is increased, and the lengths of both the ventilation and transport tunnels are increased. With 8,000 CSD-V, 1,334 HLW packages are required, each containing six CSD-Vs (Wunderlich et al., 2023). For the 10,000 CSD-C, 1,667 HLW packages are needed, also with each containing six CSD-V's. Lastly, for the 250 ECNs, 125 HLW packages are required, as each package can hold only two ECN's (Wunderlich et al., 2023). In total, 3,126 HLW packages are needed for HLW disposal. Since each disposal tunnel is assumed to hold 10 HLW packages (Bartol et al., 2025), 314 disposal tunnels will be required. Note that this number is one higher than the actual number of disposal tunnels needed; this adjustment is intentional to maintain repository symmetry and simplify the cost estimate. On each side of the transport tunnel, there will be 147 disposal galleries. In total, the lower level will have a volume of 1.27 million m^3 and will take about 8 years to construct.

4.2.3 Size lower level

At the upper level, as with the lower level, we assume that the repository can be extended by constructing new disposal rooms in the same manner as proposed in the current disposal concept. Given the expected amount of waste, the total number of disposal rooms required is estimated to be 133. For the disposal of 10,500 200 L drums, 8 disposal rooms are needed, with each room accommodating 13,635 200 L drums. For the 12,000 1000 L drums, only 5 disposal rooms are required, as each can hold up to 2,403 1000 L drums. Lastly, for the disposal of (TE)NORM, 113 disposal rooms are needed, making it the waste category that requires the largest number of rooms. Note that, compared to the cost estimate of Herold and Leonhard (2024), the number of waste packages per disposal room has been optimised without increasing the dimensions of a disposal room. In this updated cost estimate, 13,635 200 L drums are disposed in a single disposal room; 2,403 1000 L drums and 624 Konrad type II containers. Compared to the previous disposal concept, 9,000 200 L drums are disposed in a single disposal room; 2,376 1000 L drums and 624 Konrad type II containers, this is a significant increase for the 200 L drums (see Table A7-1). The upper level will have a volume of 1.2 million m^3 and will take about 9.8 years to construct.

4.2.4 Construction and ventilation

As a significantly larger amount of salt needs to be removed, the number of continuous miners is increased from one to four. This reduction in excavation time will shorten the total construction period for the entire repository from approximately 74 years when using a single continuous miner to about 9 years when using four continuous miners: about 8 years for the lower level, about 9 years for the upper level and 1 for the ramp. With the lager number of continuous miners, the workers needed to operate and maintain them is also increased by the same factor (see Table A7-4). Note that the construction period takes 23 years in total, as the shafts takes another 4 years to construct.

Table A7-4: Workers needed for the excavation of the repository

Underground operations support department	Headcount in Herold and Leonhard (2024)	Headcount in this cost estimate
underground shift supervisor	1	4
underground radiological protection supervisor	1	4
maintenance technician – foreman	1	4
maintenance technician	3	12

Furthermore, since the repository is significantly larger, we assume that the energy required for ventilation increases by a factor of 4.95 based on the factor by which the excavated volume increases compared to Herold and Leonhard (2024) (Table 1). This assumption is very conservative, as sections of the repository not in use can be temporarily sealed off, reducing ventilation requirements. Consequently, the actual energy consumption is likely to be significantly lower. However, computer models are needed to accurately calculate the ventilation requirements and, consequently, the electricity needed. In line with the cost estimate by Herold and Leonhard (2024), the electricity costs for mining the repository are assumed to be covered under ventilation costs, as only a smaller area needs to be ventilated during construction.

4.2.5 Total construction phase

As the construction of the shafts will take 4 years while the construction of the rest of the repository will take about 19 years, the total construction time is estimate to be 23 years (Table A7-2) to construct. The total costs, (see Table 2), are expected to be roughly 2.3 billion Euros, which is an increase by a factor of about 2 compared to Herold and Leonhard (2024). For a detailed cost estimate, we refer to the tables given at the end of this appendix.

4.3 Operating period

With the additional transport shift, an increased number of workers, besides equipment, are needed to transport the waste to the disposal site (Table A7-5). For HLW, approximately 4 years will be needed while approximately 31 years are needed for the disposal of LILW. The total cost for the disposal of HLW waste during the operating period is € 2.6 billion Euros, while the total costs for the operating period for the disposal of LILW is € 3.3 billion Euros. Both include the conditioning facility and the materials needed to package the waste (Konrad type II container and HLW overpack, Bartol et al., 2025). This is a significant increase compared to the cost estimate of Herold and Leonhard (2024). This increase is in part due to the increased time needed for disposal and the increased electricity demand for ventilation. Furthermore, many more HLW packages and Konrad type II containers are needed, which increases the costs as well. For a detailed cost estimate, we refer to the tables given at the end of this appendix.

Table A7-5: Workers needed for disposal of waste

Waste disposal department	Headcount in Herold and Leonhard (2024)	Headcount in this cost estimate
Waste cart pilot	2	4
Waste cart co-pilot	2	4
operator preparing the next disposal gallery	2	4

4.4 Observation period

For the observation period, a period of 10 years is assumed for both scenarios. The total cost of this period is similar in the cost estimate of Herold and Leonhard (2024) except for the electricity. The latter will increase, as a larger area needs to be ventilated. Because of this, the expected costs will increase from 134 million Euros to about 220 million Euros (see Table A7-1).

4.5 Closure Phase

In the closure phase, all the open spaces will be backfilled. It is expected that the total time needed is 8 years in the cost estimate of Herold and Leonhard (2024). This increases to 12 years in this cost estimate, assuming that backfilling will take place 4 times faster compared to the cost estimate of Herold and Leonhard (2024). This will require additional workers (see Table A7-6) and equipment. The expected costs will increase from € 780 million Euros to € 1.3 billion Euros. For a detailed cost estimate, we refer to the tables given at the end of this appendix.

Table A7-6: Workers needed for backfilling the repository

Job	Headcount in Herold and Leonhard (2024)	Headcount in this cost estimate
[backfilling disposal galleries] shift supervisor	1	4
[backfilling disposal galleries] radiological protection supervisor	1	4
[backfilling disposal galleries] operator	3	6
[Sealing disposal galleries] shift supervisor	1	4
[Sealing disposal galleries] operator	5	20
[backfilling and sealing rest] shift supervisor	1	4
[backfilling and sealing rest] operator	10	40

5 SSK

Like in Herold and Leonhard (2024), the disposal costs in rock salt are estimated using the SSK (Standaard Systematiek Kostenramingen) method, a standardised framework widely used in the Netherlands for infrastructure and construction projects. This approach ensures transparency by structuring costs into direct and indirect components through a Work Breakdown Structure (WBS).To enhance cost reliability, a Monte Carlo simulation was conducted for a repository cost estimate in rock salt. A total of 10,000 simulations were carried out using a triangular distribution. Two uncertainty distributions were considered: one with a range of -50% to +50% and another based on the AACE classification system. The AACE system categorises project components into five classes based on maturity, providing guidelines for assessing uncertainty and expected accuracy levels (see Table A7-7).

Table A7-7: AACE classification system, based on Christensen et al. (2005)

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

Notes: [a] The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.
[b] If the range index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

Class 5 corresponds to the earliest project stage, covering initial concept screening or strategic planning. As the class number decreases, project maturity increases. Class 1 represents cost calculations based on tendering processes, actual project control, or change management, where project scope and costs are nearly fully defined. For broadly defined cost items, Class 5 is thus applied, representing initial concept screenings. For specific systems or cost items comparable to other repository projects, Class 4 is used, reflecting feasibility study stages or, in some cases, Class 3. However, Class 3 is typically applied to cost estimates prepared for budget authorisations or funding requests. Given the current level of detail, even with experience from other repository projects, applying Class 3 would likely be too optimistic. Therefore, apart from the costs for land acquisition (Class 3), only Classes 4 and 5 have been applied in this cost estimation with class 5 being applied to the construction of the repository and decommissioning. Furthermore, the lowest and highest uncertainty levels are considered. For example, in Class 5, the uncertainty ranges between -50% and +100%.

5.1 SSK results

A simulation using an uncertainty range of -50% to +50% estimates that a repository in rock salt will likely cost around 12 billion Euros, including VAT (see Figure A7-2) or about 10 billion Euros excluding VAT. This aligns closely with the 10-billion-Euro estimate calculated using the deterministic method. The similarity is likely due to the symmetric uncertainty distribution and the absence of any single cost item accounting for a disproportionately large share of the total costs. Based on the simulation, there is a 5% probability that the repository will cost about 5 billion Euros (excluding VAT) and a 50% chance that it will exceed 15 billion Euros (excluding VATFigure A7-2).

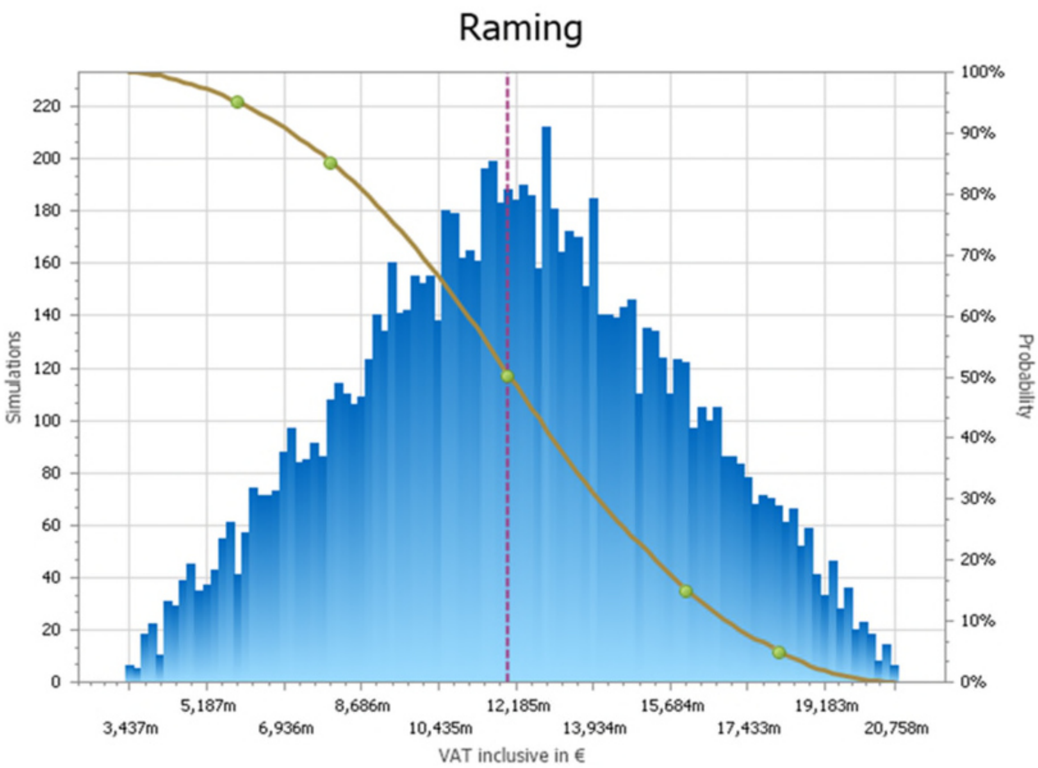


Figure A7-2: **Monte Carlo simulation of the expected cost using a -50% – 50% uncertainty in the prices. Note that the distribution shown here includes VAT**

Using the uncertainties from the AACE classification, a repository in rock salt is estimated to cost around 13 billion Euros, including VAT, or 11 billion Euros excluding VAT (Figure A7-3). This is about one billion Euros more expensive than the two previous estimates, and this difference is related to the uncertainty distribution used, which is more skewed towards higher prices. In other words, using the AACE classification, it is more likely that the prices will be higher.

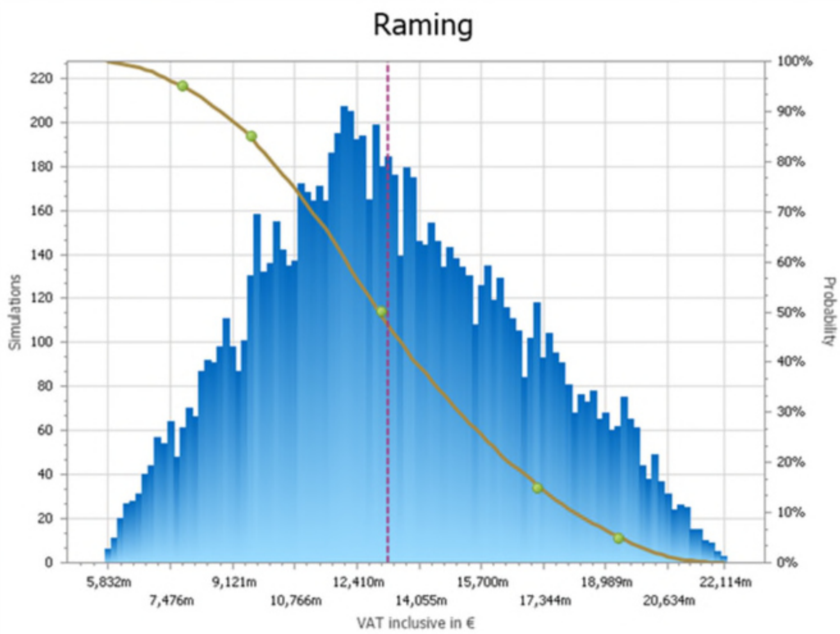


Figure A7-3: **Monte Carlo simulation of the expected cost using the AACE classification for the uncertainty in the prices. Note that the distribution shown here includes VAT**

6 Discussion

Using the (deterministic) cost estimate of Herold and Leonhard (2024) and the (stochastic) SSK method, we calculated the total costs of a repository in rock salt for the BASIS scenario. The total cost is estimated to be about 10 billion Euros, while using the SSK method resulted in an estimated total cost between 10 billion Euros and 11 billion Euros depending on the uncertainty distribution used: -50 – 50% or the AACE classification. The lower boundary is close to the cost estimate following the method of Herold and Leonhard (2024). This is because the uncertainty in the prices is taken to be between -50% and 50%, representing an even distribution. Furthermore, there is no specific item that costs significantly more than others, which could result in a significantly higher final cost, if the upper boundary of its uncertainty was selected. The higher upper boundary of the estimate — 11 billion Euros, from the SSK — is a result of the uncertainty in the prices used, as the AACE classification and, specifically, the levels used here tend to result in higher prices. While both methods and both uncertainty distributions yield somewhat different estimates, they share the same assumptions.

First, it is assumed that the repository can be extended. For bedded salt and salt pillows, this is likely not an issue, as the additional space required for an extended repository is limited. For salt domes, this is also not expected to be a problem, although their shapes and sizes vary significantly in the Netherlands. If a salt dome is too small, an additional level could be constructed. This would increase costs due to the need for an additional ramp, but the impact on the total costs would be minimal. Therefore, this assumption is not expected to significantly affect the cost estimate.

Another key assumption is that electricity consumption for ventilation is scaled with the excavated volume. However, this is likely an overestimate, as parts of the repository that are not in use can be sealed with airtight doors, reducing ventilation needs. Consequently, the electricity cost estimated here is likely higher than necessary. Its effect could be significant as it is a significant part of the cost. On the other hand, both cost estimates assume the same infrastructure area dimensions, whereas a larger repository might require a bigger infrastructure area. This could result in an underestimation of costs, although the additional expense for an extended infrastructure area is expected to be insignificant compared with other costs.

There are ways to reduce costs. One potential way is to increase the number of HLW packages per disposal tunnel, thereby reducing the number of disposal tunnels needed. While this would decrease the total cost by approximately 600 million Euros, the overall reduction is limited, as the cost of constructing the disposal tunnels accounts for only about 1% of the total construction cost, which itself represents approximately 23% of the total cost. Similarly, while constructing larger disposal rooms would reduce the total number required, the overall savings would be limited. On the other hand, eliminating HLW packages disposal in boreholes would significantly reduce costs, as approximately 2 billion Euros are required to create all the HLW packages. Likewise, using (TE)NORM in a way that eliminates the need for a Konrad type II container could further reduce costs by more than one billion Euros. For a detailed cost estimate, we refer to the tables given at the end of this appendix.

In general, this cost estimate should be considered to be a first order estimate only, because upscaling costs is difficult as larger projects introduce complexities that do not always scale proportionally. For example, the electricity needed for ventilation. On the other hand, some costs may decrease due to economies of scale, such as bulk material discounts, but others increase due to logistical challenges, regulatory hurdles, and the need for specialised personnel. Large-scale projects also face higher uncertainties, including supply chain disruptions, changing regulations, and unforeseen technical difficulties. Additionally, longer project timelines introduce risks related to inflation, financing, and evolving market conditions. These factors make it challenging to predict costs accurately, requiring detailed modelling and scenario analysis. Thus, the cost estimate here can only be regarded as a first order of estimate, and, based on experience in other larger projects (Kostka and Anzinger, 2016), it is likely that the costs will be higher.

Compared with the costs for a repository in poorly indurated clay (Neeft, 2025), the costs are similar, while there is a difference in the cost estimate. For example, clay has only one organisation (COVRA), while in this cost estimate, following OPERA, two organisations (COVRA, Operator), build and operate the repository. Having two organisations will increase the personnel costs.

7 Conclusions

Using the cost estimate for a repository in rock salt of COPERA (2020 – 2025), a new cost estimate for the new BASIS waste scenario was calculated, which includes the extended operating period of Urenco, resulting in significant additional (TE)NORM waste, as well as the operation of two new nuclear power plants. The latter leads to a substantial increase in high-level waste (HLW) processing. In comparison to the inventory assumed in Herold and Leonhard (2024), this new scenario will result in estimated overnight costs of 10 billion Euros. In total, the pre-construction phase will cost about 2% of the total and will last 8 years. The construction phase accounts for about 22% of the total cost and will span approximately 23 years. This is followed by:

- The disposal of HLW, lasting 4 years and costing about 26% of the total
- The disposal of LILW, lasting 31 years and accounting for about 32 % of the total
- An observation phase of 10 years, representing about 2 % of the total cost
- The final closure of the repository, which takes 11 years and costs about 13 % of the total

In total, the construction of the repository, the disposal of all radioactive waste, and the final closure take approximately 88 years. Using the SSK method, which applies a stochastic model with a spread of -50% to +50% in prices, the total estimated cost is 10 billion Euros. Meanwhile, using the same SSK method but with an uncertainty in prices based on the AACE classification, the estimated cost is 11 billion Euros.

Following to this conclusions the Table A7-8 to Table A7-23 and the Figure A7-4 to Figure A7-5 are attached for more detailed information.

Table A7-8: Cost estimate SSK1/4

Kostenoverzicht SSK2018 *Rekenmodel SSK2018 versie 2.3.000*

	Directe kosten - benoemd	Directe kosten - nader te detailleren	Directe kosten	Indirecte kosten	Voorziene kosten	Risicoreservering	Totaal
Investeringskosten:							
Bouwkosten Deelraming Site Prep incl A&F Fee	€ 41,850,000	€ -	€ 41,850,000	€ -	€ 41,850,000	€ -	€ 41,850,000
Bouwkosten Deelraming Site Prep excl. A&F Fee	€ 81,086,688	€ -	€ 81,086,688	€ -	€ 81,086,688	€ -	€ 81,086,688
Bouwkosten Deelraming Surface	€ 251,529,000	€ -	€ 251,529,000	€ -	€ 251,529,000	€ -	€ 251,529,000
Bouwkosten Deelraming Shaft Sinking	€ 449,000,000	€ -	€ 449,000,000	€ -	€ 449,000,000	€ -	€ 449,000,000
Bouwkosten Deelraming Repository construction	€ 35,243,959	€ -	€ 35,243,959	€ -	€ 35,243,959	€ -	€ 35,243,959
Bouwkosten Deelraming HLW Disposal	€ 191,781,824	€ -	€ 191,781,824	€ -	€ 191,781,824	€ -	€ 191,781,824
Bouwkosten Deelraming LILW (TE)NORM Disposal	€ 250,937,280	€ -	€ 250,937,280	€ -	€ 250,937,280	€ -	€ 250,937,280
Bouwkosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Repository Closure	€ 731,919,695	€ -	€ 731,919,695	€ -	€ 731,919,695	€ -	€ 731,919,695
Bouwkosten Deelraming CF arch	€ 71,875	€ -	€ 71,875	€ -	€ 71,875	€ -	€ 71,875
Bouwkosten Deelraming Cf Building	€ 17,640,000	€ -	€ 17,640,000	€ -	€ 17,640,000	€ -	€ 17,640,000
Bouwkosten Deelraming CF Installation	€ 86,000,000	€ -	€ 86,000,000	€ -	€ 86,000,000	€ -	€ 86,000,000
Bouwkosten Deelraming Cf Materials Decommissiong	€ 1,865,904,500	€ -	€ 1,865,904,500	€ -	€ 1,865,904,500	€ -	€ 1,865,904,500
Bouwkosten Deelraming TENORM Conditioning	€ 1,453,297,722	€ -	€ 1,453,297,722	€ -	€ 1,453,297,722	€ -	€ 1,453,297,722
Bouwkosten Deelraming CF incl archi	€ 470,000	€ -	€ 470,000	€ -	€ 470,000	€ -	€ 470,000
Bouwkosten	**€ 5,456,732,543**	**€ -**	**€ 5,456,732,543**	**€ -**	**€ 5,456,732,543**	**€ -**	**€ 5,456,732,543**
Engineeringskosten Deelraming Site Prep incl A&F Fee	€ 6,277,500	€ -	€ 6,277,500	€ -	€ 6,277,500	€ -	€ 6,277,500
Engineeringskosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Surface	€ 37,729,350	€ -	€ 37,729,350	€ -	€ 37,729,350	€ -	€ 37,729,350
Engineeringskosten Deelraming Shaft Sinking	€ 134,700,000	€ -	€ 134,700,000	€ -	€ 134,700,000	€ -	€ 134,700,000
Engineeringskosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Cf Building	€ 2,646,000	€ -	€ 2,646,000	€ -	€ 2,646,000	€ -	€ 2,646,000
Engineeringskosten Deelraming CF Installation	€ 25,800,000	€ -	€ 25,800,000	€ -	€ 25,800,000	€ -	€ 25,800,000
Engineeringskosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF incl archi	€ 70,500	€ -	€ 70,500	€ -	€ 70,500	€ -	€ 70,500
Engineeringskosten	**€ 207,223,350**	**€ -**	**€ 207,223,350**	**€ -**	**€ 207,223,350**	**€ -**	**€ 207,223,350**
Vastgoedkosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -

Table A7-8: Cost estimate SSK 2/4

Vastgoedkosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Objectoverstijgende risicoreservering						€ -	€ -
Verschuiving						€ 20,450,512	€ 20,450,512
Investeringskosten exclusief BTW	**€ 5,663,955,893**	**€ -**	**€ 5,663,955,893**	**€ -**	**€ 5,663,955,893**	**€ 20,450,512**	**€ 5,684,406,405**
BTW	€ 1,189,430,737	€ -	€ 1,189,430,737	€ -	€ 1,189,430,737	€ 4,294,608	€ 1,193,725,345
Investeringskosten inclusief BTW (reële kosten)	**€ 6,853,386,630**	**€ -**	**€ 6,853,386,630**	**€ -**	**€ 6,853,386,630**	**€ 24,745,120**	**€ 6,878,131,750**
Investeringskosten inclusief BTW (contante waarde), discontovoet van 02% en rekenhorizon van 88 jaar							*€ 2,000,672,904*

Bandbreedte : met een 70%-betrouwbaarheidsinterval liggen de investeringskosten inclusief BTW (reële kosten) tussen € 4598789927.7 en € 9163722694.5

De variatiecoëfficiënt bedraagt ± 30 %

Geraamde Investeringskosten inclusief BTW (reële kosten)	€ 6,878,131,750
Organisatiegebonden reservering investeringen (opgave financier)	€ -
Onzekerheidsreserve investeringen (opgave financier)	€ -
Reservering scope wijzigingen investeringen (opgave financier)	€ -
Gerealiseerde investeringskosten buiten de raming maar binnen budget (opgave financier)	€ -
Aan te houden budget investeringskosten inclusief BTW	**€ 6,878,131,750**

Table A7-8: Cost estimate 3/4

Instandhoudingskosten:							
Bouwkosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Site Prep excl. A&F Fee	€ 125,137,800	€ -	€ 125,137,800	€ -	€ 125,137,800	€ -	€ 125,137,800
Bouwkosten Deelraming Surface	€ 2,528,069,535	€ -	€ 2,528,069,535	€ -	€ 2,528,069,535	€ -	€ 2,528,069,535
Bouwkosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Repository construction	€ 459,932,655	€ -	€ 459,932,655	€ -	€ 459,932,655	€ -	€ 459,932,655
Bouwkosten Deelraming HLW Disposal	€ 71,980,115	€ -	€ 71,980,115	€ -	€ 71,980,115	€ -	€ 71,980,115
Bouwkosten Deelraming LILW (TE)NORM Disposal	€ 500,805,893	€ -	€ 500,805,893	€ -	€ 500,805,893	€ -	€ 500,805,893
Bouwkosten Deelraming Underground Observation	€ 69,811,874	€ -	€ 69,811,874	€ -	€ 69,811,874	€ -	€ 69,811,874
Bouwkosten Deelraming Repository Closure	€ 234,931,289	€ -	€ 234,931,289	€ -	€ 234,931,289	€ -	€ 234,931,289
Bouwkosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming Cf Materials Decommissiong	€ 343,844,400	€ -	€ 343,844,400	€ -	€ 343,844,400	€ -	€ 343,844,400
Bouwkosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Bouwkosten	**€ 4,334,513,561**	**€ -**	**€ 4,334,513,561**	**€ -**	**€ 4,334,513,561**	**€ -**	**€ 4,334,513,561**
Engineeringskosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**-**
Vastgoedkosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -

Table A7 8: Cost estimate 4/4

Vastgoedkosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Vastgoedkosten	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Site Prep incl A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Site Prep excl. A&F Fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Surface	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Shaft Sinking	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Repository construction	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming HLW Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming LILW (TE)NORM Disposal	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Underground Observation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Repository Closure	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF arch	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Cf Building	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF Installation	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming Cf Materials Decommissiong	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming TENORM Conditioning	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten Deelraming CF incl archi	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Overige bijkomende kosten	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Objectoverstijgende risicoreservering						€ -	€ -
Verschuiving						€ 15,650,373	€ 15,650,373
Instandhoudingskosten exclusief BTW	€ **4,334,513,561**	€ -	€ **4,334,513,561**	€ -	€ **4,334,513,561**	€ **15,650,373**	€ **4,350,163,934**
BTW	€ 910,247,848	€ -	€ 910,247,848	€ -	€ 910,247,848	€ 3,286,578	€ 913,534,426
Instandhoudingskosten inclusief BTW (reële kosten)	€ **5,244,761,409**	€ -	€ **5,244,761,409**	€ -	€ **5,244,761,409**	€ **18,936,951**	€ **5,263,698,360**
Instandhoudingskosten inclusief BTW (contante waarde), discontovoet van 02% en rekenhorizon van 105 jaar							€ *2,907,946,543*

Bandbreedte : met een 70%-betrouwbaarheidsinterval liggen de instandhoudingskosten inclusief BTW (reële kosten) tussen € 3519363088.9 en € 7012815961.4

De variatiecoëfficiënt bedraagt ± 30 %

Geraamde Instandhoudingskosten inclusief BTW (reële kosten)	€ 5,263,698,360
Organisatiegebonden reservering instandhoudingen (opgave financier)	€ -
Onzekerheidsreserve instandhoudingen (opgave financier)	€ -
Reservering scope wijzigingen instandhoudingen (opgave financier)	€ -
Gerealiseerde instandhoudingskosten buiten de raming maar binnen budget (opgave financier)	€ -
Aan te houden budget instandhoudingskosten inclusief BTW	€ **5,263,698,360**

Levenscycluskosten inclusief BTW (reële kosten)	€ **12,098,148,039**	€ -	€ **12,098,148,039**	€ -	€ **12,098,148,039**	€ **43,682,071**	€ **12,141,830,110**
Levenscycluskosten inclusief BTW (contante waarde), discontovoet van 02% en rekenhorizon van 105 jaar							€ *4,908,619,447*
Equivalente jaarlijkse kosten inclusief BTW van de gehele levenscyclus							€ *97,187,262*

Bandbreedte : met een 70%-betrouwbaarheidsinterval liggen de levenscycluskosten inclusief BTW (reële kosten) tussen € 8118153016.6 en € 16176538655.9

De variatiecoëfficiënt bedraagt ± 30 %

Geraamde Levenscycluskosten inclusief BTW (reële kosten)	€ 12,141,830,110
Organisatiegebonden reserveringen (opgave financier)	€ -
Onzekerheidsreserve (opgave financier)	€ -
Reservering scope wijzigingen (opgave financier)	€ -
Gerealiseerde kosten buiten de raming maar binnen budget (opgave financier)	€ -
Aan te houden budget levenscycluskosten inclusief BTW	€ **12,141,830,110**

Table A7-9: Costs of the repository for the different phases. The first column gives the cost item, the second column the cost as estimated by Herold and Leonhard (2023b), the third column the cost of the Conditioning Facility (CF) and material needed for the disposal of HLW (Herold and Leonhard, 2023b; Wunderlich et al., 2023). The fourth column is a cost estimate for the (TE)NORM conditioning facility including the costs for concrete, human resources and the Konrad type II container (Oudenaren and Browning, 2023). The fifth column is the total cost per item and the last column gives the percentage of the total costs (bold) and the percentage of the cost per phase.

Pre constructional phase

Totals	Cost (1)	Cost (2)	Cost (3)	Total	%
Pre constructional phase	**€ 229,679,488**	**€ 612,375**		**€ 230,291,863**	**2.29**
Land purchase	€ 62,766,688	€ 71,875		€ 62,838,563	27
Site infrastructure work	€ 48,127,500	€ 540,500		€ 48,668,000	21
Site facility construction	€ 1,920,000			€ 1,920,000	1
Security installation	€ 1,400,000			€ 1,400,000	1
Utility consumption	€ 55,462,500			€ 55,462,500	24
Human resources	€ 60,002,800			€ 60,002,800	26

Repository construction phase

Repository construction	€ 2,225,323,335			€ 2,225,323,335	22.12
Construction and outfitting shafts	€ 583,700,000				26
Construction and outfitting upper level main areas	€ 26,469,052				1
Construction and outfitting HLW main area & bunker	€ 4,146,849				0.2
Construction and outfitting HLW disposal area	€ 19,881,948				0.9
Construction/outfitting LILW and (TE)NORM disposal galleries	€ 18,046,110				0.8
Site facility construction	€ 289,258,350				13
Maintenance surface	€ 124,730,840				6
Insurance	€ 34,372,000				2
Utility consumption	€ 687,585,532				31
Human resources	€ 437,132,655				20

CF construction and operation phase

CF construction and operation		€ 2,310,742,900		€ 2,310,742,900.00	22.97
Investment - Site facility construction		€ 20,286,000			0.9
Investment - CF internals/construction and installation		€ 111,800,000			4.8
Maintenance during HLW disposal campaign		€ 231,769,200			10.0
Insurance during HLW disposal campaign		€ 26,075,200			1.1
Material for DWP and consumables		€ 1,920,812,500			83.1

(TE)NORM construction and surface operation phase

(TE)NORM construction and surface operation			€ 1,453,297,722	€ 1,453,297,722	14.44
Investment - Site facility construction			€ 10,223,222		1
Investment - CF internals/construction and installation			€ 1,443,074,500		99

HLW disposal phase

HLW	€ 407,290,351			€ 407,290,351	4.05
Disposal	€ 4,400,000				1.1
Backfilling and sealing	€ 188,781,824				46.4
Maintenance surface	€ 21,692,320				5.3
Insurance	€ 8,456,000				2.1
Utility consumption	€ 119,580,092				29.4
Human resources	€ 64,380,115				15.8

LILW and (TE)NORM disposal phase

LILW and (TE)NORM	€ 1,898,088,369			€ 1,898,088,369	18.86
Disposal	€ 13,260,000				1
Backfilling and sealing	€ 245,737,280				13
Maintenance surface	€ 926,745,717				49
Insurance	€ 168,115,480				9
Utility consumption	€ 45,284,000				2
Human resources	€ 498,945,893				26

Underground observation phase (10 years)

Underground observation (10 years)	€ 219,791,084			€ 219,791,084	2.18
Maintenance surface	€ 54,230,800				24.7
Insurance	€ 16,640,000				7.6
Utility consumption	€ 99,533,410				45.3
Human resources	€ 49,386,874				22.5

Repository closure phase

Repository closure	€ 1,313,700,238	€ 3,109,200		€ 1,316,809,437	13.09
Backfilling and sealing galleries and ramp	€ 181,919,695				13.8
Backfilling and sealing shafts	€ 500,000,000				38.0
Dismantling and decommissioning nuclear facilities	€ 100,000,000	€ 3,109,200.00			7.6
Site dismantling and clearance	€ 50,000,000	€ 3,109,200			3.8
Insurance	€ 18,004,000				1.4
Utility consumption	€ 328,845,254				25.0
Human resources	€ 134,931,289				10.2

Table A7-10: Human resources per phase for COVRA

Function		salary [EUR/hour]	involvement [hours/year]	Phase 1 Site prepa-ration	Phase 2 Re-pository construction	Phase 3 Disposal campaign LILW and (TE)NORM waste	Phase 4 Disposal campaign HLW waste	Phase 5 Un-derground observation phase	Phase 6 Repository closure
General management				1	1	1	1	1	1
	Chief executive officer	136	1720	233920	233920	233920	233920	233920	233920
	Deputy director-general	62	1720	106640	106640	106640	106640	106640	106640
	Secretary	35	1720	60200	60200	60200	60200	60200	60200
Staff functions				1	1	1	1	0.5	0.25
	Head of physical inspection	62	1720	106640	106640	106640	106640	53320	26660
	Internal service for prevention and protection at Work	62	1720	106640	106640	106640	106640	53320	26660
	Quality manager	62	1720	106640	106640	106640	106640	53320	26660
	Safety strategy & environment protection	62	1720	106640	106640	106640	106640	53320	26660
	Safety officer	62	1720	106640	106640	106640	106640	53320	26660
Management				0.5	1	1	1	1	1
	director-coach for general services	62	1720	53320	106640	106640	106640	106640	106640
	General administration			1	1	1	1	1	1
	administrative assistant (human resource)	32	1720	55040	55040	55040	55040	55040	55040
	administrative assistant (logistics)	32	1720	55040	55040	55040	55040	55040	55040
	ICT technician	47	1720	80840	80840	80840	80840	80840	80840
Legal advice				1	1	1	1	1	1
	legal advisor	62	1720	106640	106640	106640	106640	106640	106640
	Financial administration			1	1	1	1	1	1
	accountant	62	1720	106640	106640	106640	106640	106640	106640
Purchasing & contracts				1	1	1	1	1	1
	purchaser	62	1720	106640	106640	106640	106640	106640	106640
Communications				1	1	1	1	1	1

Function		salary [EUR/hour]	involvement [hours/year]	Phase 1 Site prepa-ration	Phase 2 Re-pository construction	Phase 3 Disposal campaign LILW and (TE)NORM waste	Phase 4 Disposal campaign HLW waste	Phase 5 Un-derground observation phase	Phase 6 Repository closure
	communications expert	62	1720	106640	106640	106640	106640	106640	106640
Management				0	0.5	1	1	0.5	0.5
	director-coach for prescient waste management	62	1720	0	53320	106640	106640	53320	53320
	secretary	32	1720	0	27520	55040	55040	27520	27520
Waste inventory				0	0.5	1	1	0.25	0.25
	radioactive waste treatment & conditioning expert	62	1720	0	53320	106640	106640	26660	26660
Cost evaluations				0	0.5	1	1	0	0
	cost engineer	62	1720	0	53320	106640	106640	0	0
Asset & Liability management (ALM)				0	0.5	1	1	0	0
	financial analyst	62	1720	0	53320	106640	106640	0	0
Management				0.5	0.5	1	1	1	0.5
	director-coach for long term waste management	136	1720	116960	116960	233920	233920	233920	116960
RD&D geological disposal and licensing				1	1	1	1	1	0.5
	geotechnical engineer	62	1720	106640	106640	106640	106640	106640	53320
	nuclear physicist	62	1720	106640	106640	106640	106640	106640	53320
	geologist	62	1720	106640	106640	106640	106640	106640	53320
	chemist	62	1720	106640	106640	106640	106640	106640	53320
Management				0.5	0.5	1	1	0.5	0.5
	director-coach for contemporary waste management	62	1720	53320	53320	106640	106640	53320	53320
Waste acceptance				0.5	0.5	1	1	0.5	0.5
	waste acceptance coordinator	62	1720	53320	53320	106640	106640	53320	53320
	inspection of radioactive waste for post-conditioning	35	1720	30100	30100	60200	60200	30100	30100
	inspection waste package	35	1720	30100	30100	60200	60200	30100	30100
Installations management				0.5	0.5	1	1	0.5	0.5
	management of the post-conditioning installations	62	1720	53320	53320	106640	106640	53320	53320

Function		salary [EUR/hour]	involvement [hours/year]	Phase 1 Site prepa-ration	Phase 2 Re-pository construction	Phase 3 Disposal campaign LILW and (TE)NORM waste	Phase 4 Disposal campaign HLW waste	Phase 5 Un-derground observation phase	Phase 6 Repository closure
Installations dismantling				0.5	0.5	1	1	0.5	0.5
	dismantling of the post-conditioning installations	62	1720	53320	53320	106640	106640	53320	53320
Operator human resources									
Total salary cost			[EUR]	2421760	2715880	3347120	3347120	2432940	1969400
Various expenses (3% of the salary cost)			[EUR]	72653	81476	100414	100414	72988	59082
Total cost (Per year)				2494413	2797356	3447534	3447534	2505928	2028482

Table A7-11: Human resources per phase for the operator

Function	Head count	Salary [EUR/hour]	Involvement [hours/year]	Phase 1 Site preparation	Phase 2 Repository Construction	Phase 3 Disposal Campaign LILW and (TE)NORM	Phase 4 Disposal campaign HLW waste	Phase 5 Underground Observation Phase	Phase 6 Repository Closure	Phase 7 Post-operational phase
General management				1	1	1	1	0	1	0
chief executive officer	1	136	1720	233920	233920	233920	233920	0	233920	0
secretary	1	35	1720	60200	60200	60200	60200	0	60200	0
Human resources				1	1	1	1	0	1	0
legal advisor	1	62	1720	106640	106640	106640	106640	0	106640	0
administrative assistant	1	32	1720	55040	55040	55040	55040	0	55040	0
Finance				1	1	1	1	0	1	0
financial controller	1	62	1720	106640	106640	106640	106640	0	106640	0
accountant	1	47	1720	80840	80840	80840	80840	0	80840	0
Contracts				1	1	1	1	0	1	0
contract specialist	1	62	1720	106640	106640	106640	106640	0	106640	0
administrative assistant	1	32	1720	55040	55040	55040	55040	0	55040	0
Archival				0.5	1	1	1	1	1	0
knowledge management officer	1	62	1720	53320	106640	106640	106640	106640	106640	0
filing clerk	1	32	1720	27520	55040	55040	55040	55040	55040	0
ICT				1	1	1	1	0	1	0
ICT coordinator	1	47	1720	80840	80840	80840	80840	0	80840	0
ICT assistant	1	35	1720	60200	60200	60200	60200	0	60200	0
Visitors Centre				1	1	1	1	1	1	1
supervisor	1	47	1720	80840	80840	80840	80840	80840	80840	0
receptionist	1	32	1720	55040	55040	55040	55040	55040	55040	0
touring guide	3	32	1720	165120	165120	165120	165120	165120	165120	0
Service management				1	1	1	1	0	1	0
service manager	1	62	1720	106640	106640	106640	106640	0	106640	0
General maintenance (non-industrial site infrastructure)				0	1	1	1	1	0.5	0

Function	Head count	Salary [EUR/hour]	Involvement [hours/year]	Phase 1 Site preparation	Phase 2 Repository Construction	Phase 3 Disposal Campaign LILW and (TE)NORM	Phase 4 Disposal campaign HLW waste	Phase 5 Underground Observation Phase	Phase 6 Repository Closure	Phase 7 Post-operational phase
supervisor	1	47	1720	0	80840	80840	80840	80840	40420	0
maintenance technician	4	35	1720	0	240800	240800	240800	240800	120400	0
materials/stock manager	1	35	1720	0	60200	60200	60200	60200	30100	0
Radiological laboratory				1	1	1	1	0	1	0
radiological laboratory technician	1	47	1720	80840	80840	80840	80840	0	80840	0
Land survey (surface + underground)				1	1	1	1	1	1	0
land surveyor	1	62	1720	106640	106640	106640	106640	106640	106640	0
assistant land surveyor	1	62	1720	106640	106640	106640	106640	106640	106640	0
Fire brigade				1	1	1	1	1	0.5	0
fire brigade captain	1	47	1720	80840	80840	80840	80840	80840	40420	0
Site security management				1	1	1	1	0	1	0
security manager	1	62	1720	106640	106640	106640	106640	0	106640	0
				1	1	1	1	1	1	0
entry/exit control guard	4	32	1720	220160	220160	220160	220160	220160	220160	0
patrol guard	4	32	1720	220160	220160	220160	220160	220160	220160	0
Daytime reinforcement outer perimeter				1	1	1	1	0	1	0
entry/exit control guard	1.5	32	1720	82560	82560	82560	82560	0	82560	0
patrol guard	1.5	32	1720	82560	82560	82560	82560	0	82560	0
Permanent security inner perimeter				1	1	1	1	0	1	0
entry/exit control guard	4	35	1720	240800	240800	240800	240800	0	240800	0
patrol guard	4	35	1720	240800	240800	240800	240800	0	240800	0
Daytime reinforcement inner perimeter				1	1	1	1	0	1	0
entry/exit control guard	1	35	1720	60200	60200	60200	60200	0	60200	0
General tasks				1	1	1	1	0	1	0

Function	Head count	Salary [EUR/hour]	Involvement [hours/year]	Phase 1 Site preparation	Phase 2 Repository Construction	Phase 3 Disposal Campaign LILW and (TE)NORM	Phase 4 Disposal campaign HLW waste	Phase 5 Underground Observation Phase	Phase 6 Repository Closure	Phase 7 Post-operational phase
nuclear and eviromental evnitomental safety coordinator	2	62	1720	213280	213280	213280	213280	0	213280	0
environmental protection coordinator	1	62	1720	106640	106640	106640	106640	0	106640	0
general QA coordinator	1	62	1720	106640	106640	106640	106640	0	106640	0
Emergency management				1	1	1	1	0	1	0
emergency manager	1	62	1720	106640	106640	106640	106640	0	106640	0
Follow-up team				1	1	1	1	0	1	0
construction engineer	1	62	1720	106640	106640	106640	106640	0	106640	0
geotechnical engineer	1	62	1720	106640	106640	106640	106640	0	106640	0
electro-mechanical engineer	1	62	1720	106640	106640	106640	106640	0	106640	0
nuclear engineer	1	62	1720	106640	106640	106640	106640	0	106640	0
Industrial operations management department				0.5	1	1	1	0	1	0
industrial operations manager	1	62	1720	53320	106640	106640	106640	0	106640	0
planning coordinator	1	35	1720	30100	60200	60200	60200	0	60200	0
Post-conditioning facility				0	0.5	1	1	0	0.5	0
shift supervisor	1	47	1720	0	40420	80840	80840	0	40420	0
operator	8	35	1720	0	240800	481600	481600	0	240800	0
radiological protection supervisor	1	35	1720	0	30100	60200	60200	0	30100	0
QA supervisor	1	35	1720	0	30100	60200	60200	0	30100	0
maintenance technician – foreman	1	47	1720	0	40420	80840	80840	0	40420	0
maintenance technician	2	35	1720	0	60200	120400	120400	0	60200	0
Underground operations support department				0	0.5	1	1	0.5	1	0
underground shift supervisor	4	47	1720	0	161680	323360	323360	161680	323360	0

Function	Head count t	Salary [EUR/hour]	Involvement [hours/year]	Phase 1 Site preparation	Phase 2 Repository Construction	Phase 3 Disposal Campaign LILW and (TE)NORM	Phase 4 Disposal campaign HLW waste	Phase 5 Underground Observation Phase	Phase 6 Repository Closure	Phase 7 Post-operational phase
underground radiological protection supervisor	4	35	1720	0	120400	240800	240800	120400	240800	0
maintenance technician – foreman	4	47	1720	0	161680	323360	323360	161680	323360	0
maintenance technician	12	35	1720	0	361200	722400	722400	361200	722400	0
Shaft and ramp operation and maintenance department				0	1	1	1	0	0.5	0
supervisor (mechanical)	2	47	1720	0	161680	161680	161680	0	80840	0
supervisor (electrical)	2	47	1720	0	161680	161680	161680	0	80840	0
maintenance electrician	10	47	1720	0	808400	808400	808400	0	404200	0
maintenance mechanic	10	35	1720	0	602000	602000	602000	0	301000	0
Mine rescue team				0	1	1	1	0	0.5	0
team captain	1	47	1720	0	80840	80840	80840	0	40420	0
Waste disposal department				0	0	1	1	0	0	0
waste cart pilot	4	35	1720	0	0	240800	240800	0	0	0
waste cart co-pilot	4	35	1720	0	0	240800	240800	0	0	0
operator preparing the next disposal gallery section	4	35	1720	0	0	240800	240800	0	0	0
Backfilling of disposal galleries				0	0	1	1	0	0	0
shift supervisor	4	47	1720	0	0	323360	323360	0	0	0
radiological protection supervisor	4	35	1720	0	0	240800	240800	0	0	0
operator	12	35	1720	0	0	722400	722400	0	0	0
Sealing of disposal galleries				0	0	1	1	0	0	0
shift supervisor	4	47	1720	0	0	323360	323360	0	0	0
operator	20	35	1720	0	0	1204000	1204000	0	0	0
Backfilling and sealing of access galleries, shafts and ramp				0	0	0	0	0	1	0

Function	Head count	Salary [EUR/hour]	Involvement [hours/year]	Phase 1 Site preparation	Phase 2 Repository Construction	Phase 3 Disposal Campaign LILW and (TE)NORM	Phase 4 Disposal campaign HLW waste	Phase 5 Underground Observation Phase	Phase 6 Repository Closure	Phase 7 Post-operational phase
shift supervisor	4	47	1720	0	0	0	0	0	323360	0
operator	40	35	1720	0	0	0	0	0	2408000	0
Total salary cost	[EUR/year]			4106500	7714200	12497520	12497520	2383920	10111880	0
Various expenses (1% of the salary cost)	[EUR/year]			41065	77142	124975	124975	23839	101118	0
Overall personnel cost	[EUR/year]			4147565	7791342	12622495	12622495.2	2407759	10212998	0
Board of directors	[EUR/year]			25000	25000	25000	25000	25000	25000	0
Office support	[EUR/year]									
Total cost	[EUR/year]				4172565	7816342	12647495	12647495	2432759	10237998

Table A7-12: Pre-constructional phase cost

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
1.1	**Land purchase**				**€ 62,766,688**
1.1.1	Exploration				€ 53,180,000
1.1.2	Nominal cost of land purchase	345000	m²	€ 25.00	€ 8,625,000
1.1.3	Notary fee	1	%	11.15%	€ 961,688
1.2	**Site infrastructure works**				**€ 48,127,500**
1.2.1	Landscaping	345000	m²	€ 100	€ 34,500,000
1.2.2	Roads and parking lots	10000	m²	€ 400	€ 4,000,000
1.2.3	Green Park area	15000	m²	€ 50	€ 750,000
1.2.4	Architect/engineer fee	15	%		€ 6,277,500
1.2.5	Sewage system	1500	m	€ 450	€ 675,000
1.2.6	Roads (incl. temporary construction roads)	5000	m	€ 280	€ 1,400,000
1.2.7	Electricity	1500	m	€ 250	€ 375,000
1.2.8	Telecommunications	1500	m	€ 100	€ 150,000
1.3	Site facility construction				€ 1,920,000
1.3.1	Utility buildings	192	unit cost/month	€ 10,000	€ 1,920,000
1.4	**Security installation**				**€ 1,400,000**
1.4.1	Fence including: security camera's	1400	lfm	€ 1,000	€ 1,400,000
1.5	**Utility consumption**				**€ 55,462,500**
1.5.1	Electricity	8.5	year	€ 6,000,000	€ 54,000,000
1.5.1	Gas	8.5	year		
1.5.1	Water	8.5	m³ /a	€ 15,000	€ 202,500
1.5.1	Consumables waste handling e.g. waste oil	8.5	€ / a	€ 140,000	€ 1,260,000
1.6	**Human resources**				**€ 60,002,800**
1.6.1	Operator	8.5	year	€ 4,172,565	€ 37,553,085
1.6.2	COVRA	8.5	year	€ 2,494,412	€ 22,449,715
				Total	**€ 229,679,488**

Table A7-13: Construction cost. Note that the value of 2.3.4 is negative to account for the rounding errors

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
2.1	**Construction and outfitting shafts**				**€ 583,700,000**
2.1.1	Personnel shaft construction	850	m	€ 70,000	€ 59,500,000
2.1.2	Personnel shaft hoisting system		unit		€ 40,000,000
2.1.3	Waste shaft construction	1500	m	€ 100,000	€ 150,000,000
2.1.4	Waste shaft hoisting system		unit		€ 120,000,000
2.1.5	Ventilation shaft construction	850	m	€ 70,000	€ 59,500,000
2.1.6	Ventilation shaft hoisting system		unit		€ 20,000,000
2.1.7	Architect/engineer fee	30	%	€ 599,000,000	€ 134,700,000
2.2	**Construction and outfitting upper level main area**				**€ 26,469,052**
2.2.1	Excavation cost CM (Infrastructure area only)	19993.96	m³	€ 3	€ 59,982
2.2.2	Continuous Miner	4	piece	€ 2,500,000	€ 10,000,000
2.2.3	Continuous miner maintenance & other vehicles maintenance	1	a	€ 1,200,000	€ 1,200,000
2.2.4	Roof bolting machine	4	piece	€ 450,000	€ 1,800,000
	Roof Bolts, 10 pieces/100m	10	n/100m	€ 20	€ 2,000
2.2.5	Scaler	4	piece	€ 500,000	€ 2,000,000
2.2.6	LHD	4	piece	€ 600,000	€ 2,400,000
2.2.7	Dumper	4	piece	€ 450,000	€ 1,800,000
2.2.8	Working platform	4	piece	€ 200,000	€ 800,000
2.2.9	Mine car	16	piece	€ 150,000	€ 2,400,000
2.2.10	Outfitting (electricity, fire protection)	70.7	m	€ 100	€ 7,070
2.2.11	Infrastructure area equipment Incl. workshop, drill core storage, charging stations, rescue room, decontamination & monitoring room, parking area, group room, bunker	4	piece	€ 1,000,000	€ 4,000,000
2.3	**Construction and outfitting HLW main area & bunker**				**€ 5,745,941**
2.3.1	Ramp construction inc. hoisting system	1920	m	€ 2,300	€ 4,146,849
2.3.2	Excavation cost CM (Infra + salt bunker)	998.56	m³	€ 3	€ 4,416,000
2.3.3	Continuous miner				€ 233,397

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
2.3.4	Continuous miner maintenance & other vehicles maintenance	0.68	a	€ 1,200,000	
2.3.5	Roof bolting machine		piece		€ -1,200,000
	Roof Bolts, 10 pieces/100m	10	n/100m	€ 20	
2.3.6	Scaler		piece		€ 3,872
2.3.7	LHD		piece		
2.3.8	Dumper		piece		
2.3.9	Working platform		piece		
2.3.10	Mine car		piece		
2.3.11	Outfitting (electricity, fire protection)	15.8	m	€ 100	
2.3.12	Infrastructure area equipment Incl. workshop, drill core storage, charging stations, rescue room, decontamination & monitoring room, parking area, group room, bunker	1	piece	€ 500,000	€ 193,580
2.4	**Construction and outfitting HLW disposal area Rest of the area)**				**€ 18,666,384**
2.4.1	Excavation cost CM	1270448	m³	€ 3	
2.4.2	Continuous miner		piece		
2.4.3	Continuous miner maintenance & other vehicles maintenance	8	a	€ 1,200,000	€ 19,881,948
2.4.4	Roof bolting machine		piece		€ 3,809,568
		10	n/100m	€ 20	
2.4.5	Scaler		piece		€ 10,800,000
2.4.6	LHD		piece		
2.4.7	Dumper		piece		€ 103,380
2.4.8	Working platform		piece		
2.4.9	Mine car		piece		
2.4.10	Outfitting (electricity, fire protection)	51520	m	€ 100	
2.4.11	Infrastructure area equipment Incl. workshop, drill core storage, charging stations, rescue room, decontamination & monitoring room, parking area, group room, bunker		piece		
2.5	**Construction and outfitting LILW and (TE)NORM disposal tunnel**				**€ 18,046,110**

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
2.5.1	Excavation cost CM	1158740	m³	€ 3	€ 5,169,000
2.5.2	Continuous miner		piece		
2.5.3	Continuous miner maintenance & other vehicles maintenance	10	a	€ 1,200,000	
2.5.4	Roof bolting machine		piece		€ 18,046,110
2.5.5		10	n/100m	€ 20	€ 3,476,220
2.5.6	Scaler		piece		
2.5.7	LHD		piece		€ 12,000,000
2.5.8	Dumper		piece		
2.5.9	Working platform		piece		€ 50,390
2.5.10	Mine car		piece		
2.5.11	Outfitting (electricity, fire protection)	25195	m	€ 100	
2.5.111	Infrastructure area equipment Incl. workshop, drill core storage, charging stations, rescue room, decontamination & monitoring room, parking area, group room, bunker		piece		
2.6	**Site facility construction**				**€ 289,258,350**
2.6.1	Transformer station	1	unit	€ 126,000	€ 126,000
2.6.2	Emergency power system station	1	unit	€ 3,375,000	€ 3,375,000
2.6.3	Fuel tank building	1	unit	€ 412,500	€ 412,500
2.6.4	Ventilation building Main fan	1	unit	€ 6,450,000	€ 6,450,000
2.6.5	Main fan, technical equipment	1	unit	€ 10,000,000	€ 10,000,000
2.6.6	Administration building (incl. central control)	1	unit	€ 17,331,500	€ 17,331,500
2.6.7	Visitors centre	1	unit	€ 3,264,000	€ 3,264,000
2.6.8	Handling facility (Inc. Entrance, drying, hot cell, decontamination)	1	unit	€ 97,200,000	€ 97,200,000
2.6.9	Shaft tower waste shaft	1	unit	€ 30,000,000	€ 30,000,000
2.6.10	Shaft hall access shaft	1	unit	€ 6,000,000	€ 6,000,000
2.6.11	Shaft tower access shaft	1	unit	€ 20,000,000	€ 20,000,000
2.6.12	Locker room access	1	unit	€ 2,975,000	€ 2,975,000
2.6.13	Engine building access shaft	1	unit	€ 1,500,000	€ 1,500,000
2.6.14	Ventilation shaft building incl. equipment	1	unit	€ 10,000,000	€ 10,000,000

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
2.6.15	Workshops, vehicle storage	1	unit	€ 9,000,000	€ 9,000,000
2.6.16	Guardhouse	1	unit	€ 510,000	€ 510,000
2.6.17	Water supply / wastewater	1	unit	€ 2,700,000	€ 2,700,000
2.6.18	Weather station	1	unit	€ 1,785,000	€ 1,785,000
2.6.19	Laboratory / drill core storage	1	unit	€ 12,750,000	€ 12,750,000
2.6.20	Washing place vehicles	1	unit	€ 200,000	€ 200,000
2.6.21	Dump	1	m³		
2.6.22	Engine building ventilation (transformer station)	1	unit	€ 3,000,000	€ 3,000,000
2.6.23	Collection and treatment of radioactive waste	1	unit	€ 450,000	€ 450,000
2.6.24	Fire station	1	unit	€ 7,500,000	€ 7,500,000
2.6.25	Backfill processing plant	1	unit	€ 5,000,000	€ 5,000,000
2.6.26	Architect/engineer fee	15	%	€ 2,515,290	€ 37,729,350
2.7	**Maintenance surface**				**€ 124,730,840**
2.7.1	Maintenance surface facilities	5,030,580.00		2	€ 115,703,340
2.7.2	Maintenance surface areas	392,500.00		1	€ 9,027,500
2.8	**Insurance**				**€ 34,372,000**
2.8.1	Combined construction/assembly insurance incl. assembly equipment	23	year	€ 200,000	€ 4,600,000
2.8.2	Builder's liability insurance		total	€ 3,000,000	€ 3,000,000
2.8.3	Public liability insurance conventional	23	year	€ 14,000	€ 322,000
2.8.4	Public liability insurance nuclear	23	year	€ 600,000	€ 13,800,000
2.8.5	Nuclear insurance	23	year	€ 550,000	€ 12,650,000
2.8.6	Further insurance (visitors etc.)				
2.9	**Utility consumption**				**€ 687,585,532**
2.9.1	Utility consumption				
2.9.2	Electricity	23	year	€ 6,000,000	€ 683,848,032

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
2.9.3	Water	23	m³ /a	€ 15,000	€ 517,500
2.9.4	Consumables waste handling e.g. waste oil	23	€ / a	€ 140,000	€ 3,220,000
2.10	**Human resources**				**€ 437,132,655**
2.10.1	Operator	23	year	€ 7,816,342	€ 179,775,866
2.10.1	COVRA	23	year	€ 11,189,426	€ 257,356,789
				Total	**€ 2,225,323,335**

Table A7-14: HLW disposal

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
3.1	**Disposal**				**€ 4,400,000**
3.1.1	Waste transport cart	2	unit	€ 1,500,000	€ 3,000,000
3.1.2	Waste transport cart maintenance	4	a	€ 150,000	€ 600,000
3.1.3	Backfilling equipment maintenance	4	a	€ 200,000	€ 800,000
3.2	**Backfilling and sealing**				**€ 188,781,824**
3.2.1	Disposal tunnel heat-generating			1	€ 88,378,752
3.3.2	Disposal tunnel non heat-generating			1	€ 100,403,072
3.3	**Maintenance surface**				**€ 21,692,320**
3.3.1	Maintenance surface facilities	2	%	2	€ 20,122,320
3.3.2	Maintenance surface areas	1	%	1	€ 1,570,000
3.4	**Insurance**				**€ 8,456,000**
3.4.1	Combined construction/assembly insurance incl. assembly equipment	4	year	€ 200,000	€ 800,000
3.4.2	Builder's liability insurance		total	€ 3,000,000	€ 3,000,000
3.4.3	Public liability insurance conventional	4	year	€ 14,000	€ 56,000
3.4.4	Public liability insurance nuclear	4	year	€ 600,000	€ 2,400,000
3.4.5	Nuclear insurance	4	year	€ 550,000	€ 2,200,000
3.4.6	Further insurance (visitors etc.)		year		
3.5	**Utility consumption**				**€ 119,580,092**
3.5.1	Utility consumption				
	Electricity	4	year	€ 29,732,523	€ 118,930,092
	Water	4	m³ /a	€ 15,000	€ 90,000
	Consumables waste handling e.g. waste oil	4	€ / a	€ 140,000	€ 560,000
3.6	**Human resources**				€ 64,380,115
3.6.1	1 Operator	4	year	€ 12,647,495	€ 50,589,981
3.6.2	2 COVRA	4	year	€ 3,447,533	€ 13,790,134
				Total	**€ 407,290,352**

Table A7-15: Disposal LILW – (TE)NORM

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
4.1	**Disposal**				**€ 13,260,000**
4.1.1	Waste transport cart / forklift	4	unit	€ 300,000	€ 1,200,000
4.1.2	Waste transport cart maintenance	31	a	€ 60,000	€ 1,860,000
4.1.3	Backfilling equipment	4	unit	€ 1,000,000	€ 4,000,000
4.1.4	Backfilling equipment maintenance	31	a	€ 200,000	€ 6,200,000
4.2	**Backfilling and sealing**				**€ 245,737,280**
4.2.1	Disposal Tunnel	1	unit	€ 35,307,776	€ 35,307,776
4.2.2	Disposal room	1	unit	€ 210,429,504	€ 210,429,504
4.3	**Utility consumption**				**€ 926,745,717**
4.3.1	Utility consumption				
	Electricity	31	year	€ 6,000,000	€ 921,708,217
	Water	31	m³ /a	€ 15,000	€ 697,500
	Consumables waste handling e.g. waste oil	31	€ / a	€ 140,000	€ 4,340,000
4.4	**Maintenance surface**				**€ 168,115,480**
4.4.1	Maintenance surface facilities	2	%	2	€ 155,947,980
4.4.2	Maintenance surface areas	1	%	1	€ 12,167,500
4.5	**Insurance**				**€ 45,284,000**
4.5.1	Combined construction/assembly insurance incl. assembly equipment	31	year	€ 200,000	€ 6,200,000
4.5.2	Builder's liability insurance		total	€ 3,000,000	€ 3,000,000
4.5.3	Public liability insurance conventional	31	year	€ 14,000	€ 434,000
4.5.4	Public liability insurance nuclear	31	year	€ 600,000	€ 18,600,000
4.5.5	Nuclear insurance	31	year	€ 550,000	€ 17,050,000
4.5.6	Further insurance (visitors etc.)		year		
4.6	**Human resources**				**€ 498,945,893**
4.6.1	Operator	31	year	€ 12,647,495	€ 392,072,351
4.6.2	COVRA	31	year	€ 3,447,533	€ 106,873,542
				Total	€ 13,260,000

Table A7-16: Observation period

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
5.1	**Maintenance surface**				**€ 54,230,800**
5.5.1	1 Maintenance surface facilities	2	%	€ 5,030,580	€ 50,305,800
5.5.2	2 Maintenance surface areas	1	%	€ 392,500	€ 3,925,000
5.2	**Insurance**				**€ 16,640,000**
5.2.1	Combined construction/assembly insurance incl. assembly equipment	10	year	€ 200,000	€ 2,000,000
5.2.2	Builder's liability insurance	1	total	€ 3,000,000	€ 3,000,000
5.2.3	Public liability insurance conventional	10	year	€ 14,000	€ 140,000
5.2.4	Public liability insurance nuclear	10	year	€ 600,000	€ 6,000,000
5.2.5	Nuclear insurance	10	year	€ 550,000	€ 5,500,000
5.2.6	further insurance (visitors etc.)				
5.3	**Utility consumption**				**€ 99,533,410**
5.3.1	Utility consumption				
	Electricity	10	year	€ 9,910,841	€ 99,108,410
	Water	10	m^3 /a	€ 5,000	€ 75,000
	Consumables waste handling e.g. waste oil	10	€ / a	€ 35,000	€ 350,000
5.4	**Human resources**				**€ 49,386,874**
5.4.1	Operator	10	year	€ 2,432,759	€ 24,327,592
5.4.2	COVRA	10	year	€ 2,505,928	€ 25,059,282
				Total	**€ 219,791,084**

Table A7-17: Cost closure phase

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
6.1	**Backfilling and sealing galleries and ramp**				**€ 181,919,695**
6.1.1	Ventilation tunnel lower level				€ 60,996,096
6.1.2	Service tunnel Upper level				
6.1.3	Transport tunnel lower level				€ 57,935,360
6.1.4	Infrastructure area lower level				€ 243,649
6.1.5	Ramp				€ 18,739,200
6.1.6	Ventilation tunnel upper level				€ 18,528,384
6.1.7	Service tunnel Lower level				€ 2,131,584
6.1.8	Transport tunnel upper level				€ 18,466,896
6.1.9	Salt bunker				
6.1.10	Infrastructure upper level				€ 4,878,526
6.2	**Backfilling and sealing shafts**				**€ 500,000,000**
6.2.1	Dismantling of the underground plant technology		total		€ 50,000,000
6.2.2	Dismantling hoisting systems and rent of 2 temporary hoisting systems		total		€ 200,000,000
6.2.3	Dismantling and removal of the shaft interior		total	€ 50,000,000	€ 50,000,000
6.2.4	Shaft backfill & closure structure (4 times)	4	€		€ 200,000,000
6.3	**Dismantling and decommissioning nuclear facilities**				**€ 20,000,000**
6.3.1	Clearance measurement of nuclear facilities incl. hoisting systems and	5	year		€ 100,000,000
6.4	**Site dismantling and clearance**				**€ 50,000,000**
6.4.1	Dismantling of conventional surface facilities		total		€ 50,000,000

	Cost item	Quantity	Unit	Unit cost [€]	Total cost [€]
6.5	**Insurance**				**€ 18,004,000**
6.5.1	Combined construction/assembly insurance incl. assembly equipment	12	year	€ 200,000	€ 2,200,000
6.5.2	Builder's liability insurance		total	€ 3,000,000	€ 3,000,000
6.5.3	Public liability insurance conventional	12	year	€ 14,000	€ 154,000
6.5.4	Public liability insurance nuclear	12	year	€ 600,000	€ 6,600,000
6.5.5	Nuclear insurance	12	year	€ 550,000	€ 6,050,000
6.5.6	Further insurance (visitors etc.)		year	€ 200,000	
6.6	**Utility consumption**				**€ 328,845,254**
6.6.1	Utility consumption			€ 6,000,000	
	Electricity	12	year	€ 15,000	€ 327,057,754
	Water	12	m³ /a	€ 140,000	€ 247,500
	Consumables waste handling e.g. waste oil	12	€ / a		€ 1,540,000
6.7	**Human resources**			**€ 10,237,998**	**€ 134,931,289**
6.7.1	1 Operator	12	year	€ 2,028,482	€ 112,617,987
6.7.2	2 COVRA	12	year	€ 50,000,000	€ 22,313,302
				Total	**€ 1,313,700,238**

Table A7-18: Cost of the HLW conditioning facility

HLW disposal facility	Cost item	Duration	Quantity	Unit	Unit cost [€]	Total cost [€]
1.1	**Investment - Land purchase**					**€ 71,875**
1.1.1	Nominal costs of land purchase		2500	m²	€ 25	€ 62,500
1.1.2	Notary fee		15	%	€ 28	€ 9,375
1.2	**Investment - Site infrastructure works**					**€ 540,500**
1.2.1	Landscaping		2500	m²	€ 100	€ 250,000
1.2.2	Roads and parking lots		100	m²	€ 400	€ 40,000
1.2.3	Green Park area		800	m²	€ 50	€ 40,000
1.2.4	Sewage system		200	m²	€ 450	€ 90,000
1.2.5	Connection to utilities networks and sewage				€ 50,000	€ 50,000
1.2.6	Architect/engineer fee		15	%	€ 4,700	€ 70,500
2.1	**Investment - Site facility construction**					
2.1.1	CF building		25200	m²		€ 20,286,000
2.1.2	Architect/engineer fee		15	%	€ 700	€ 17,640,000
2.2	**Investment - CF internals/construction and installation**				**€ 176,400**	**€ 2,646,000**
2.2.1	Fuel handling systems, cranes and lifts		2	unit		€ 111,800,000
2.2.2	Process systems		2	unit	€ 16,000,000	€ 32,000,000
2.2.3	Automatizations and telecommunication		2	unit	€ 9,000,000	€ 18,000,000
2.2.4	Electric power system		2	unit	€ 6,000,000	€ 12,000,000
2.2.5	HVAC		2	unit	€ 5,000,000	€ 10,000,000
2.2.6	Radiation protection and monitoring		2	unit	€ 5,000,000	€ 10,000,000
2.2.7	Architect/engineer fee		30	%	€ 2,000,000	€ 4,000,000
2.4	**Maintenance during HLW disposal campaign**				**€ 86,000,000**	**€ 25,800,000**
2. 4. 1	CF building		39	year		€ 231,769,200
2. 4. 2	CF internals/construction and installation, incl. replacement		39	year	€ 352,800	€ 13,759,200
2. 5	**Insurance during HLW disposal campaign**				**€ 5,590,000**	**€ 218,010,000**
2.5.1	CF building		43	year		€ 26,075,200
2.5.2	CF internals/construction and installation		43	year	€ 176,400	€ 7,585,200

HLW disposal facility	Cost item	Duration	Quantity	Unit	Unit cost [€]	Total cost [€]
2.6	**Material for DWP and consumables**				**€ 430,000**	**€ 18,490,000**
2.6.1	DWP lid and flap ECN "hot"		125	piece		€ 1,920,812,500
2.6.2	DWP lid and flap CSD "hot and cold"		3000	piece	€ 499,000	€ 62,375,000
2.6.3	Transport cap		3125	pieces	€ 583,000	€ 1,749,000,000
2.6.4	CF utility consumption (electricity, HVAC)		39	years	€ 7,500	€ 23,437,500
2.6.5	Operational waste management		39	years	€ 1,500,000	€ 64,500,000
3.1	**Investment - Dismantling and decommissioning nuclear facilities**				**€ 500,000**	**€ 21,500,000**
3.1.1	Conditioning facility		1	Unit		
3.1.2	Internals		1	unit		€ 31,092,000
					Total	**€ 5,292,000**

Table A7-19: (TE)NORM conditioning facility

Item	Cost
Building and installation	€ 10,223,222
Total cost per container	€ 20,015
Personal cost per container	€ 600
Total cost per container including personal	€ 20,615

Table A7-20. Total m³ of salt that needs to be excavated for the upper level

Upper Level [m]	Width (m)	Height (m)	Total Length (m)	m³ each 1 m	m³ total
Disposal Gallery	5.6	4	6460	22.4	144704
Disposal Room	10.6	6	13560	63.6	862416
Ventilation Tunnel	5.6	4	3390	22.4	75936
Transport Tunnel	10.6	4	1785	42.4	75684
Infrastructure area	70.7	4	70.7	282.8	19993
Total					1178733

Table A7-21. Total m³ of salt that needs to be excavated for the spiral ramp and lower level

Lower Level [m]	Width (m)	Height (m)	Total Length (m)	m³ each 1 m	m³ total
Disposal tunnel heat-generating	5.6	4	16170	22.4	362208
Disposal tunnel non heat-generating	5.6	4	18370	22.4	411488
Ventilation tunnel	5.6	4	11160	22.4	249984
Service tunnel	5.6	4	390	22.4	8736
Transport tunnel	10.6	4	5600	42.4	237440
Salt bunker	0	0	0	0	0
Infrastructure area / Salt bunker	15.8	4	15.8	63.2	998
Total					1271446

Table A7-22. Total time needed to excavate the spiral ramp, upper level, and lower level

Upper level

Type	Total length m
Total Tunnel length 5,6 x 4 m	9850
Total Tunnel length 10,6 x 4 m	1785
Total Tunnel length 10,6 x 6 m	13560
Infrastructure 125 x 4 m	70.7
Type	**Total hours**
Excavation Infrastructure area	353.5
Excavation time #3	1231.25
Excavation time #4	446.25
Excavation time #5	6780
Type	**Total days**
Excavation Infrastructure area	59
Excavation time #3	205
Excavation time #4	74
Excavation time #5	1130
Type	**Total years**
Excavation Infrastructure area	0.4
Excavation time #3	1.4
Excavation time #4	0.5
Excavation time #5	7.5
Total	**9.8**

Lower level

Type	Total length
Infrastructure + salt bunker	15.8
Total Tunnel length 5,6 x 4 m	45700
Total Tunnel length 10,6 x 4 m	5590
Type	Total hours
Excavation Infrastructure area	79
Excavation time 5,6 x 4 m	5712.5
Excavation time 10,6 x 4 m	1497.5
Type	Total days
Excavation Infrastructure area	13
Excavation time 5,6 x 4 m	952
Excavation time 10,6 x 4 m	250
Type	Total years
Excavation Infrastructure area	0.1
Excavation time 5,6 x 4 m	6.3
Excavation time 10,6 x 4 m	1.6
Total (years)	**8.1**

Spiral ramp

Ramp excavation	Width (m)	Height (m)	Total Length (m)	m^3 each 1 m	m^3 total
Ramp	4	10	1920	40	76800
Excavation time ramp (hours)	480				
Total (years)	**0.6**				

Table A7-23: Total time and cost needed to backfill the repository. Note that for the calculation of the total duration in Table 2 of the main report, rounded numbers are used for each segment (upper level, lower level, and shaft). As a result, the backfilling process takes a year longer because the 7.02 years for the lower level is rounded up to 8 years.

Upper level [m]	Width (m)	Height (m)	Length (m)	each m3	€/m³	m³ total	Sum [€]	Backfill shifts	Duration (years)
Disposal gallery	5.6	4	6460	22.4	244	144704	35307776	96.9	0.4
Disposal room	10.6	6	13560	63.6	244	862416	210429504	406.8	1.8
Ventilation tunnel	5.6	4	339	22.4	244	75936	18528384	50.85	0.2
Transport tunnel	10.6	4	1785	42.4	244	75684	18466896	53.55	0.2
Infrastructure area	70.7	4	70.7	282.8	244	19993.96	4878526.24	21.21	0.1
Backfilling disposal rooms								503.7	2.3
Backfilling remaining area								125.61	0.5
Total						1178733.96	287611086.2	629.31	2.8
Lower level [m]	**Width [m]**	**Height [m]**	**Length total [m]**	**m³ each 1 m tunnel length**	**€/ m³**	**m³ total**	**Sum [€]**	**Backfill shifts**	**years**
Disposal gallery heat-generating	5.6	4	16170	22.4	244	362208	88378752	485.1	2.2
Disposal gallery non heat-generating	5.6	4	18370	22.4	244	411488	100403072	551.1	2.5
Ventilation tunnel	5.6	4	11160	22.4	244	249984	60996096	334.8	1.5
Service tunnel	5.6	4	390	22.4	244	8736	2131584	11.7	0.05
Transport tunnel	10.6	4	5600	42.4	244	237440	57935360	168	0.7
Salt bunker	0	0	0	0	244	0	0	0	0
Infrastructure area	15.8	4	15.8	63.2	244	998.56	243648.64	0.474	0.0
Ramp	4	10	1920	40	244	76800	18739200	230.4	1
Total (excluding ramp)						1271446.56	310232960.6	1546.074	7.0
Total Including ramp									8.0

Probabilistische resultaten levenscycluskosten		
Deterministische levenscycluskosten inclusief BTW = modus (T_waarde)	€	12,098,148,039
Verschuiving levenscycluskosten inclusief BTW	€	43,682,071
Probabilistische levenscycluskosten inclusief BTW = gemiddelde (Mu_waarde)	**€**	**12,141,830,110**
Variatiecoëfficiënt levenscycluskosten		**30%**
Standaardafwijking levenscycluskosten	€	3,641,978,969
Scheefheid		(0.01)
Minimum waarde	€	3,349,552,152
Maximum waarde	€	20,845,127,737
5% onderschrijdingskans	€	6,031,559,166
Ondergrens 70% interval	**€**	**8,118,153,017**
50% overschrijdingskans	€	12,136,494,512
Bovengrens 70% interval	**€**	**16,176,538,656**
5% overschrijdingskans	€	18,254,895,521
[All] Electricity , 0.85 kW/h, (object: Surface, oorzaak: price)		41.2%
[CF] DWP lid and flap CSD "hot and cold", (object: Cf Materials Decommissiong, oorzaak: price)		29.5%
[TE]Conrad container, (object: TENORM Conditioning, oorzaak: price)		21.0%
[LILW disposal] Operator LILW Disposal Campaign, (object: LILW (TE)NORM Disposal, oorzaak: price)		1.4%
[All] Maintenance surface facilities, (object: Surface, oorzaak: price)		1.2%
[Construction] COVRA Construction, (object: Repository construction, oorzaak: price)		0.7%
[Post closure] Shaft backfill & closure structure (3 times), (object: Repository Closure, oorzaak: price)		0.6%
[LILW disposal] Disposal Room Backfilling and closing, (object: LILW (TE)NORM Disposal, oorzaak: price)		0.5%
Other		4.0%
Total		100.0%

Hierboven staan de risicobijdragen levenscycluskosten (kostenposten die de grootte van de standaardafwijking bepalen)

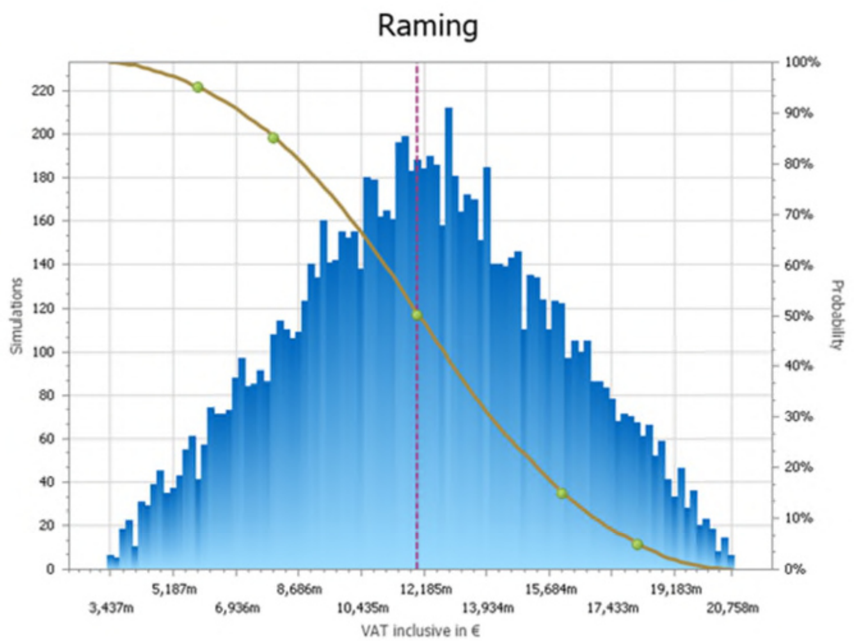


Figure A7-4: The estimated cost distribution using a Monte Carlo simulation using the -50% – 50% uncertainty in the prices

Probabilistische resultaten levenscycluskosten		
Deterministische levenscycluskosten inclusief BTW = modus (T_waarde)	€	12,098,148,039
Verschuiving levenscycluskosten inclusief BTW	€	1,291,083,078
Probabilistische levenscycluskosten inclusief BTW = gemiddelde (Mu_waarde)	**€**	**13,389,231,118**
Variatiecoëfficiënt levenscycluskosten		**26%**
Standaardafwijking levenscycluskosten	€	3,454,380,132
Scheefheid		0.19
Minimum waarde	€	5,797,098,135
Maximum waarde	€	22,300,898,081
5% onderschrijdingskans	€	7,918,190,736
Ondergrens 70% interval	**€**	**9,678,254,033**
50% overschrijdingskans	€	13,171,621,039
Bovengrens 70% interval	**€**	**17,308,414,951**
5% overschrijdingskans	€	19,430,116,357
[All] Electricity , 0.85 kW/h, (object: Surface, oorzaak: price)		38.3%
[CF] DWP lid and flap CSD "hot and cold", (object: Cf Materials Decommissiong, oorzaak: price)		26.7%
[TE]Conrad container, (object: TENORM Conditioning, oorzaak: price)		20.5%
[All] Maintenance surface facilities, (object: Surface, oorzaak: price)		2.8%
[LILW disposal] Disposal Room Backfilling and closing, (object: LILW (TE)NORM Disposal, oorzaak: price)		1.7%
[LILW disposal] Operator LILW Disposal Campaign, (object: LILW (TE)NORM Disposal, oorzaak: price)		1.4%
[Post closure] Dismantling hoisting systems and rent of 2 temporary hoisting systems, (object: Repository Closure		1.0%
[Post closure] Shaft backfill & closure structure (3 times), (object: Repository Closure, oorzaak: price)		1.0%
Other		6.7%
Total		100.0%

Hierboven staan de risicobijdragen levenscycluskosten (kostenposten die de grootte van de standaardafwijking bepalen)

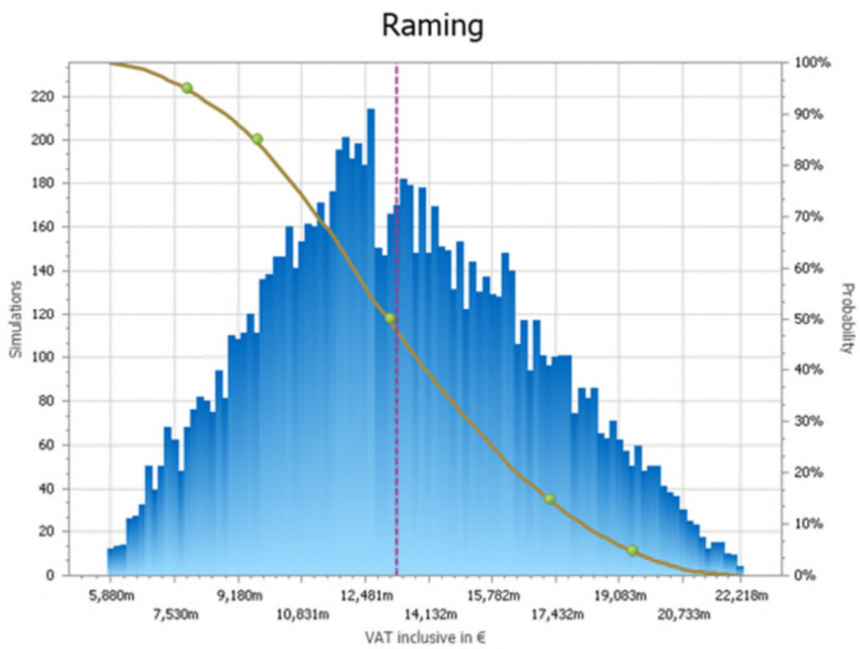


Figure A7-5: The estimated cost distribution using a Monte Carlo simulation using the AACE classification uncertainty in the prices

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BGE TECHNOLOGY GmbH
Eschenstraße 55
31224 Peine – Germany
T + 49 5171 43-1520
F + 49 5171 43-1506
info@bge-technology.de
www.bge-technology.de