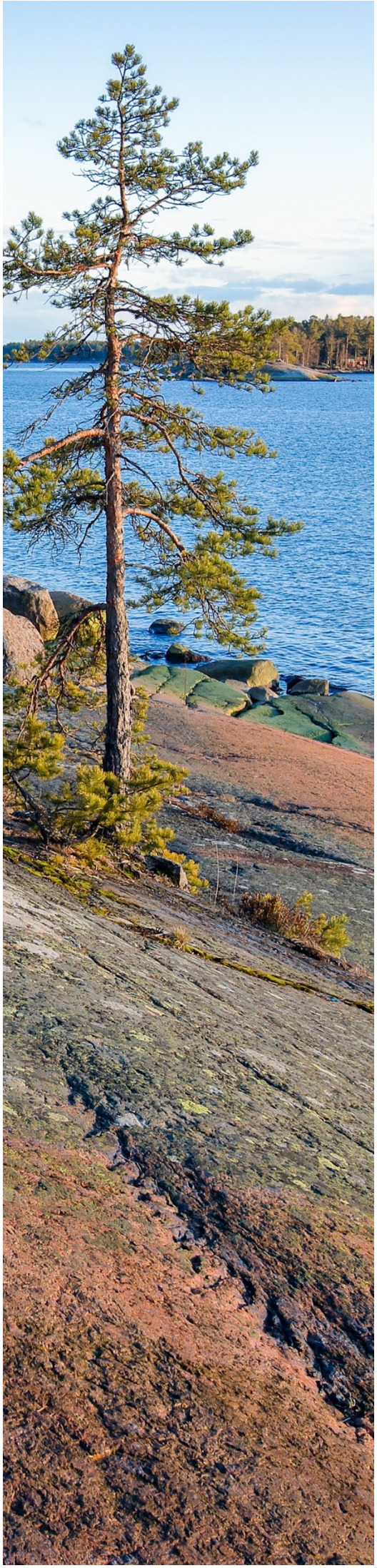

Technical memorandum

Stand-alone repository DGR and Deep borehole – cost estimation

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1 Introduction

Norwegian Nuclear Decommissioning NND has signed a contract with Finnish AINS Group together with subconsultants VTT Technical Research Centre of Finland and BGE Technology GmbH of Germany. The group assists NND with the concept development and technical design for their disposal solution for radioactive waste in Norway.

NND is studying several different concepts for how to update the Norwegian infrastructure for management of radioactive waste. One concept consists of combining different types of facilities into a National Facility for management of radioactive waste. The AINS Group and subconsultants are working with NND in developing the National Facility and estimating the associated costs.

A National Facility would contain the following repository types for the waste:

- Intermediate depth repository for very low, low- and intermediate-level waste,
- Deep geological repository (DGR) for high-level waste,
- Deep borehole repository for high-level waste as an alternative to the DGR,
- Landfill-type repository as an option for non-radioactive decommissioning waste, mainly soil and concrete.

Repository types and the National Facility have been presented in the report “Concept Description for Norwegian National Disposal Facility for Radioactive waste“ (Ikonen et al. 2020). Cost estimation of the National Facility is presented in the report “Cost Estimation for Norwegian National Facility” (Saanio et al. 2020).

In the above-mentioned studies, repository alternatives for high-level waste are part of the National Facility. This memorandum is the cost estimation study for high-level waste repository alternatives in case repositories would be stand-alone repositories meaning that the repositories are not part of the National Facility. Designs for the stand-alone repositories are done very simply by picking up relevant parts from the National Facility. No further design or optimisation is done in this phase. Designs may be very conservative. The National Facility is designed for 100 years operational period. The actual disposal (operation) of the high-level waste will take only couple of years. Due to shorter operation time, many buildings and structures in the stand-alone repositories could be temporary or lighter than in the National Facility. Above ground buildings need to be designed and studied more detailed in the next design phase if the stand-alone alternatives are developed further. Buildings can be optimised for very short operation time. Buildings can be temporary and some of them may even be leased or rented.

Amount of the high-level spent fuel for this study is the same as for the National Facility:

- 28 KBS-3 canisters in the Deep Geological Repository or
- 69 BSK canisters in the Deep Borehole Repository.

2 Repositories

Both stand-alone repository alternatives are described in this chapter. Chapter 2.1 includes description of the stand-alone Deep Geological Repository. The stand-alone Deep Borehole Disposal Facility is introduced in Chapter 2.2.

2.1 Deep Geological Repository alternative

The Deep Geological Repository alternative consists of above ground facilities and underground repository. An operation building, a waste reception building, some auxiliary buildings and infrastructure are constructed above ground. The theoretical surface area of the site is 200 meters by 400 meters. The site is surrounded by security fencing. Employee and visitor parking area is outside the fenced area.

The following components of the facility are located at a depth of 400 m under ground level: two deposition tunnels for 28 deposition holes, two demonstration tunnels, reloading hall, parking hall, safety centre, electrical rooms, the sedimentation pool with the pumping station and air shaft connections. The access tunnel, inlet air shaft and exhaust air shaft connect the Deep geological repository to the surface ventilation building. The length of the access tunnel is roughly four kilometres and depth of the shafts is 400 meters. The Deep Geological Repository is presented in Figure 2-1.

During the operation period, the access tunnel vehicle will transfer canister transport containers from the waste reception building above ground to the reloading hall in the -400 meters level. In the reloading hall, canisters are reloaded to the canister transfer and installation vehicle. This vehicle transfers the canisters to the deposition tunnel and installs the canisters in the deposition holes. Operation of the Deep geological repository will take roughly two years.

The deposition tunnels are backfilled and plugged after the canisters are installed in each deposition tunnel. After all canisters are installed, structures (walls, floors, doors, ventilation channels, electricity supply etc.) from the deep geological repository will be removed and the facilities in -400 meters level, shafts and access tunnel will be backfilled and plugged up to the surface (Ikonen et al. 2020). It is assumed that after the confirmation of the closure (License for Closure), the site will be decommissioned. All buildings will be removed and site green-fielded. Site remains in institutional control as required by the authorities.

The repository, operations and closure has been presented more detailed in the report “Concept Description for Norwegian National Disposal Facility for Radioactive waste“ (Ikonen et al. 2020).

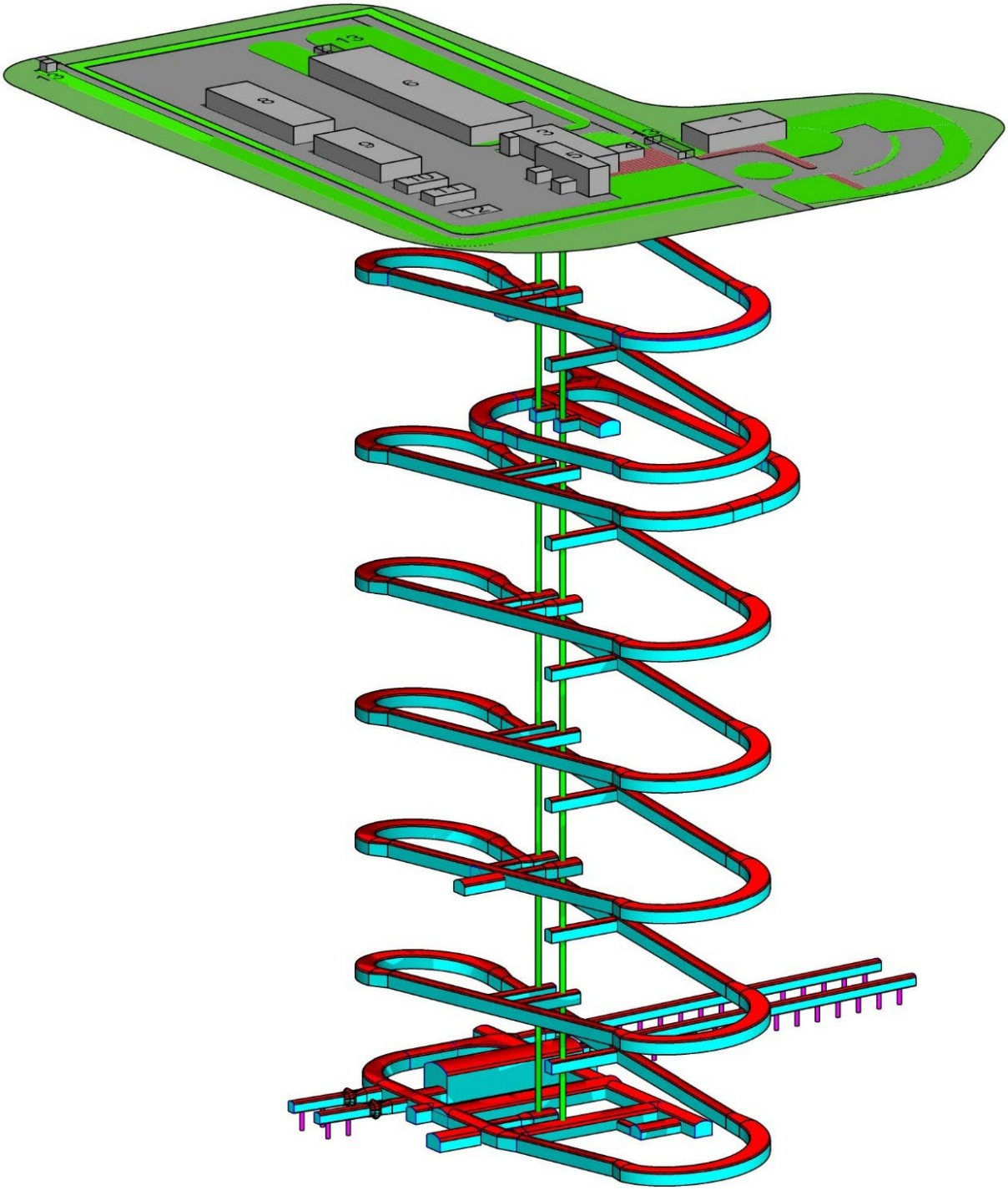

Figure 2-1. Illustration of the stand-alone Deep geological repository alternative. Above ground buildings: 1) Office building, 3) Operation building, 4) Guard, 5) Ventilation building, 6) Tunnel portal building, 8) Waste reception building, 9) Maintenance and storage hall, 10) Research building, 11) Backup power supply, 12) Refuelling station and 13) Control.

2.2 Stand-alone Deep Borehole Disposal Facility

The Deep Borehole Disposal Facility consists of above ground facilities and a deep borehole. An operation building, a waste reception building, some auxiliary buildings and infrastructure are constructed above ground. Figure 2-2 illustrates a potential site layout. The layout and location of the buildings are not optimised in this study. The theoretical surface area of the site is 200 meters by 400 meters. The site is surrounded by security fencing. Employee and visitor parking area is outside the fenced area.

In normal operations waste arrives via Control (13) in a vehicle (truck) and drives to the Disposal building (15). The canister is offloaded. Truck exits, and refuels (12) if needed. The waste canister is inspected and confirmed. It is then moved to the disposal rig and disposed to the borehole below Disposal building (15). Waste reception building (8) is for situations where several waste canisters arrive (near) simultaneously and temporary storage and shelter is needed. Alternative this can be organised in the Disposal building (15) reserving some space for interim storage. In this case separate waste building (8) can be excluded from the site. Research building (10) consists of on-site laboratory for site investigation activities. Due to the expected short duration of the site lifetime, these activities could be potentially incorporated in the enlarged Office building (1). In this case Research building (10) can be excluded. For completeness, and conservativeness, in this study it is assume that these buildings will be built.

Once all the waste canisters are disposed in the borehole, the casing will be removed and the borehole will be sealed and plugged. It is assumed that after the confirmation of the closure (License for Closure), the site will be decommissioned. All buildings will be removed and site green-fielded. Site remains in institutional control as required by the authorities.

The total duration of the site is assumed 5 years from the site confirmation to the closure.

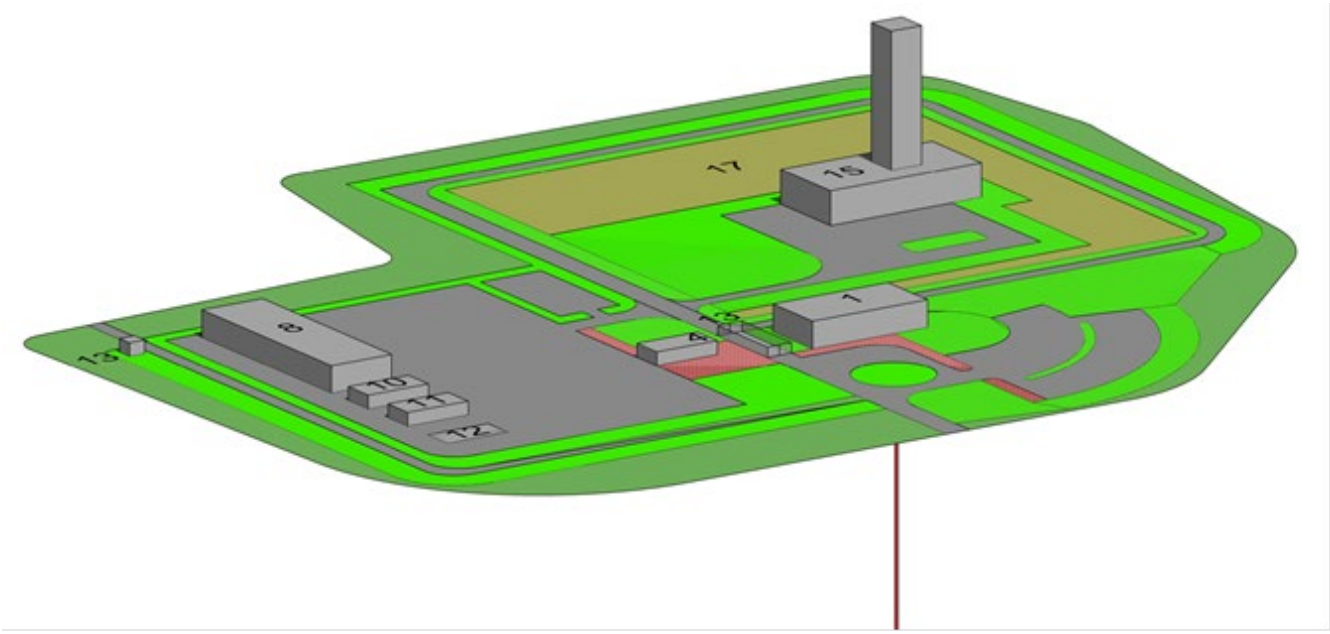

Figure 2-2. Illustration of potential layout of a stand-alone Deep Borehole Disposal Facility for Norway. 1) Office building, 4) Guard, 8) Waste reception building (also storage / inspection with temporary waste storage capacity), 10) Research building, 11) Backup power supply, 12) Refuelling station, 13) Control, 15) Disposal building, and 17) safe zone around disposal rig.

3 Cost estimations

All costs are calculated and presented in euro. The prices do not include the value-added tax (VAT).

Cost estimation is based on working methods used in EU-countries and average EU-prices of materials and labour costs are applied. It should be noted that the price level in Norway differs from the price level in EU-countries.

The cost level is 1/2020. The interest rate of the money has not been taken into account.

Owner costs are included in the investment costs, closure costs and partly in the operational costs. Owner costs contain developing costs, design costs, project costs and license costs. Developing costs include only “normal level costs”, which are the costs that are needed for construction in normal case, for example grouting development in particular rock conditions.

During the lifetime of a radioactive waste management program, a significant amount of research and development activities take place much before the construction of the facility begins. The research and development (R&D) activities support for example generic concept developments and long-term safety issues. R&D costs, testing and other waste management costs (encapsulation and transports) before construction of the Repository are not included in this work, which is bounded inside the Repository site.

Generally, owner costs are estimated as:

- Initiation fees to systems such as electric network, IT network, water distribution, sewage system and district heat distribution 1%
- Construction supervision costs 2%
- Developing and licence costs 2,2 - 4,8%
- Design and survey costs 4,3 - 7,4%
- The usage costs of the construction site 1 -2 %.

In this report owner costs are assumed to be 3 - 15% of the investment costs depending on the cost item.

Personnel costs for construction/investment and closure are included in the corresponding tables for construction period and closure period. Both Stand-alone Repository alternatives are operated only for short period. It is assumed that most of the NND administration personnel are working permanently mainly in NND headquarter, not in the Repository site. Their costs are not included in this cost estimation. For the operation period this cost estimation covers personnel costs only for:

- Deep Geological Repository: 20 persons above ground and 20 persons underground working for direct disposal of canisters and buffer, security, admin, maintenance.

- Deep Borehole Repository: 30 persons above ground working for running the disposal rig, security, admin, maintenance.

Possible post-closure costs after closure on the Repository are excluded.

3.1 Deep Geological Repository alternative

Cost estimation of the Deep Geological alternative is based on the WP3 report “Cost Estimation for Norwegian National Facility” (Saanio et al. 2020). The disposal concept is presented generally in Chapter 2.1. of this report. More detailed information can be found in the above mentioned WP3 report and in the WP2 report “Concept Description for Norwegian National Disposal Facility for Radioactive waste” (Ikonen et al. 2020).

3.1.1 Site selection and licensing

Site selection and safety cases are assumed to be the same as presented in WP3. The cost items are repeated here for completeness in the following tables.

Table 3-1. Site investigation costs in two phases (EUR).

Investigation phase	Costs / site	Number of sites	EUR Total
Preliminary site investigations	6 000 000	1	6 000 000
Detailed site investigations	15 800 000	1	15 800 000
Total			**21 800 000**

Table 3-2. Safety case costs for one municipality (EUR).

Activity	EUR
Safety case to support site selection	2 000 000
Detailed safety case to support the construction license	5 000 000
Detailed safety case to support the operation license	5 000 000
Total	**12 000 000**

3.1.2 Facilities above ground

3.1.2.1 Site investigations, planning

Information about site conditions is needed for the design of above ground structures and buildings. Rough estimate of the costs is 1 000 000 Euros.

3.1.2.2 Investments / construction

Investment costs for the above ground buildings and structures are summarized in Table 3-3.

Table 3-3. Investment costs (EUR).

Investment / construction	EUR
Buildings and structures	29 686 000
Equipment, installations	7 070 000
HVAC, electricity	7 422 000
Infrastructure	8 965 000
Owner costs	7 971 000
Sub-total	**61 114 000**
Contingency for uncertainties, 30%	18 334 000
Total	**79 448 000**

Costs for buildings and structures include construction costs for all buildings that are listed in Figure 2-1. Costs for the buildings and structures are presented in detailed in Table 3-4.

Equipment and installations include furniture, computers etc. for buildings listed in Figure 2-1.

HVAC and electricity costs include costs for buildings that are listed in Figure 2-1.

Infrastructure costs include costs for ground works, fencing, asphalt, draining systems, sewage, water systems, parks, grass, electricity and lightning for the area.

In this report owner costs are assumed to be 3 - 15% of the other investment costs – depending on the facility and its lifetime. Typically, owner costs include design and survey costs, developing and license costs, construction supervision costs, the usage costs of the construction site and initiation fees to systems as electric network, IT network, water distribution, sewage system and district heat distribution.

Table 3-4. Construction costs for the buildings and structures (EUR).

Building / structure	EUR
Office building	3 040 000
Operation building	4 144 000
Guard	300 000
Ventilation building	2 616 000
Tunnel portal building	8 676 000
Waste reception building	6 500 000
Maintenance and storage hall	3 000 000
Research building	360 000
Backup power supply	300 000
Refuelling station	300 000
Control	50 000
Sedimentation pool	400 000
Total	**29 686 000**

3.1.2.3 Operating

20 persons are assumed to work above ground during the operation period for the Deep Geological Repository alternative.

A rough estimate for the energy costs of the repository is 200 000 EUR/year while those for the water and water treatment costs of the above ground facilities are 30 000 EUR/year.

The maintenance and repair costs are 1% of the construction costs of buildings and structures, equipment and installations, HVAC and electricity and infrastructure per year. Costs are calculated for 2 years operation period.

The insurance cost includes the insurance for the building. In this chapter the building means buildings, structures, equipment, installations, HVAC and electricity. The insurance covers fires, water damages, electrical damages etc. The insurance cost is 0,2% of the investment costs per year. Costs are calculated for 2 years operation period.

Table 3-5. Operating costs (EUR) per year and for 2 years period.

Operating	EUR / year	EUR Total
Personnel	2 000 000	4 000 000
Energy	200 000	400 000
Water and water treatment	30 000	60 000
Maintenance and reparation	531 000	1 063 000
Insurance	88 000	176 000
Sub-total	**2 850 000**	**5 700 000**
Contingency for uncertainties, 30%	855 000	1 710 000
Total	**3 705 000**	**7 410 000**

3.1.2.4 Closure

Closure costs include costs for the closure phase and are presented in Table 3-6.

Table 3-6. Closure costs (EUR).

Closure	EUR
Dismantling of the structures	12 320 000
Owner costs	1 848 000
Sub-total	**14 168 000**
Contingency for uncertainties, 30%	4 250 000
Total	**18 418 000**

Dismantling costs include removal and transfer of the structures that have been constructed and installed above ground of the Deep Geological Repository. Generally, all the structures will be removed after operation period. Costs for dismantling of the structures are estimated to be 30% of the construction costs of buildings, structures and infrastructure and 5% of the investment costs for equipment, installations, HVAC and electricity.

Owner's costs, 15%, consist of developing costs, design costs, project costs and license costs. Owner costs are calculated for dismantling of the structures.

3.1.2.5 Facilities above ground total costs

Total costs to construct, operate and close above ground parts of the National Facility is presented in Table 3-7. Operational period is assumed to take 2 years.

Table 3-7. Total costs of the above ground facilities (EUR).

Total costs	EUR
Site investigations	1 000 000
Investment / construction	79 448 000
Operating	7 410 000
Closure	18 418 000
Total	**106 276 000**

3.1.3 Underground parts of the Deep geological repository

3.1.3.1 Site investigations, planning

After the site is selected for the Deep Geological Repository, more detailed site investigations are still needed on the site for deep geological repository to locate the repository exactly on the site and to decide exactly the depth of the repository. These detailed site investigations include drilling, borehole investigations, hydrogeological investigations, rock mechanics and other investigations. A rough estimate of the site investigation costs is presented in Table 3-8.

Table 3-8. Site investigation costs (EUR).

Site Investigations	EUR
Detailed site investigations on the site	5 000 000
Sub-total	**5 000 000**

3.1.3.2 Investments / construction

Investment costs are summarized in Table 3-9.

Table 3-9. Investment costs (EUR).

Investment / construction	EUR
Excavation	44 454 000
Construction	17 684 000
Deposition holes	991 000
Systems	17 000 000
Equipment	5 000 000
Investigations during construction	6 000 000
Owner costs	13 669 000
Sub-total	**104 798 000**
Contingency for uncertainties, 30%	31 439 000
Total	**136 237 000**

Excavation costs include all underground excavations, but not drilling of the deposition holes. This cost item also includes rock support and grouting of the tunnels and shafts.

Construction costs include all construction in underground excavations. This covers for example floors, wall and doors that will be constructed in the deep geological repository.

Deposition holes include grouting and boring of the deposition holes.

Costs for systems are rough estimates. HVAC systems are assumed to include for example heating system, plumbing system, drainage system, ventilation system, building automation. Electrical systems are assumed to include for example power supply, lighting, telecommunication, telephone, loudspeaker, antenna, mobile phone, fire detection, camera control, access control and alarm systems.

Equipment includes the canister transfer and installation vehicle and all other equipment that is assumed to be needed. Operational period of the deep geological repository is very brief, about 2 years. Some equipment can also be rented. Development costs for the equipment are not included in the estimations.

Costs for the investigations during construction are estimated assuming 6 years period for excavation and construction works.

In this report owner costs are assumed to be 15% of the other investment costs. Typically, owner costs include design and survey costs, developing and license costs, construction supervision costs, the usage costs of the construction site and initiation fees to systems as electric network, IT network, water distribution, sewage system and district heat distribution.

3.1.3.3 Operation

2-year operational period is assumed for the operating costs that are time depended. Operating costs are presented in Table 3-10.

Table 3-10. Operating costs (EUR).

Operating	EUR / year	EUR Total
Personnel	2 000 000	4 000 000
Canisters		10 100 000
Bentonite blocks		1 000 000
Backfilling and plugs		2 413 000
Energy	200 000	400 000
Water and water treatment	100 000	200 000
Maintenance and reparation	397 000	794 000
Insurance	170 000	340 000
Owner costs		512 000
Sub-total	**2 867 000**	**19 759 000**
Contingency for uncertainties, 30%	806 000	5 928 000
Total	**3 493 000**	**25 687 000**

20 persons are assumed to work underground during the operation period for the Deep Geological Repository alternative.

Costs per canister is assumed to be 300 000 EUR for the smaller canister and 400 000 EUR for the larger canister.

Bentonite blocks include the costs for the bentonite in the deposition holes. The cost for the bentonite is assumed to be 350 EUR/t.

Backfilling and plugging costs in the operation phase includes the backfilling and closure of the deposition tunnels. Backfilling costs for the other parts of the deep repository are included in the closure costs. Unit costs for the backfilling are assumed to be 300 EUR/m3 and for the plug 1000 EUR/m3.

Rough estimate for the energy costs of the deep geological repository is 200 000 EUR/year.

Rough estimate for the water and water treatment costs of the deep geological repository is 100 000 EUR/year.

The maintenance and reparation costs are 1% of the construction costs, of the equipment and of the systems per year. Costs are calculated for two years operation period.

The insurance cost includes the insurance for the building. In this case the building means the deep geological repository. The insurance covers fires, water damages, electrical damages etc. The insurance cost is 0,2% of the investment costs per year. Costs are calculated for two years operation period.

3.1.3.4 Closure

Closure costs include costs for the closure phase and are presented in Table 3-11.

Table 3-11. Closure costs (EUR).

Closure	EUR
Dismantling of the structures	6 155 000
Backfilling	23 028 000
Plugs	225 000
Owner costs	4 411 000
Sub-total	33 819 000
Contingency for uncertainties, 30%	10 146 000
Total	**43 965 000**

Dismantling costs include removal and transfer of the structures that have been constructed and installed in the deep geological repository. Generally, all the structures will be removed before closure of the tunnels. Costs for dismantling of the structures before backfilling are estimated to be 30% of the construction costs and 5% of the investment costs for systems.

Backfilling costs in the closure phase includes the backfilling of the tunnels and shafts that are below the intermediate depth repository. Unit costs for the backfilling in the lower parts of the deep geological repository are assumed to be 130 EUR/m3 and in the upper parts of the repository 65 EUR/m3.

The upper parts of the shafts and the access tunnel are assumed to be plugged with a concrete structure, with a unit cost of 1000 EUR/m3.

Owner's costs, 15%, consist of developing costs, design costs, project costs and license costs. Owner costs are calculated for dismantling of the structures, backfilling and plugs.

3.1.3.5 Total costs

Total costs to construct, operate and close underground parts of the Deep Geological Repository are presented in Table 3-12. The operational period is assumed to be two years. Post-closure costs are not included.

Table 3-12. Total costs of the deep geological repository (EUR).

Total costs	EUR
Site investigations	5 000 000
Investment / construction	136 237 000
Operating	25 687 000
Closure	43 965 000
Total	**210 889 000**

3.1.4 Deep Geological Repository alternative total costs

Altogether total costs to construct, operate and close both above ground and underground parts of the Deep Geological Repository are presented in Table 3-13.

Table 3-13. Total costs of the deep geological repository (EUR).

Total costs		EUR	EUR	EUR
	Site Selection	Above ground	Underground	Total
Site selection	33 800 000			33 800 000
Site investigations		1 000 000	5 000 000	6 000 000
Investment / construction		79 448 000	136 237 000	215 685 000
Operating		7 410 000	25 687 000	33 097 000
Closure		18 418 000	43 965 000	62 383 000
Total	**33 800 000**	**106 276 000**	**210 889 000**	**350 965 000**

3.2 Stand-alone Deep Borehole Disposal Facility

The site operation, cost and schedule were presented in detailed WP3 report (Saanio et al. 2020). In this work only the main differences from WP3 are introduced and explained. The phases of the disposal facility are the same as presented in WP3. The disposal concept is assumed to be the same as presented in WP2 (Ikonen et al. 2020). The depth of the borehole is 3500 meters, of which the lowest 500 meters are used for disposal of the waste packages. Seal and backfill zones are above the disposal section. For the costing, it is assumed that there are 69 BSK canisters to be disposed of.

3.2.1 Site selection and licensing

Site selection and safety cases are assumed to be the same as presented in WP3. The cost items are repeated here for completeness in the following tables.

Site selection	Costs / site	Number of sites	EUR Total
Preliminary site investigations	6 000 000	1	6 000 000
Detailed site investigations	15 800 000	1	15 800 000
Total			**21 800 000**

Safety cases	EUR
Safety case to support site selection	2 000 000
Detailed safety case to support the construction license	5 000 000
Detailed safety case to support the operation license	5 000 000
Total	**12 000 000**

3.2.2 Site investigations and planning

Site characterisation supports the construction of the surface facilities and will confirm the location and trajectory of the borehole. The cost is considered single lump sum and presented in Table 3-14.

Table 3-14. Site investigations and planning costs for the deep borehole repository (EUR).

Site investigations, planning	EUR	Contingency for uncertainty and risks
Lump sum for site characterization activities and analysis	2 000 000	30%
Total	**2 600 000**	

3.2.3 Construction / drilling

The largest single cost item is the drilling of the borehole. This cost includes casing, cementing, energy and so forth. Construction costs are summarised in Table 3-15.

Table 3-15. Investments / construction costs for the deep borehole repository (EUR).

Investment / Construction	EUR	Contingency for uncertainty and risks
Site preparation (including infrastructure)	800 000	30%
Surface facilities, including Disposal Building*	11 850 000	30%
Borehole (including drilling, completing, coring, measurements)	63 000 000	30%
Setup of a groundwater monitoring system in the area	1 500 000	30%
Owner's cost (Management, admin, engineering, design)	2 314 500	[1]
Sub-total	79 464 500	23 145 000
TOTAL	**102 609 500**	

* see the main text regarding the cost of surface facilities

Site preparation and construction of surface facilities include asphalt roads, parking, administrative, security and support buildings (as listed in Figure 2-2), and fencing. This is followed by preparation for drilling operations: drilling rig and equipment.

It is noted and emphasised that the surface buildings are assumed to be at same quality and lifetime as in WP3 work, which assumed decades of operations. In reality as the borehole disposal site operates only a year or so, the surface buildings could be of temporary type, such as office containers and similar. Most buildings could also be leased for the short duration of the project. In this case the cost of the surface facilities can be assumed significantly lower. It can be estimated that the cost range of the surface facilities is 1 million euro (leased temporary facilities) to 10 million euro (properly built long-term structures). In addition as explained in Section 2.2, Research (10) and Waste (8) Buildings are not necessarily needed. The estimated construction cost of these two units is about 7 million euro together.

Drilling costs is a rough estimate of 75 000 EUR per day. All usual drill site equipment is included in this day rate. During the drilling process, the borehole is characterized. Not only to gather information for the operation period, but also to confirm the stability of the hole for safety analyses.

During the drilling operation, the groundwater monitoring system plays a role. This has been taken into account in the costing. These systems secure that potential drilling fluid losses into the groundwater will be detected immediately and counteractions to this can be taken to avoid short and especially long-term environmental damage.

3.2.4 Operations

Facility operation consists mainly in emplacing the waste and running of the site. A breakdown of the operating costs is shown in Table 3-16.

[1] There is no direct calculation of contingency for Owner cost. Owner cost is recalculated from the (sub-)total cost similarly as without contingency, i.e. percentage of the (sub-)total cost.

Table 3-16. Operating costs for the deep borehole repository (EUR).

Operations	EUR	Contingency for uncertainty and risks
Canisters	1 725 000	30%
Disposal operation (running the drill rig, power, fluids, rig rent, etc.)	1 500 000	30%
Construction work during disposal (backfilling of the buffer zone between the canisters)	750 000	30%
Personnel cost (30 people, running disposal operations, support, security, admin, etc., 12 months)	3 000 000	- Not accounted for personnel
Owner's cost (3%)	119 250	
Sub-total	7 094 250	1 192 500
TOTAL	**8 286 750**	

3.2.5 Closure

The final item on the list is the closure of the borehole and decommissioning of the site. The closure costs are presented in Table 3-17.

Table 3-17. Closure costs for the deep borehole repository (EUR).

Closure	EUR	Contingency for uncertainty and risks
Dismantling of structures (30% of construction costs)	3 555 000	30%
Estimated borehole closure (casing removal, sealing and backfilling costs, including material, rig costs and crew)	9 000 000	30%
Greenfielding of the site	150 000	30%
Owner costs (3%)	381 150	
Sub-total	13 086 150	3 811 500
TOTAL	**16 897 650**	

3.2.6 Summary of cost

The following table summarises the costs for the stand-alone Deep Borehole Disposal Facility.

Table 3-18. Summary of costs (EUR).

Summary of cost (including contingencies)	EUR	In case surface facilities are temporary structures due to short operation time
Site selection and licensing	33 800 000	-
Site investigation and planning	2 600 000	-
Construction / borehole drilling	102 609 500	~ 94 100 000
Operations, disposal	8 286 750	-
Closure	16 897 650	~12 000 000
TOTAL	**164 193 900**	**~ 151 000 000**

The above cost estimate assumed the disposal concept described in WP2 and WP3, which had a conservative borehole depth of 3500 meters. Based on the more recent work for COO3, the geology in Norway might allow shorter borehole for the disposal purpose. Quick calculations were made to see what the cost effect is if the borehole was 2500 meters depth. The main cost drivers for the borehole are the construction (drilling operations), disposal operations, and backfilling material. For the shorter borehole the construction time is shorter, which brings down the cost about 10 million euro (shorter rig rent time). Similarly the operation time is slightly shorter but the cost effect is minimal. For the closure there is less material needed for the backfilling and sealing. This brings down the cost about 2 million euro. In total it is estimated that the 2500 meter borehole is about 10…12 million euro cheaper than 3500 meter borehole. This quick analysis did not look into other aspects in the site construction and operation with regards to the shorter borehole. The analysis also ignored the fact that with a shorter borehole the diameter of the upper borehole can be smaller. This again would impact the drilling operation and is most likely to reduce the total drilling time.

4 Comparison of costs

The below table provides simple comparison of the costs between DGR and Borehole Facility. The table also identifies concisely the main cost difference drivers.

Table 4-1. Cost comparison, costs in million euro.

Phase	DGR	Borehole	Difference	Note
Siting and licensing	33,8	33,8	0	Assumption was the same process and investigations
Site investigation	6	2,6		Not significant differences
Investment	216	95...103		• Borehole cost has high contingency. • DGR construction cost is almost directly related to excavated volume. Both volume and related cost are fairly well defined • The cost range related to surface facilities is similar in both cases due to expected short operation time
Operations	33	8		Simple operations and shorter operational time contributes to the lower cost of the borehole disposal.
Closure	62	12…17		The main cost driver is the rock volume that needs to be sealed and backfilled. It is obvious that the volume of DGR caverns and tunnels is in completely different level than a single borehole.
	351	**152...164**		

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