NUMO
原子力発電環境整備機構

Repository Concepts

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Nuclear Waste Management Organization of Japan

Nuclear Waste Management Organization of Japan (NUMO)

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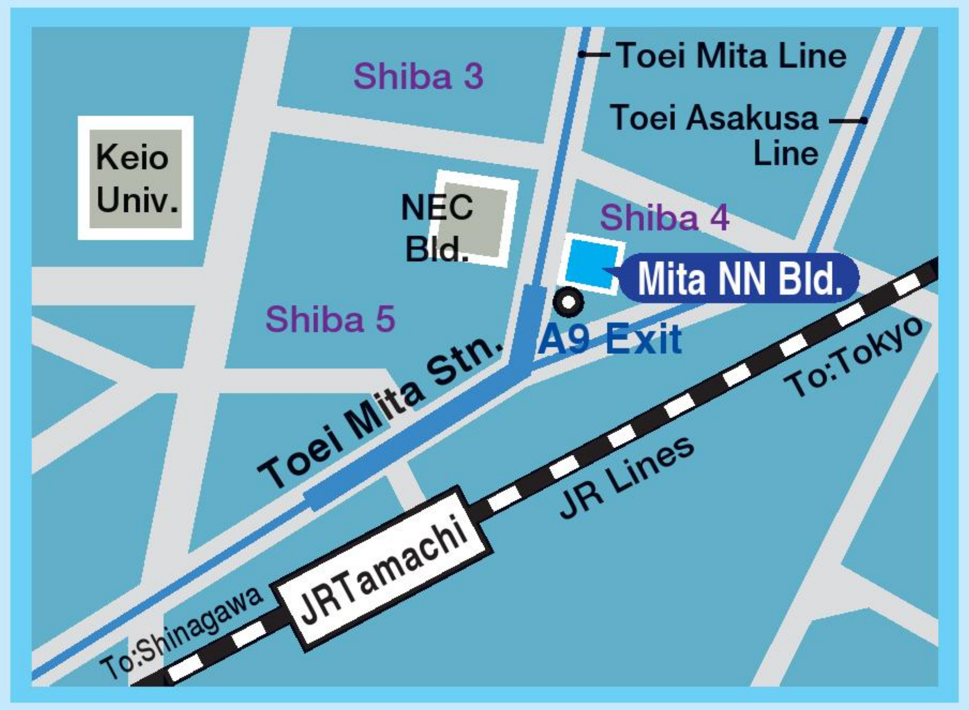

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JR (Tamachi Station): 5-minute walk

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Introduction

What is this "Repository Concepts" Document?

Based on the "Specified Radioactive Waste Final Disposal Act", NUMO will solicit volunteers for areas to explore the feasibility of constructing a final repository for high-level radioactive waste using four documents published together as an information package.

The information package aims to support discussions with stakeholders, especially residents of interested municipalities, leading to a decision on whether an investigation program can be accepted or not. The four documents are entitled "Instructions for Application", "Siting Factors for the Selection of Preliminary Investigation Areas", "Repository Concepts" and "Outreach Scheme".

This "Repository Concepts" (RC) document is aimed at providing information on what the planned repository is and how it will be developed for siting environments at candidate sites. The document includes examples of repository components, repository construction, operation and closure and illustrates the safety of the disposal system.

Direct inquiries about this document or the open solicitation procedure to

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What is High-Level Radioactive Waste (Vitrified HLW)?

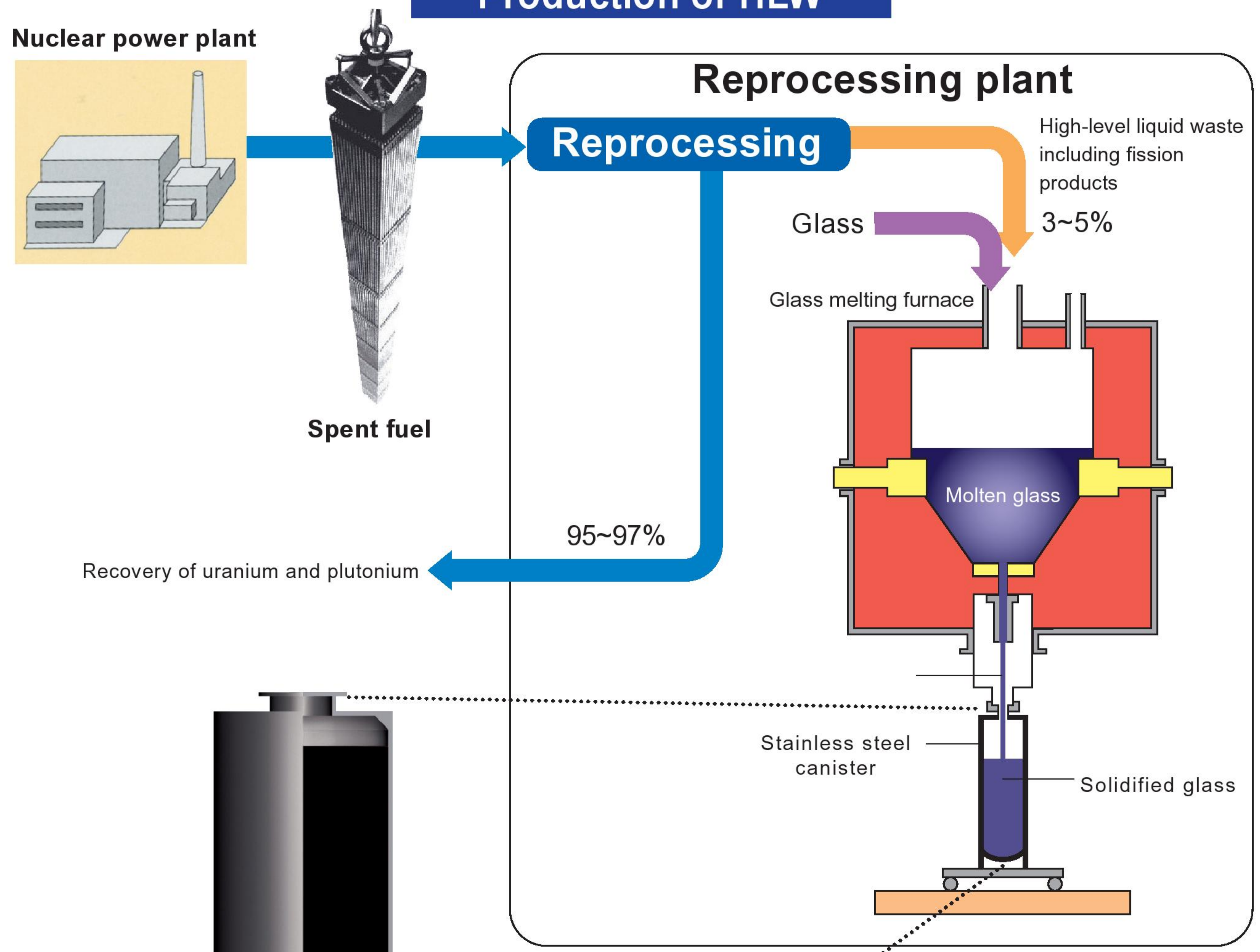
Vitrified HLW is produced from liquid waste arising from the reprocessing of spent fuel.

Its radioactivity decreases with time.

A by-product of reprocessing of the spent fuel from nuclear power plants is liquid waste with a high level of radioactivity. This waste is solidified in a stable glass matrix (vitrification) in stainless steel fabrication containers. The vitrified waste from reprocessing is referred to as high-level radioactive waste (HLW).
One vitrified HLW canister is produced from one metric ton of spent fuel. Vitrified HLW will be completely isolated from the human environment in storage facilities after its generation because of its high radioactivity and heat generation. Radioactivity decreases spontaneously with time and the activity of vitrified HLW will be approximately 0.03% of the activity on initial production after a period of 1,000 years, and about 0.003% of the initial activity after 100,000 years.

In a stable form and easy to handle...

Production of HLW



Vitrified HLW
- Height : ~1.3 m
- Diameter : 40 cm
- Weight : ~500 kg
- Volume : ~150L

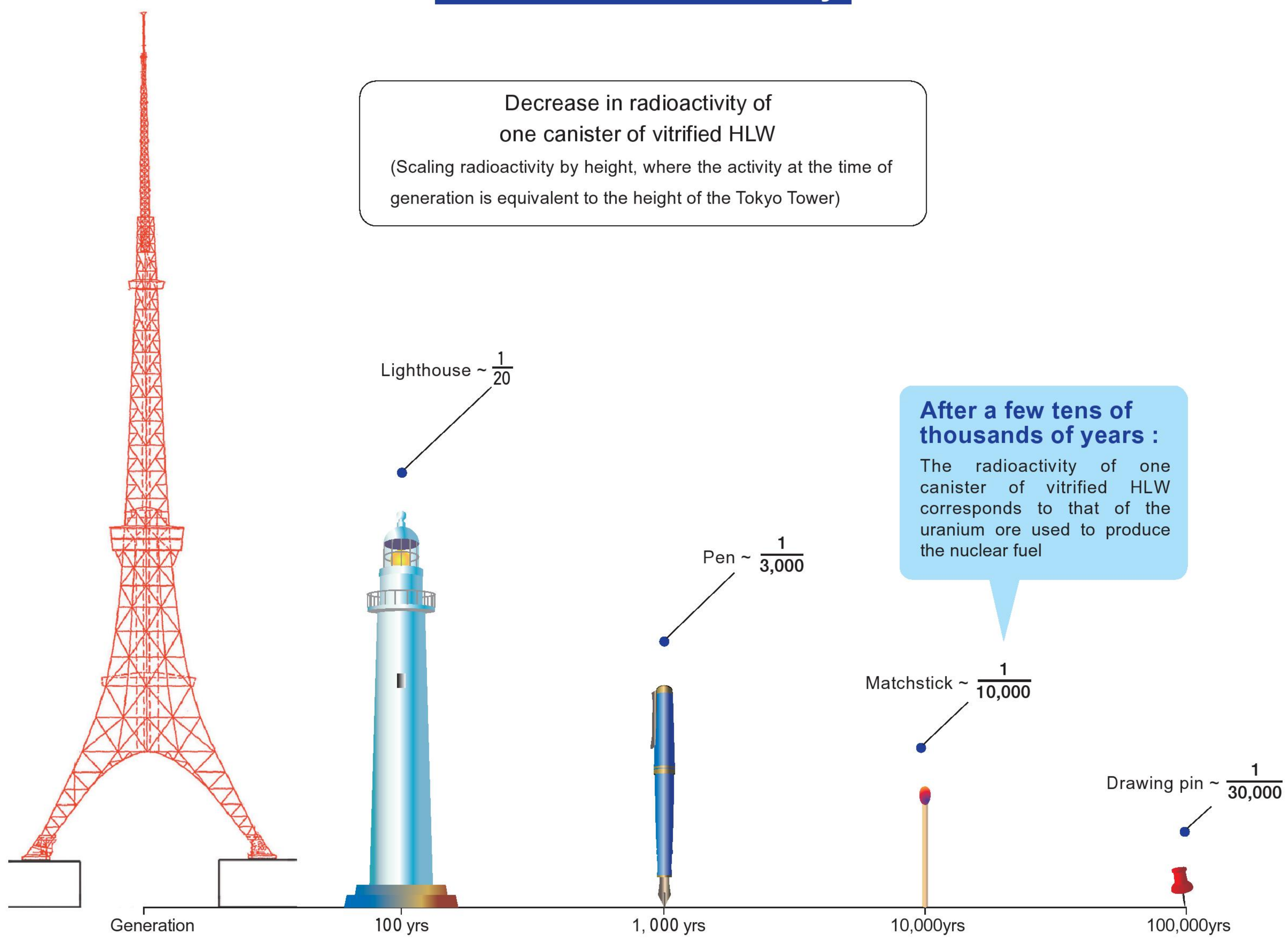
How much volume ?

The annual electricity consumption of around 100,000 households, if generated by nuclear power, will lead to production of one canister of vitrified HLW.

Assuming that the total electricity consumption of one Japanese person during his/her lifetime (80 years) comes from nuclear power, the resulting amount of vitrified waste has a volume equivalent to three golf balls.

From "333m of Tokyo Tower" to "1cm of drawing pin".

Decrease in radioactivity



Need for long-term management

It is therefore necessary to effectively isolate HLW from the human environment for several tens of thousands of years.

How is HLW Managed for Long Periods of Time?

Geological disposal is adopted. Siting proceeds in a stepwise manner before construction of the repository.

It is necessary to isolate vitrified HLW from the human environment for several tens of thousands years due to its radioactivity, even though this decreases with time.
Isolation by means of disposal deep underground is termed "geological disposal" and is the most appropriate option for HLW as it offers safety for a long period of time without requiring active control of the repository over this period.
The geological disposal of vitrified HLW will be carried out within a regulatory framework in accordance with the national disposal program.

Why geological disposal?

Ensures safety for long periods of time without requiring any institutional control

The deep underground has inherently favorable features for HLW disposal. Geological disposal is considered an effective way to isolate HLW from the human environment using current technologies and without requiring any long-term active control. This is internationally accepted and forms the backbone of HLW management programs in most countries*.

Characteristics of the deep underground

① **Less impact from surface changes**
Such as natural phenomena and human actions

② **Limited alteration of materials**
Due to stable chemical conditions

③ **Limited movement of radioactivity**
Due to restricted water flow

*:more information on HLW management programs in other countries is available through the NUMO website at http://www.numo.or.jp/kaigaijoho/index.html.

From initiation of siting to closure of the repository

Confirmation of safety within the legal framework

Ensuring safety

Ensuring safety in all phases of HLW disposal is the top priority of NUMO. Positive efforts will be made to communicate with volunteer communities and the public about NUMO's commitment to safety throughout the implementation of the disposal program in order to build confidence in NUMO's activities.

Ensuring openness

It is a priority of NUMO to ensure openness of decision-making throughout its implementation program. This will be based on public communication and disclosure of information.
The Final Disposal Act states that a disposal site should be selected in a stepwise manner with more detailed investigation of fewer candidate sites with each successive step.

At each stage, NUMO will clarify its own selection criteria, publish investigation results for each site and hold public meetings for comment. Taking account of the results and all comments, NUMO will select the sites for investigation in the next step with approval from METI.

Safety regulations

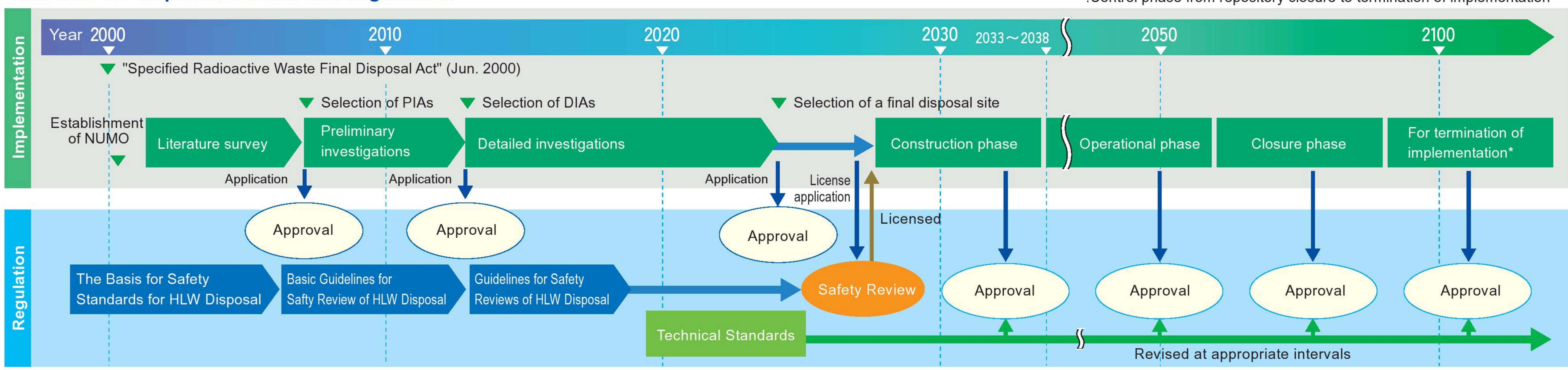
Government discussions of safety regulations for HLW will establish appropriate guidelines and standards for safe geological disposal. NUMO will need to demonstrate that their proposals meet these standards by submitting a safety review as part of the license application for a repository. Following licensing, the stages of repository construction, operation and closure will each also require approval from METI, based on compliance with safety standards.

Basic plan for HLW disposal

- Interim storage of HLW for 30 to 50 years to allow cooling prior to disposal based on the Basic Policy for Specified Radioactive Waste
- Disposal of HLW more than 300m underground, based on the Specified Radioactive Waste Final Disposal Act
- Start of repository operation around 2033~2038, based on the Final Disposal Plan for Specified Radioactive Waste

Schedule for implementation and regulation

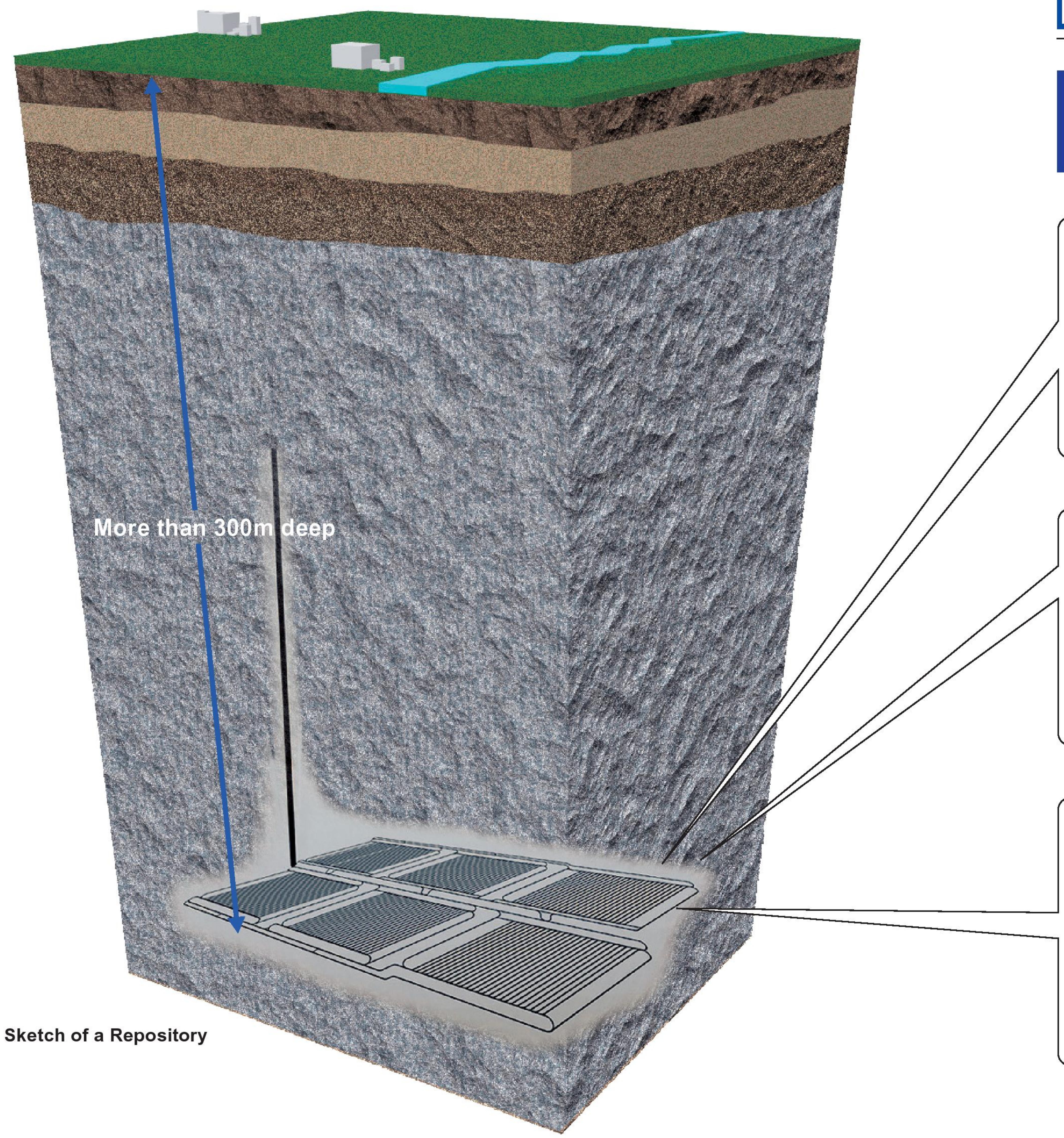
*:Control phase from repository closure to termination of implementation



What Does a Geological Disposal System Look Like?

Selection of an area with a stable geological situation for siting of the repository. The multi-barrier disposal system for a HLW repository consists of natural (rock) and engineered barriers.

In Japan, there exist geological situations ("environments") stable enough to isolate a HLW repository from the human environment for a very long time.
After selection of an area with a suitable stable geological environment, vitrified HLW will be disposed of more than 300 meters below the ground surface.
The multi-barrier concept consists of the natural barrier (the stable geological environment) and engineered barriers (other structures designed to contain the HLW) which act together to effectively isolate vitrified HLW from the human environment for very long times.



Sketch of a Repository

Host rock located deep underground

Long-term stability of the underground

Less impact from natural phenomena such as earthquakes

The underground is less affected than the surface by human activities (such as terrorism) and natural phenomena (such as typhoons and earthquakes).

Slow change in ancient rocks

It is common to find deep rock formations that have not changed perceptibly since they were formed, many millions of years ago.

Preservation

The extremely slow changes in deep rocks mean that crystals and sediment structures and fossilized animals and plants are often preserved from the time that the rocks were formed.

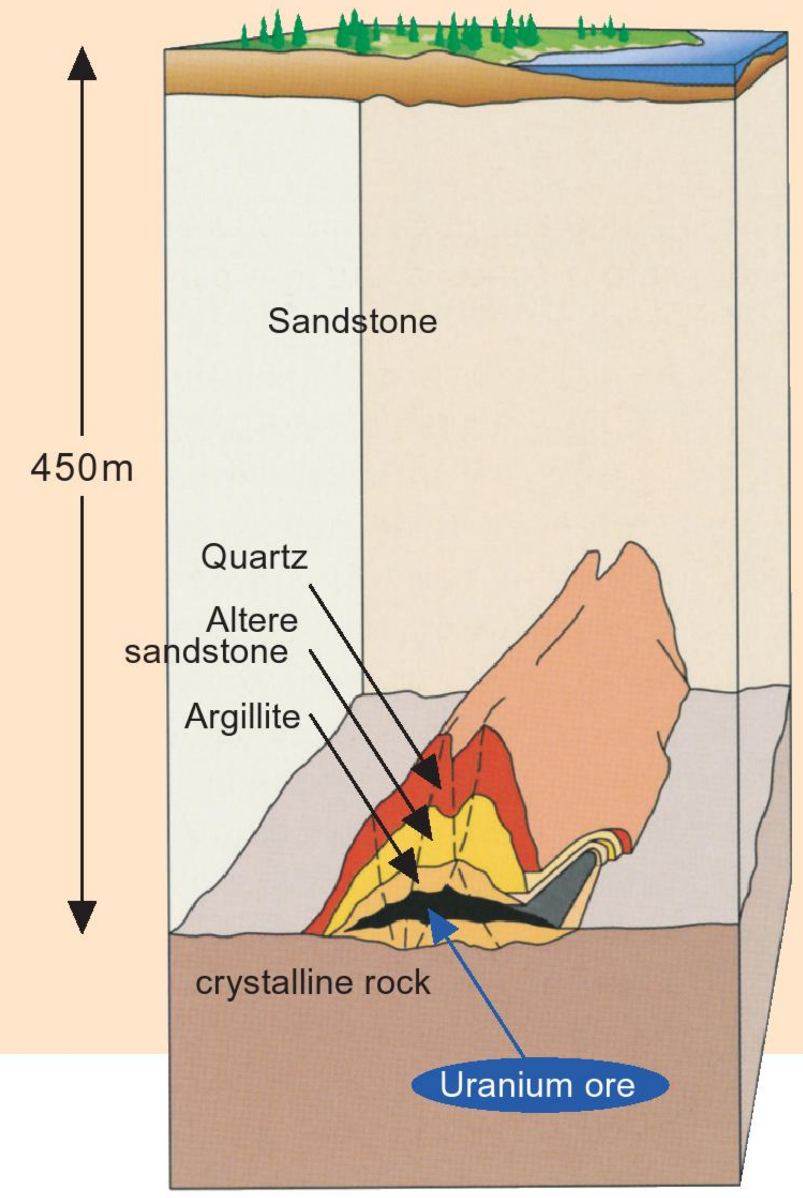
Stable deep underground is a reliable natural barrier

The preservation of old geological anomalies, such as ore deposits and salt deposits, indicate that the natural barrier can function effectively for long periods of time.

Example of a natural analogue

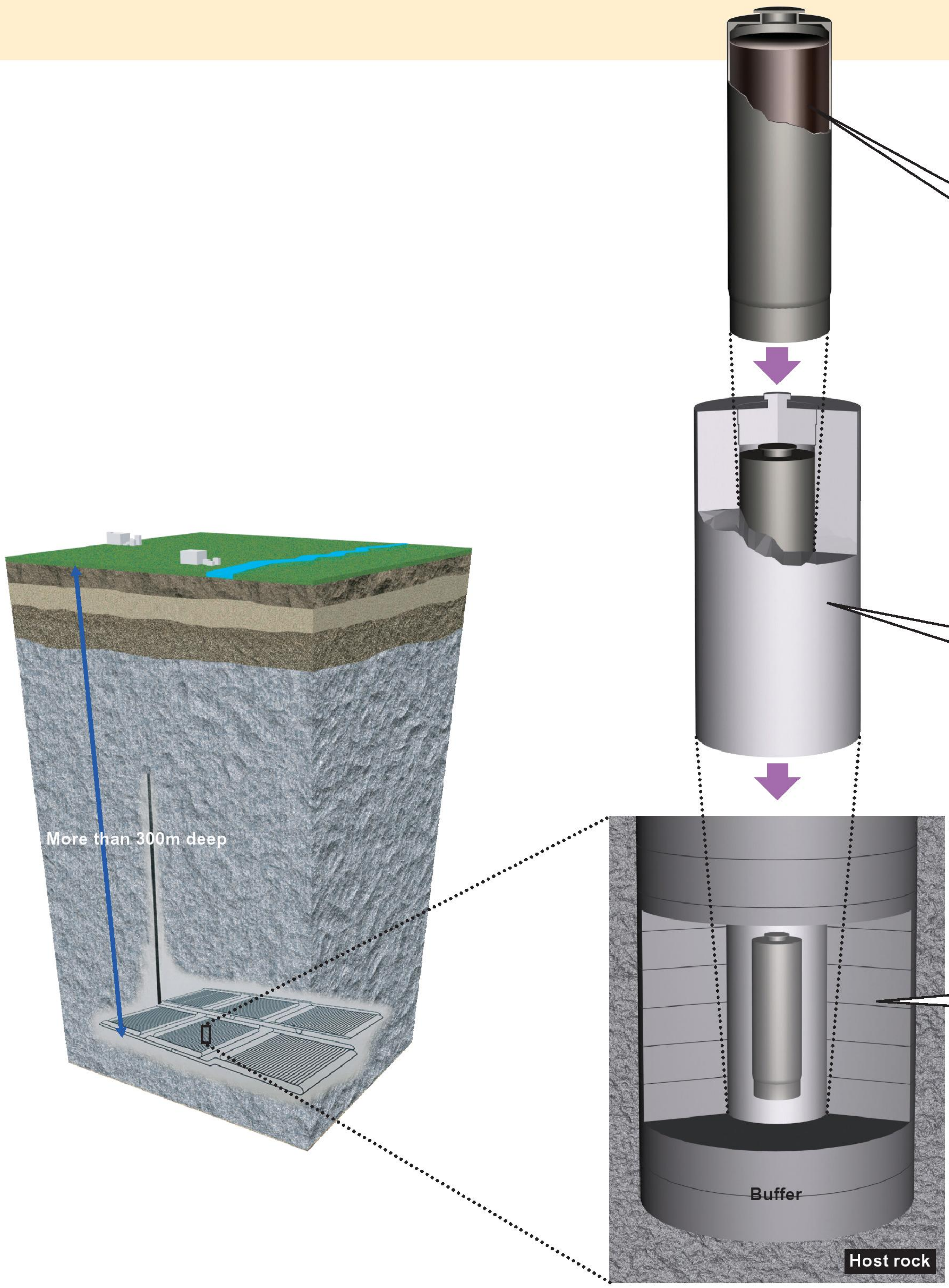
The uranium ore of Cigar Lake, Canada, has been isolated for over 1,300 million years since its formation. This means that appropriate deep underground conditions lead to isolation of materials for a long period of time.

Uranium ore in Cigar Lake



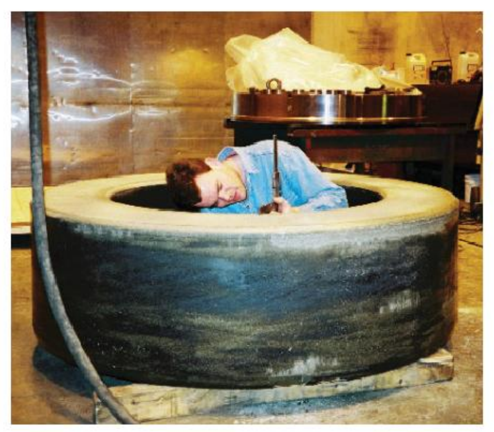
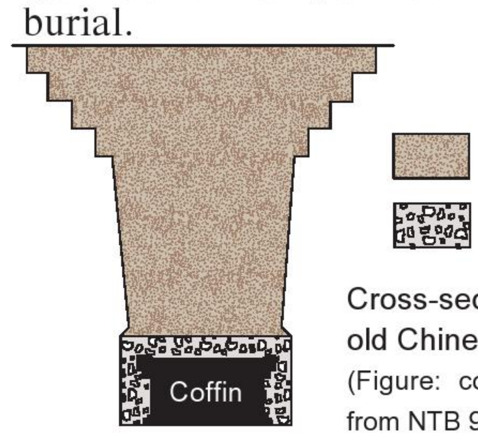
Courtesy of Nagra: modified figure from Nagra Bulletin No.30 (1997).

The engineered barriers consist of the glass matrix which contains the radioactive waste, the overpack and the buffer. Even if radioactive materials are dissolved from the glass into water, the engineered barrier system is designed to limit their movement.
The materials of the engineered barriers are designed to function passively in the deep underground environment. Studies of similar materials from archeological sites have been used to demonstrate their stability over long periods.



Engineered Barriers

Engineered barriers for containment of radioactive materials over a long time period

Three barriers	Archeological analogue
Vitrified Waste Radioactive material is immobilized in a glass matrix and is only released as the glass is dissolved.	From ancient glass artefacts and volcanic glass, it is known that glass is physico-chemically stable and is very slow to dissolve.  A vase of Egyptian age (BC1550~1300) (photo: Pacific Press Service)
Overpack (steel container) The vitrified HLW is encapsulated in an overpack (steel container) to prevent contact with groundwater during the time when its radioactivity and heat generation are high.  Example of trial manufacturing of a carbon steel overpack (photo: JNC, 2000) Major specifications Material: steel Dimensions: height~1.7m ;diameter~80cm ;thickness~20cm Weight: ~6 metric tons Alternative designs of copper-steel (composite) /titanium-steel (composite) can be considered	Steel and iron corrode only very slowly in the absence of oxygen, as seen with iron nails buried in clay soil 1,900 years ago at Inchtuthil, UK.  Photograph of nails from the central part of the hoard at Inchthuthil
Buffer (compacted clay) The buffer is mainly bentonite clay compacted to high density so as to have low permeability, which slows the movement of dissolved radioactive waste. The buffer is also designed to protect the overpack.  Example of trial manufacturing of bentonite buffer (photo: courtesy of SKB) Major specifications Material: mixture of bentonite (70%) and silica sand (30%) Dimensions: height ~3.1m diameter ~2.2m (outer); ~0.8m (inner) thickness ~0.7m	It is known that layers of clay preserve materials, as seen in a 2,100 year old Chinese tomb in which a well preserved cadaver was found that was not mummified before burial.  Coffin Cross-section of the 2100 year old Chinese tomb (Figure: courtesy of Nagra taken from NTB 93-03 (1994))

What are Siting Environments?

A siting environment is a combination of geography, topography and host rock. A repository is constructed in a siting environment where long-term safety can be ensured.

Not all locations in Japan are suitable for selection as a candidate repository site. The areas where volcanic activity or fault movement are likely to occur must be avoided.
Taking account of these phenomena, NUMO specified "Siting Factors for Selection of PIAs". Detailed Investigation Areas (DIAs) will be selected from the PIAs, and the Final Disposal Site will then be selected from the DIAs.

The disposal site will be selected in 3 stages from PIAs to DIAs to Final Disposal Site

Evaluation factors for qualification

Selection of Preliminary Investigation Areas (PIAs)

In the selection of PIAs, areas with the following unsuitable characteristics will be excluded.

① Earthquakes,Fault Activity
Areas with active faults
Areas in which faults may occur in future, or be reactivated

② Igneous Activity
Areas within 15km of the center of active Quaternary volcanoes (defined as volcanic areas)
Areas where igneous activity is foreseen to occur in the future
Areas considered likely to be significantly affected by thermal effects, strongly acidic hydrothermal water or hydrothermal convection

③ Uplift /erosion
Areas with uplift amounting to more than 300m during the last 100,000 years

④ Quaternary Unconsolidated Deposits
Areas with geological formations in relevant depth ranges consisting of Quaternary unconsolidated deposits

⑤ Mineral Resources
Areas with geological formations bearing economically valuable mineral resources

In addition to the above, the characteristics of the repository host rock and the groundwater, availability of land and transportation of the waste must be considered when evaluating the selected PIAs in a comprehensive manner and making comparisons between multiple candidate areas.

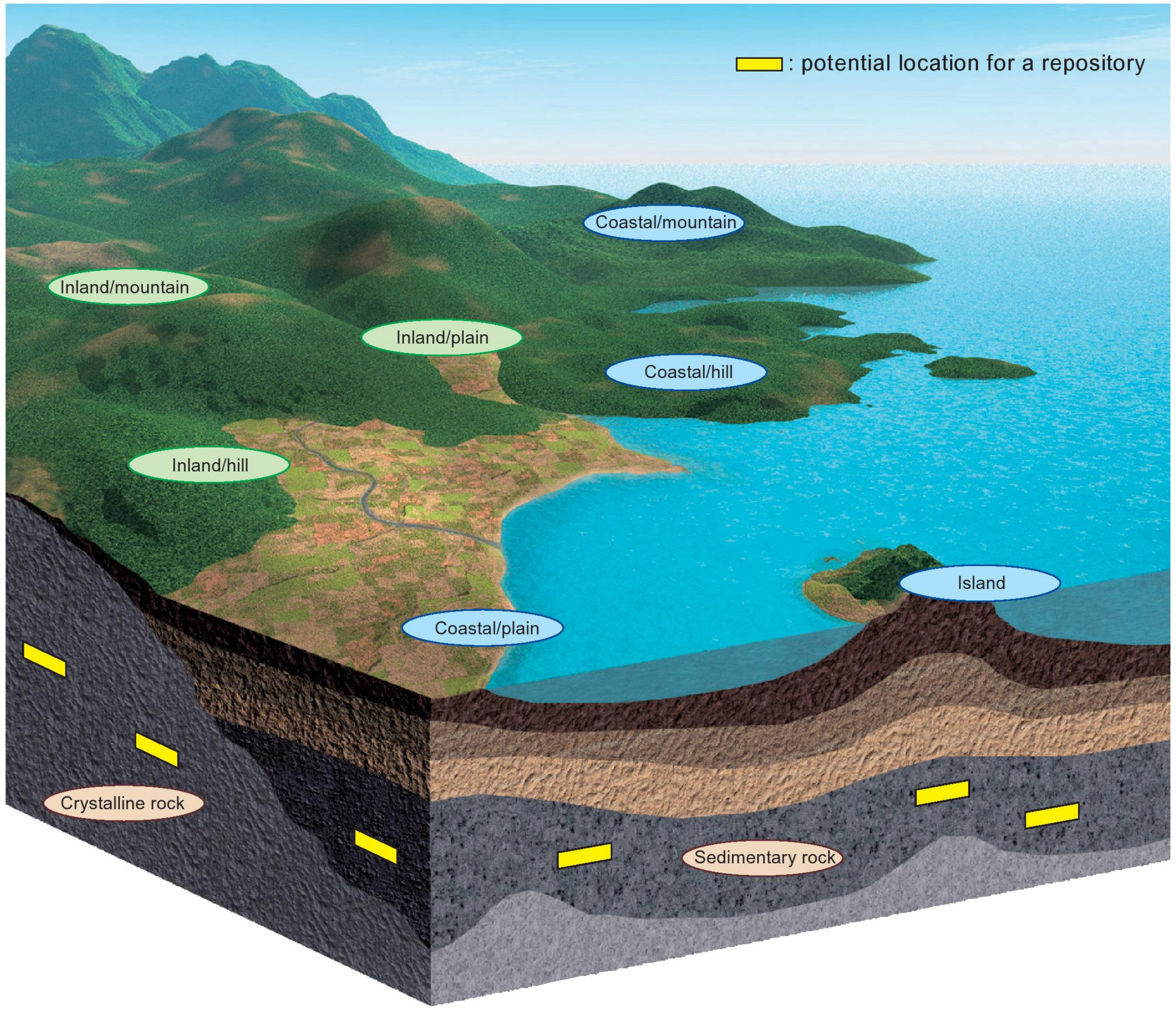
Selection of Detailed Investigation Areas (DIAs) and Final Disposal Site

DIAs will be selected from the PIAs based on the results of preliminary investigations and the Final Disposal Site will then be selected from the DIAs based on the results of detailed investigations. Evaluation factors for qualification of these areas will be set by NUMO at a later stage. The Final Disposal Site will ultimately be a specific area chosen within a siting environment.

Appropriate siting environment for a repository

Varieties of siting environment

A siting environment is a combination of geography (inland, coastal), topography (mountain, hill, plain) and host rock (crystalline rock, sedimentary rock)

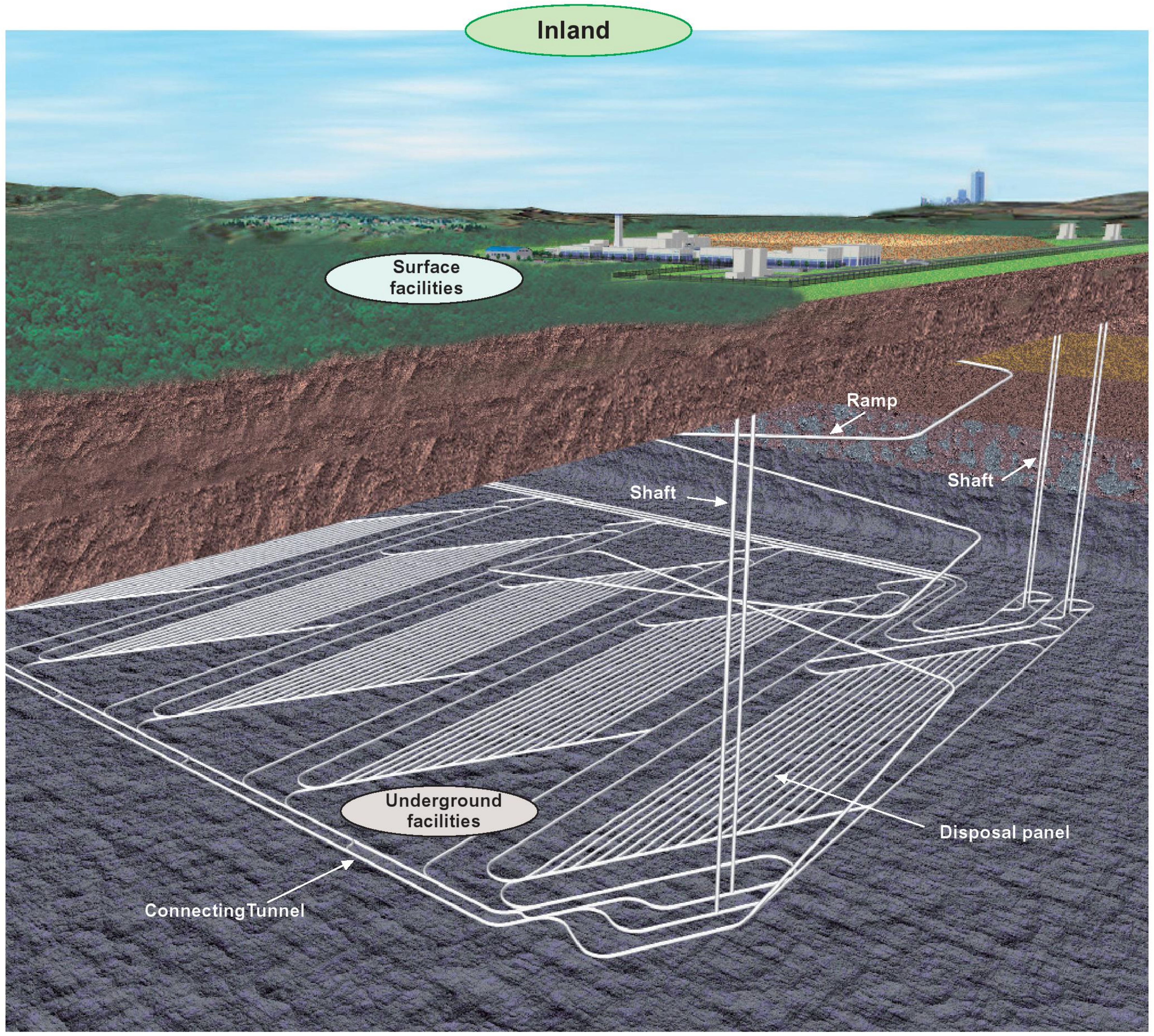


What are Repository Concepts?

A HLW repository concept includes surface facilities, underground facilities and an engineered barrier system (EBS) laid out in a stable host rock.

Surface and underground facilities are designed and constructed taking account of the characteristics of the siting environment. Underground facilities and the engineered barriers are located in a stable host rock more than 300m below ground and have capacity for at least 40,000 canisters of vitrified HLW.

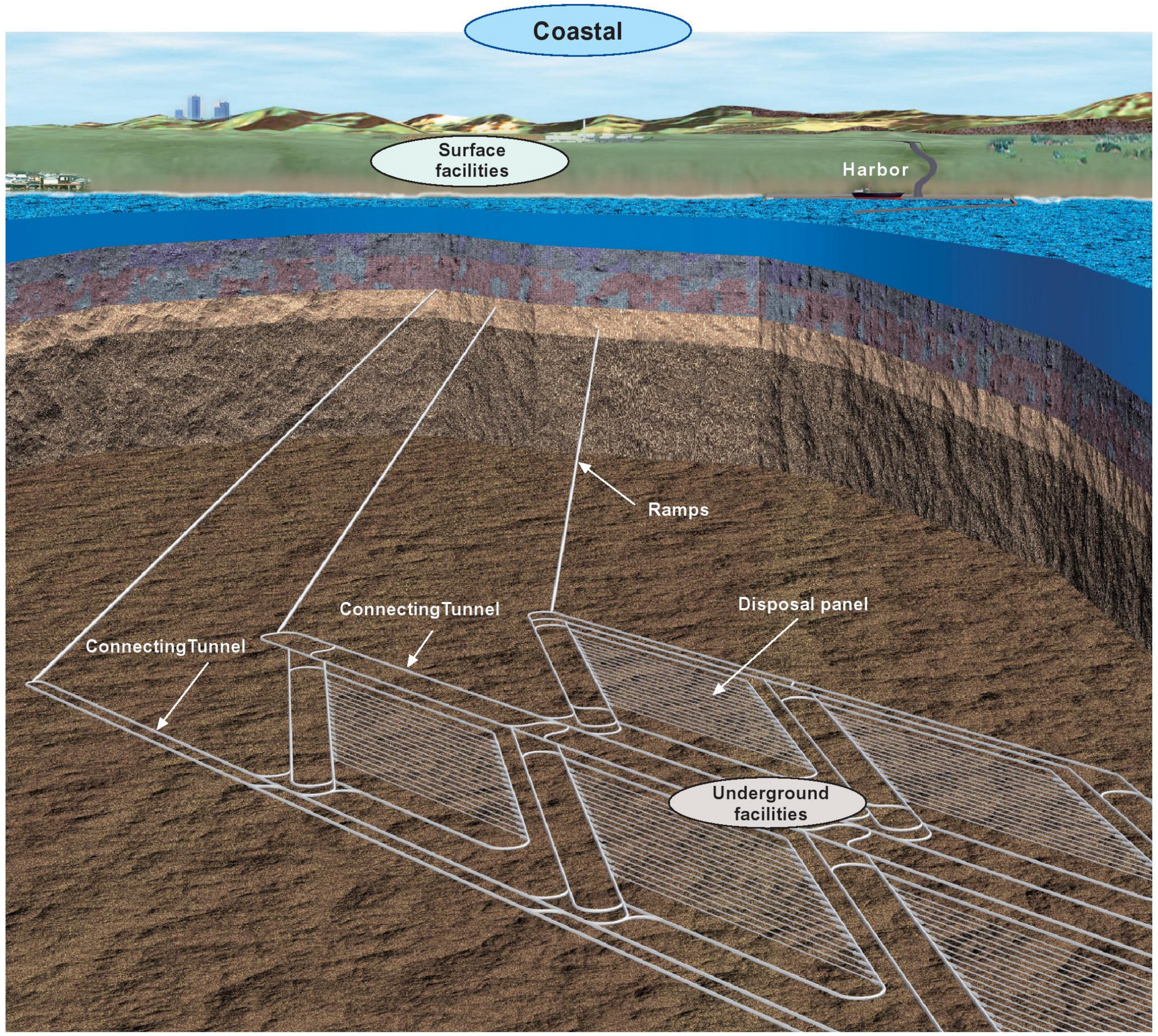
In the case of a coastal site, underground facilities can be constructed under the sea-bed.



Example of major specifications for inland/crystalline rock repository site

Surface facilities
- area: around $1km^2$

Underground facilities
- depth: 1,000m
- emplacement method for vitrified waste: vertical emplacement
- area: around 3km × 2km
- access shafts: 6
- access ramps: 1
- total length of tunnels: around 250km



Example of major specifications for coastal / sedimentary rock repository site

Surface facilities
- area: around $1km^2$

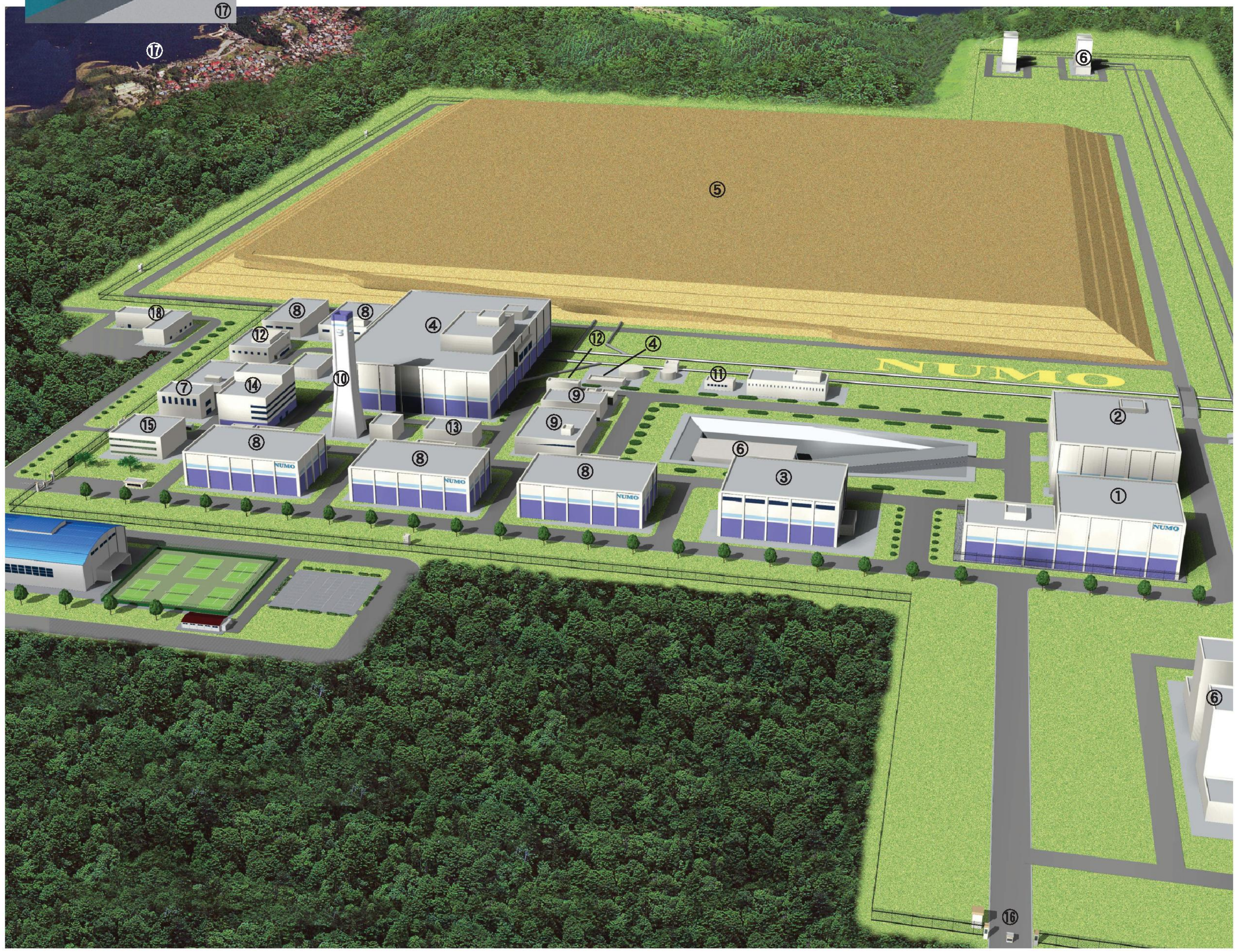
Underground facilities
- depth: 500m
- emplacement method for vitrified waste: horizontal emplacement
- area: around 3.5km × 1.5km
- access shafts: 0
- access ramps: 3
- total length of tunnels: around 200km

What are Surface Facilities?

Surface facilities provide the infrastructure for repository construction, operation and closure.

Surface facilities include: waste reception and encapsulation plant (including welding and inspection of the overpack), facilities for manufacturing and inspecting buffer material and a security control building. The layout of the surface facilities can be modified flexibly in accordance with the features of the site. If necessary, most of the buildings can be underground.

Full view of surface facilities



Main gate

Control room

① Waste reception and encapsulation plant
② Facility for manufacturing and inspecting buffer material
③ Facility for manufacturing plug material
④ Facility for manufacturing and quality assuring backfill material
⑤ Rock spoil storage area
⑥ Facility for controlling ramp access to the underground facilities
⑦ Ventilation
⑧ Drainage water treatment plant
⑨ Conditioning facility for radioactive waste arising during the operational phase
⑩ Stack
⑪ Concrete batch plant
⑫ Utility building
⑬ Maintenance facility
⑭ Offices
⑮ Security control building
⑯ Main gate
⑰ Harbor
⑱ PR facilities

Option

Flexible layout depending on the features of the site

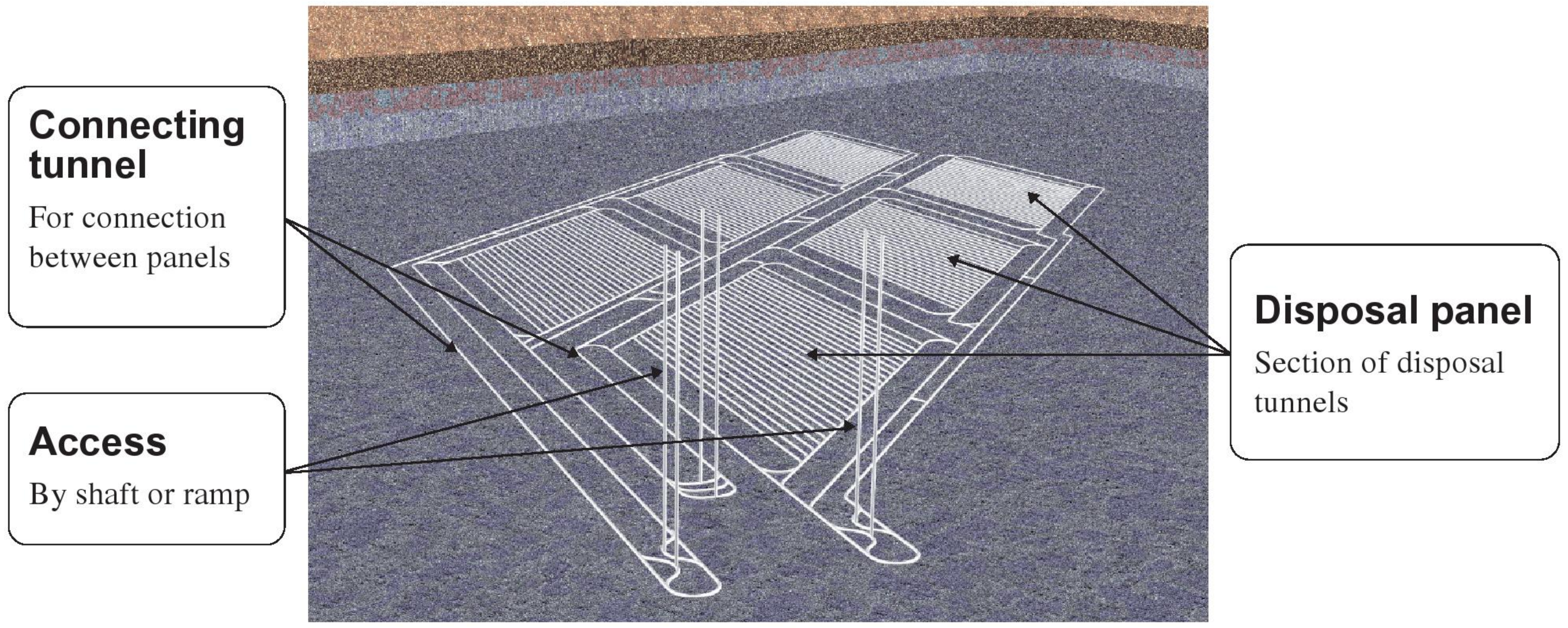
Example layout where most of the buildings are underground (e.g. to reduce risks from terrorism)

What are Underground Facilities?

Construction of shafts, access tunnels and disposal tunnels grouped in panels. Emplacement of the EBS and HLW in each panel as its construction is completed.

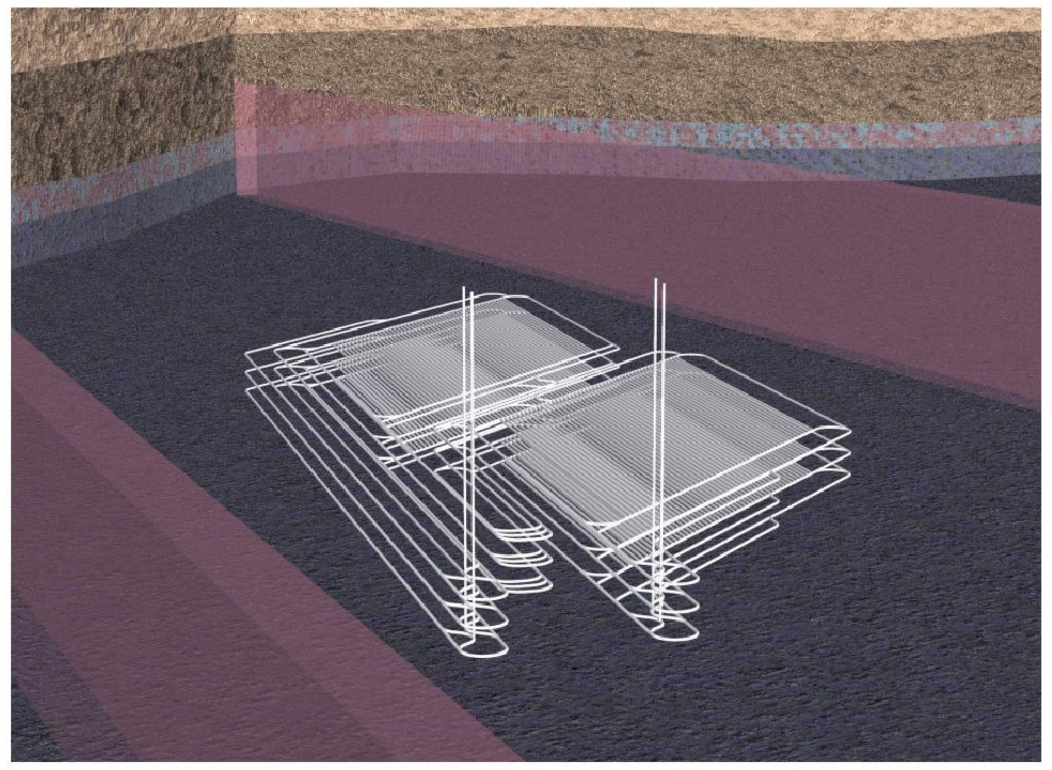
The underground facilities include access ramps or shafts for transportation of waste packages from the surface facilities and disposal pits and tunnels.
The layout of the underground facilities and the emplacement method for waste packages can be designed flexibly to take account of the features of the geological environment.

Basic components of underground facilities



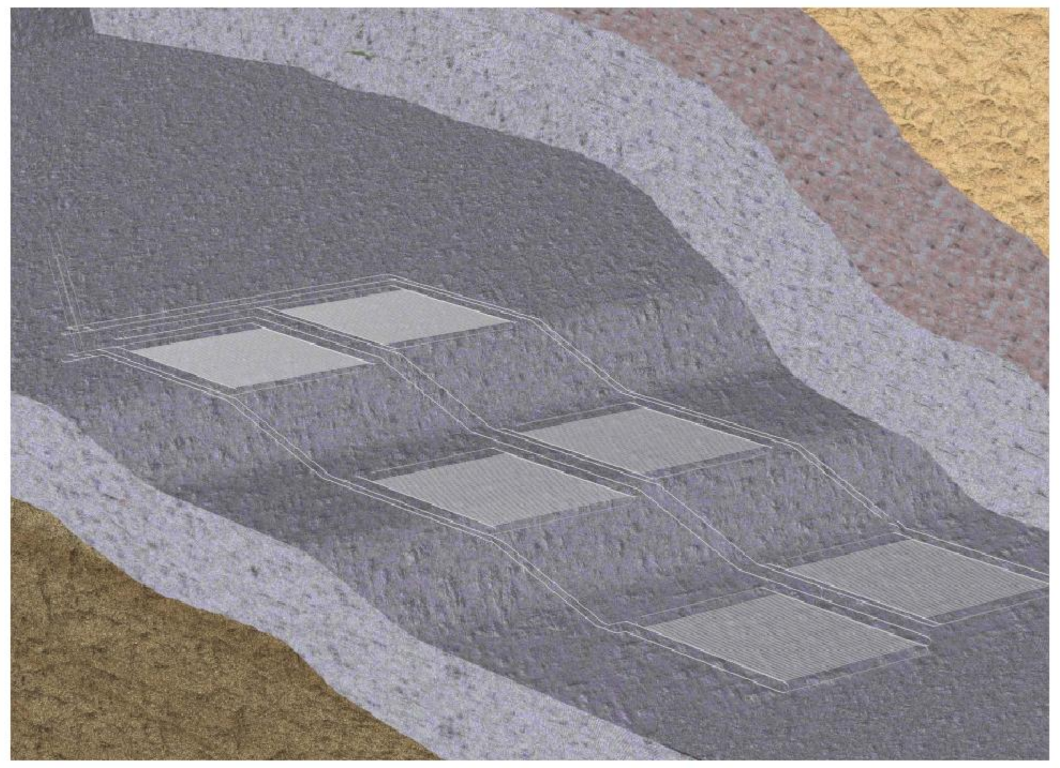
Variation of layout considering features of geological structures

For small areas of host rock (case of horizontal restriction)



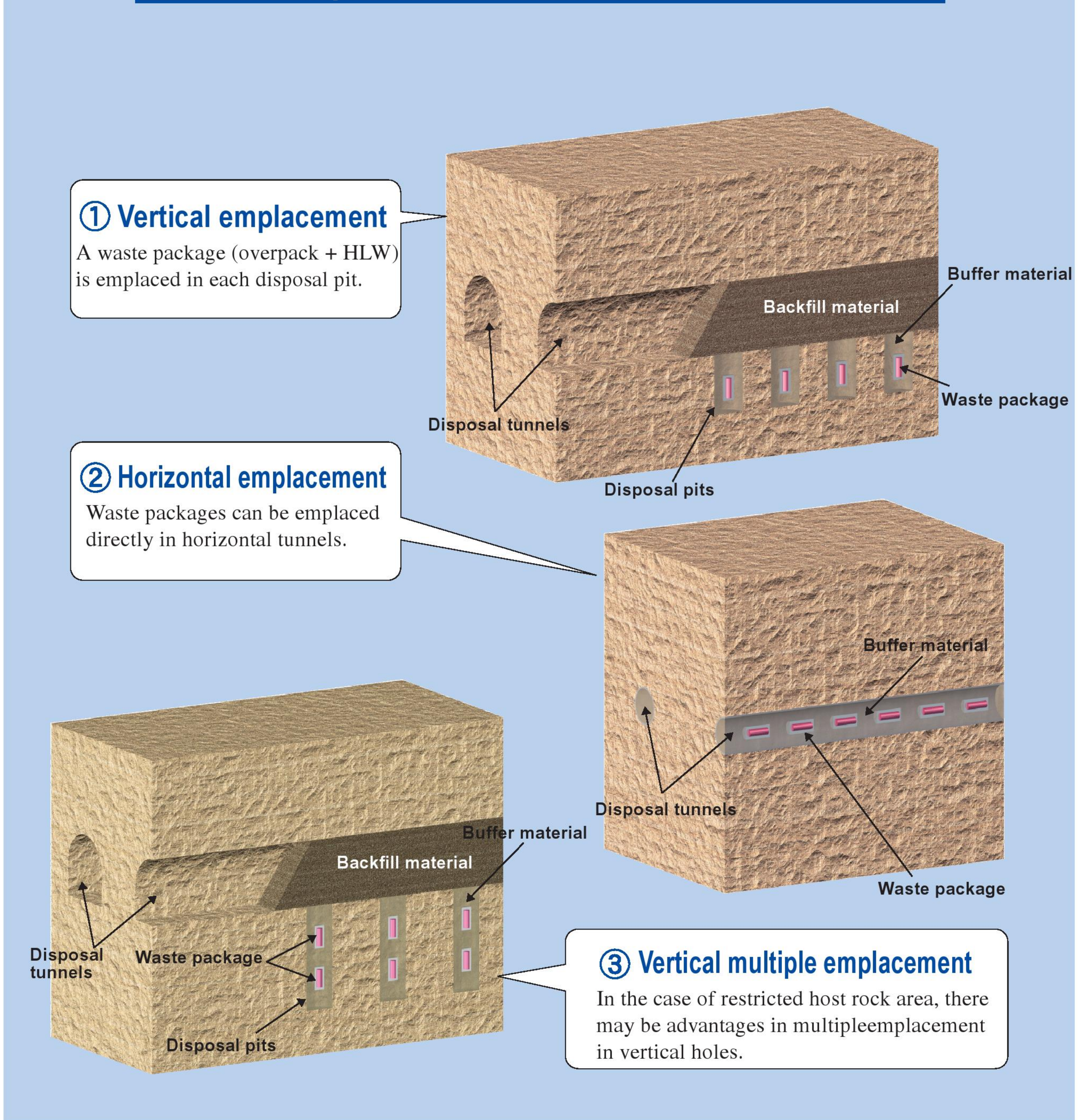
In the case of a smaller area of host rock, a multi-level layout can be designed if permitted by mechanical stability, thermal loading, etc.

For complex host rock formations



In the case of an inclined host rock formation, the repository layout can be designed to take account of the geological structure.

Various emplacement methods for vitrified waste



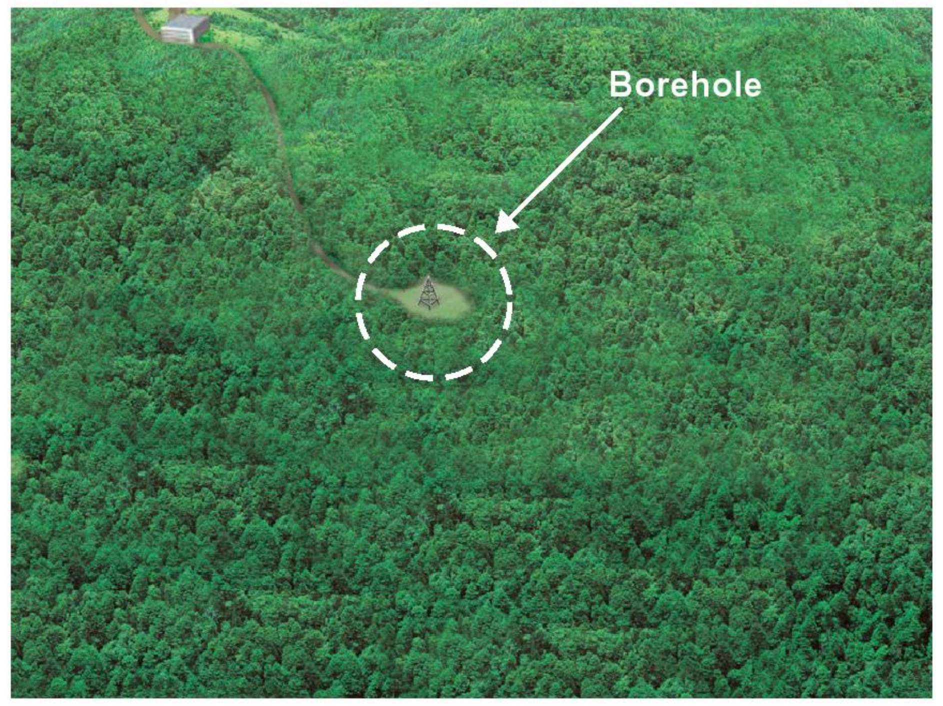
How is HLW Disposal Implemented?

A major project lasting about 100 years from siting to closure of the repository

Site investigations carried out in PIAs and DIAs are expected to take approximately 25 years.
After selection of the disposal site, the surface facilities are built in about 10 years.
Following construction of the underground facilities, the repository will operate for about 50 years in order to dispose of 40,000 canisters of vitrified HLW.

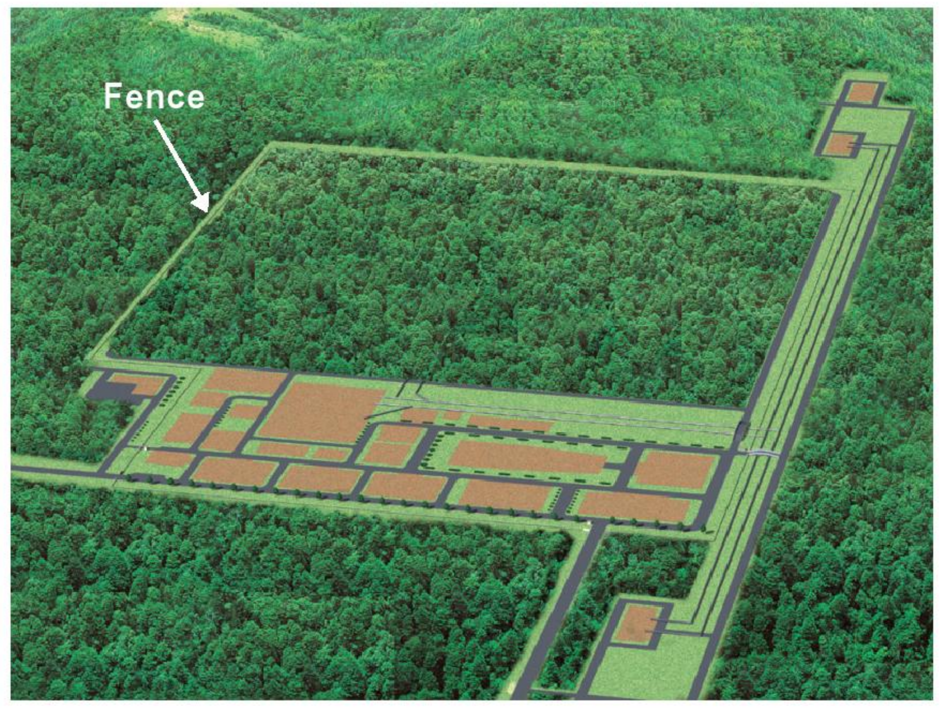
about 25 years		about 10 years	about 50 years
Preliminary investigations	Detailed investigations	Construction of surface facilities	Construction of underground facilities and repository operation

Surface Facilities

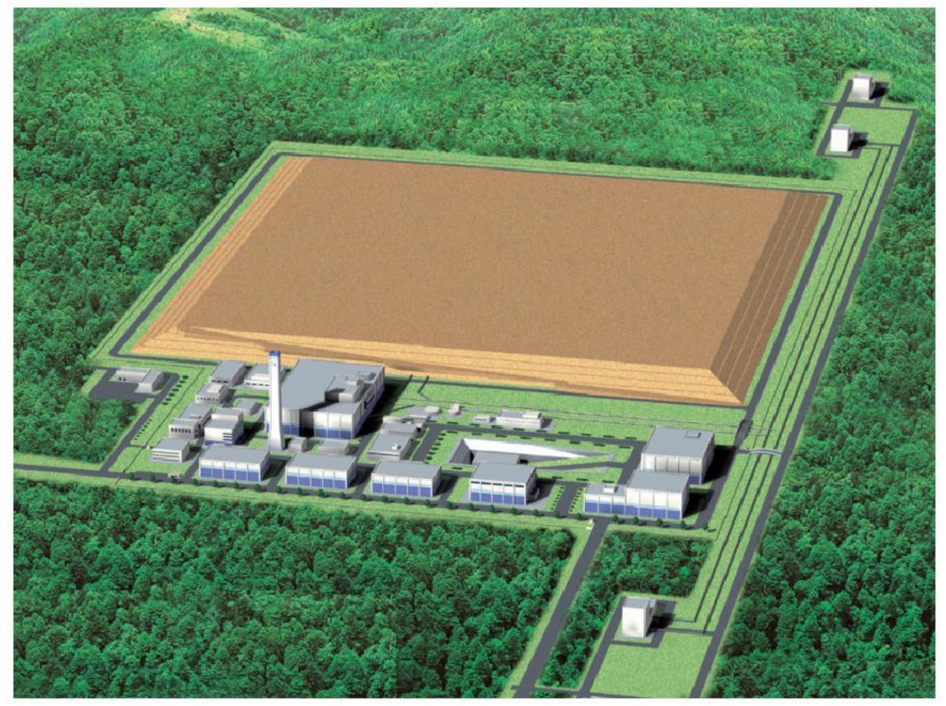


Surface-based investigations, including boreholes, are carried out for selection of DIAs.

Surface-based investigations are continued, followed by evaluation of the Final Disposal Site based on results of both surface-based and underground investigations.

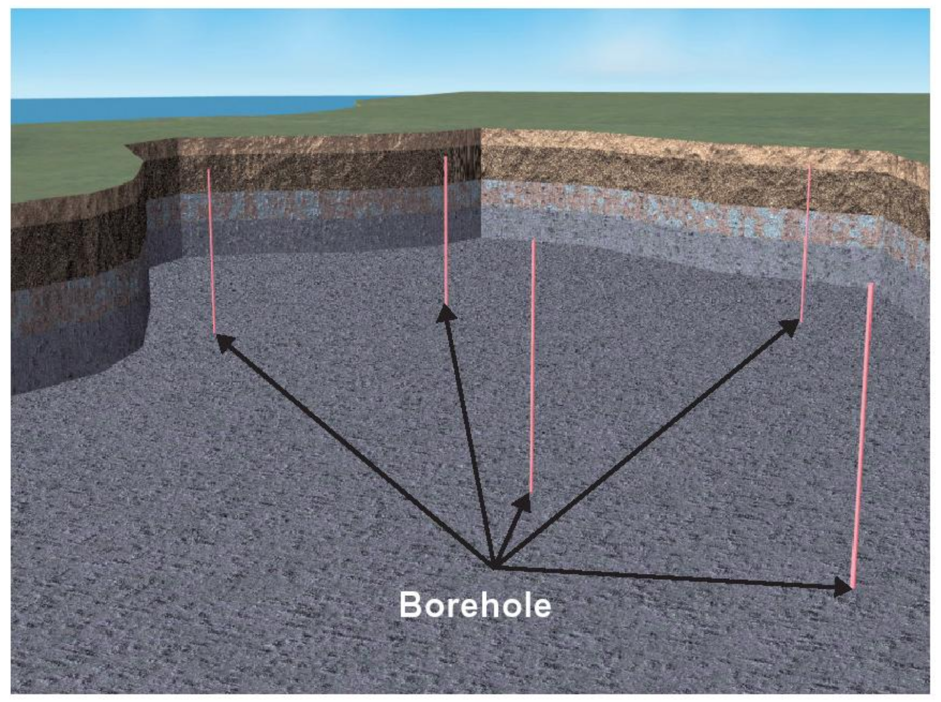


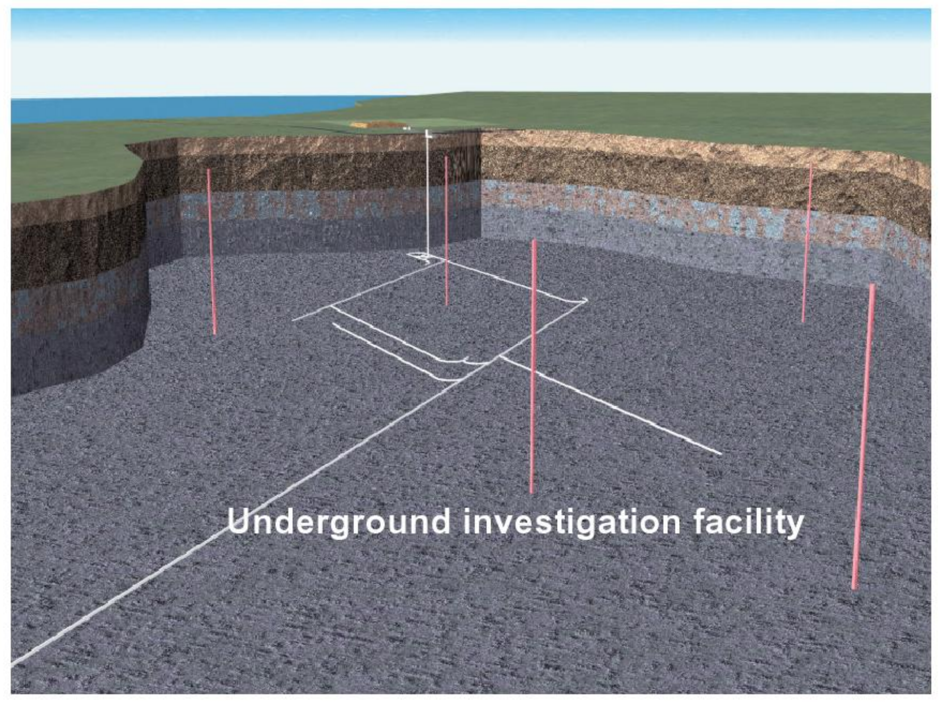
Surface facilities including private transportation road and harbor are constructed.



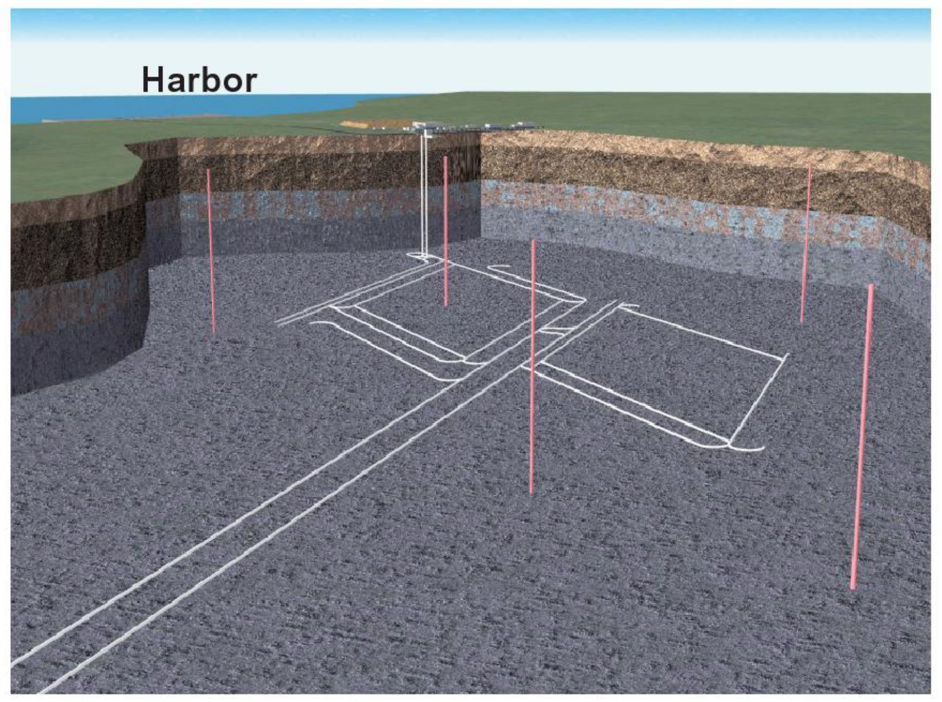
Repository operation starts, including transportation of HLW from interim storage centers. Following encapsulation, waste packages with buffer/backfill materials are transferred to the underground facilities.

Underground Facilities

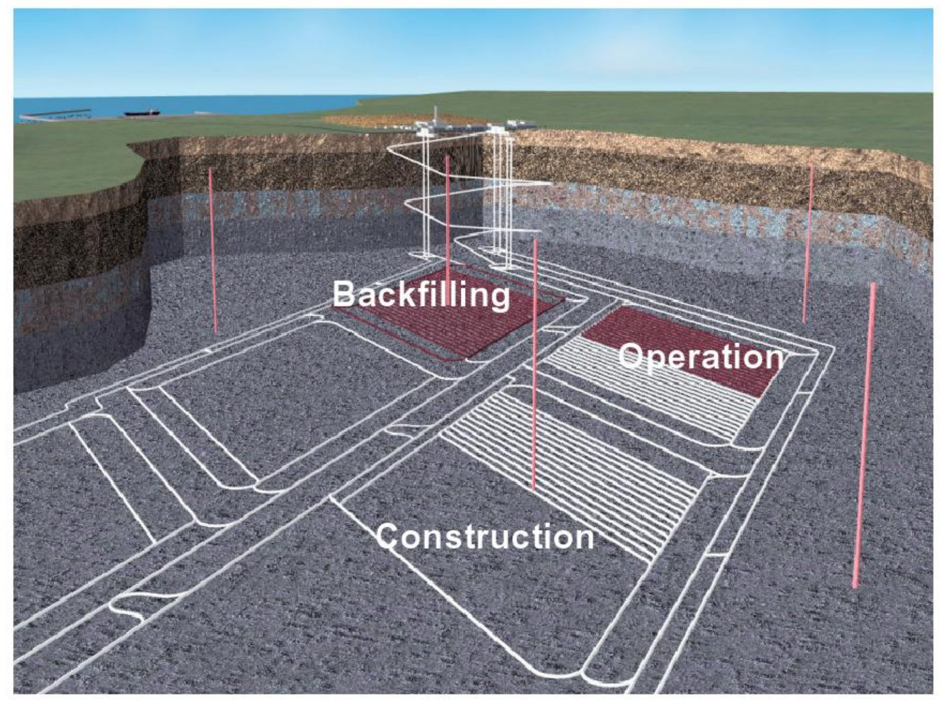




Following construction of an underground investigation facility, investigations are carried out for more detailed characterization of the host rock.



Following construction of the surface facilities, underground construction is initiated.



Construction of disposal tunnels is carried out in each disposal panel, then waste packages are emplaced, followed by backfilling of disposal tunnels.

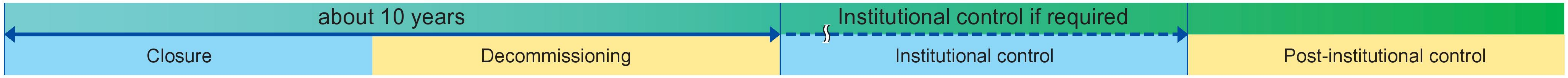
3. Implementation of Disposal

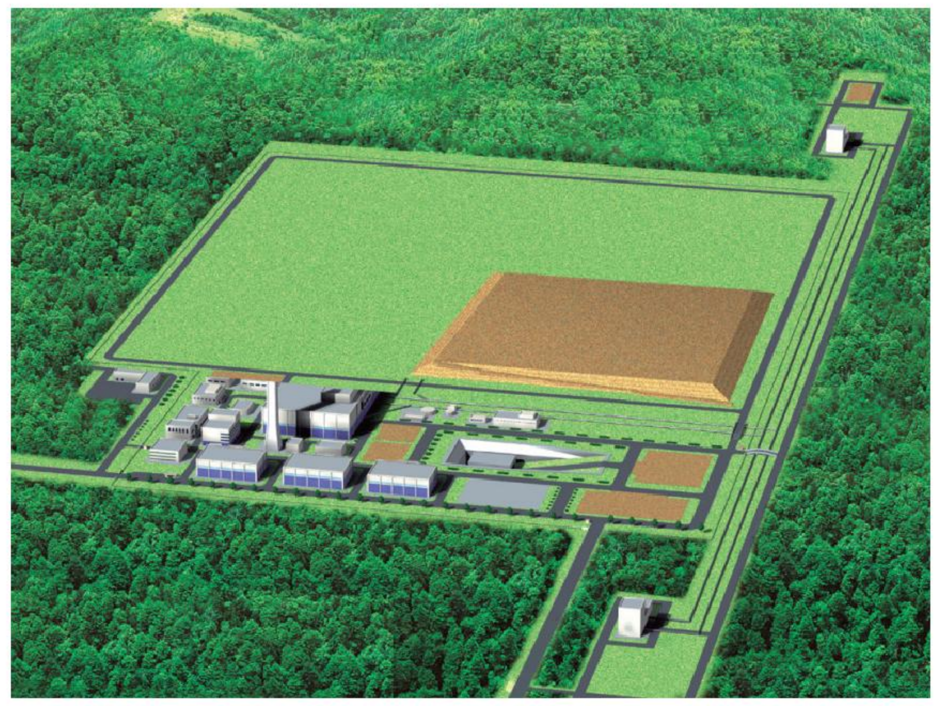
Following the operational phase, underground facilities including access ramps or shafts are backfilled. It is expected to take approximately 10 years for repository closure, so that the overall disposal project requires about 100 years from the initiation of siting.

During the implementation of the disposal program, appropriate measures for ensuring environmental and radiation protection are taken. Monitoring activities demonstrate the effectiveness of these measures.

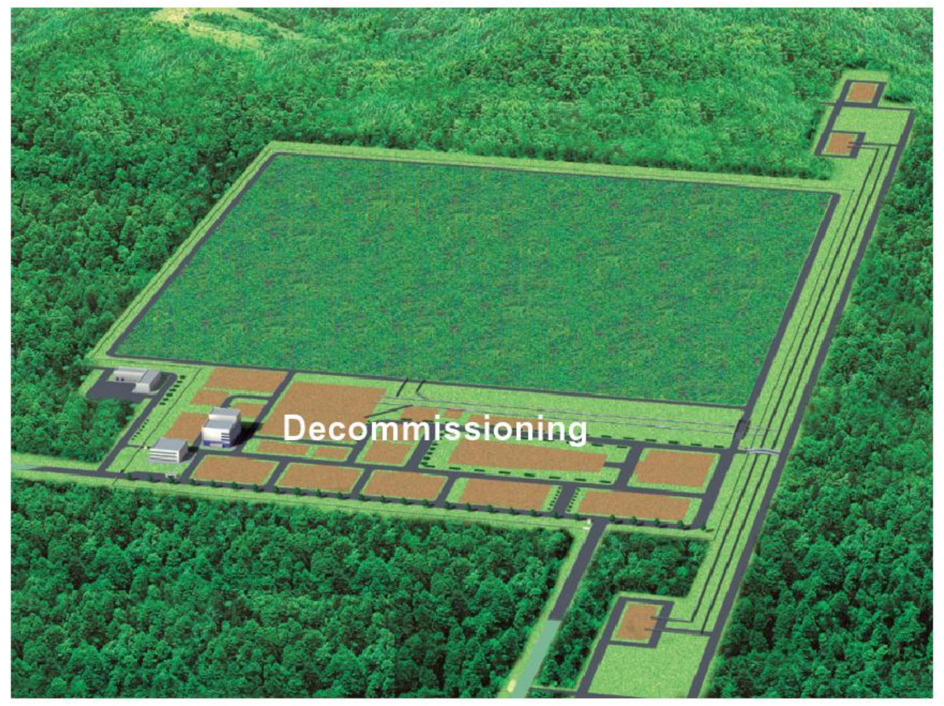
At the time of repository closure, it is required that the results of the safety assessment performed for the license application be confirmed by taking into account additional data obtained during the construction and operational phases. Until this confirmation is made, it is necessary to ensure retrievability of the HLW.

In general, it is technically possible to retrieve emplaced HLW even after repository closure.

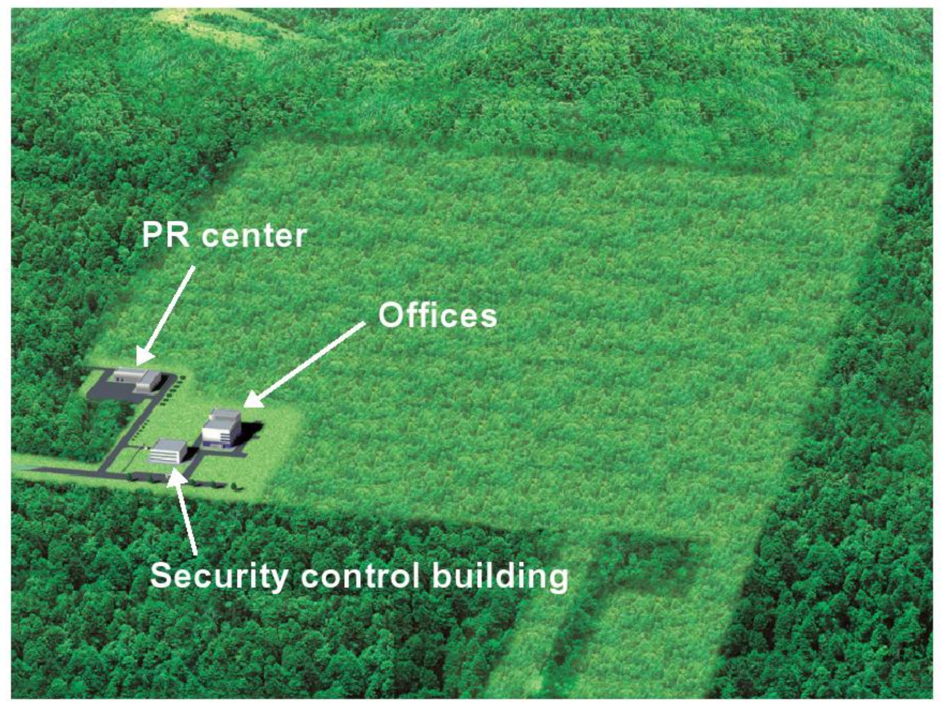




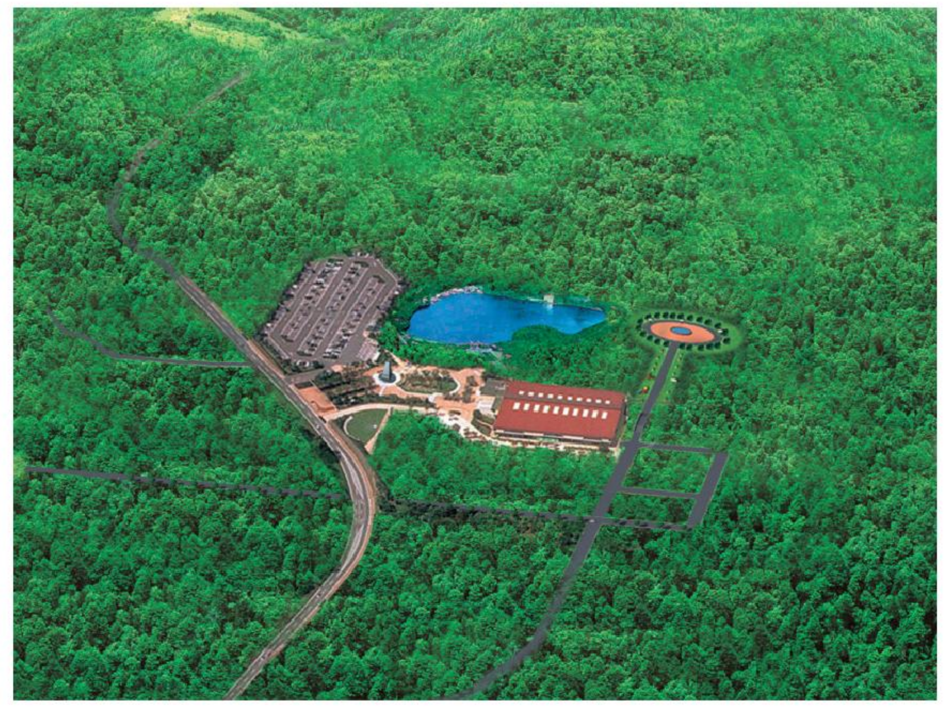
For repository closure, backfill materials are transferred underground. At the same time, redundant surface facilities are removed.



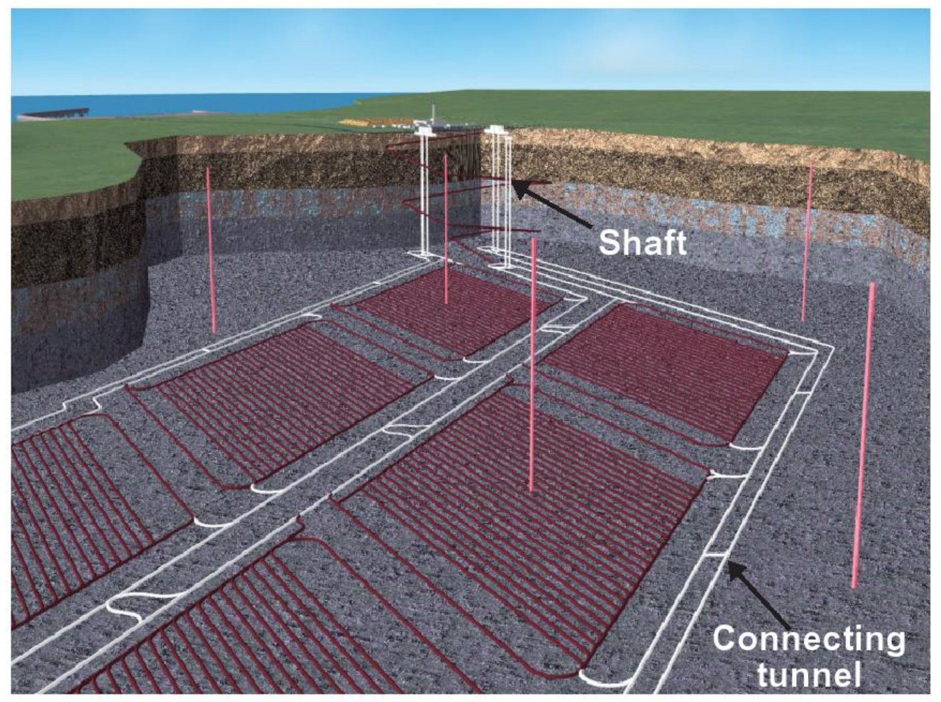
After closure of the underground facilities, surface facilities are removed.



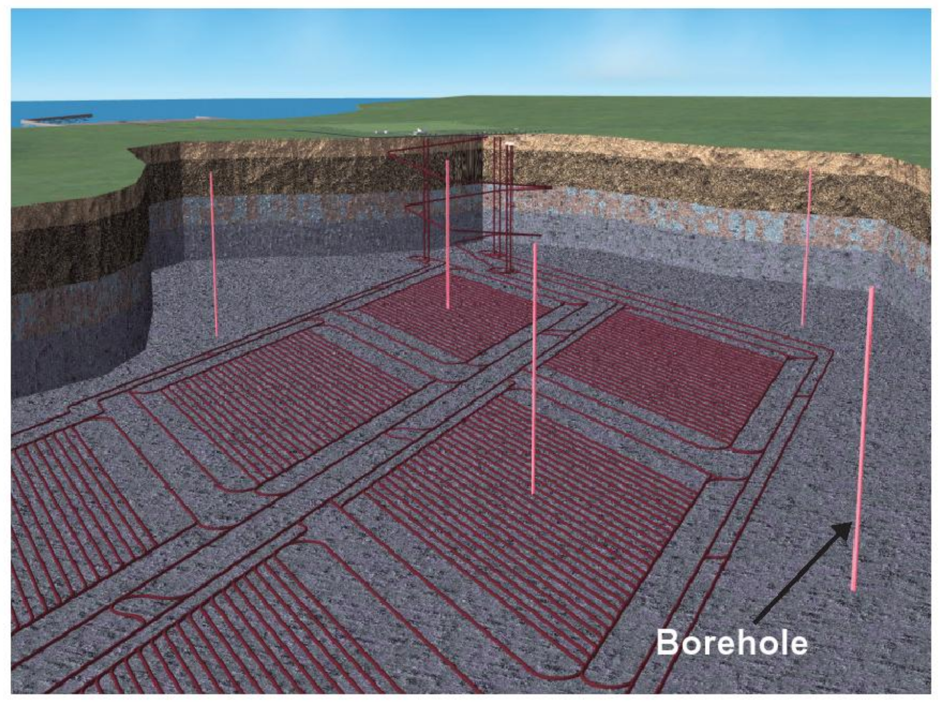
If necessary, surface-based monitoring can be continued. In the event that an institutional control period is required, the security control building, offices, PR center etc. will remain.



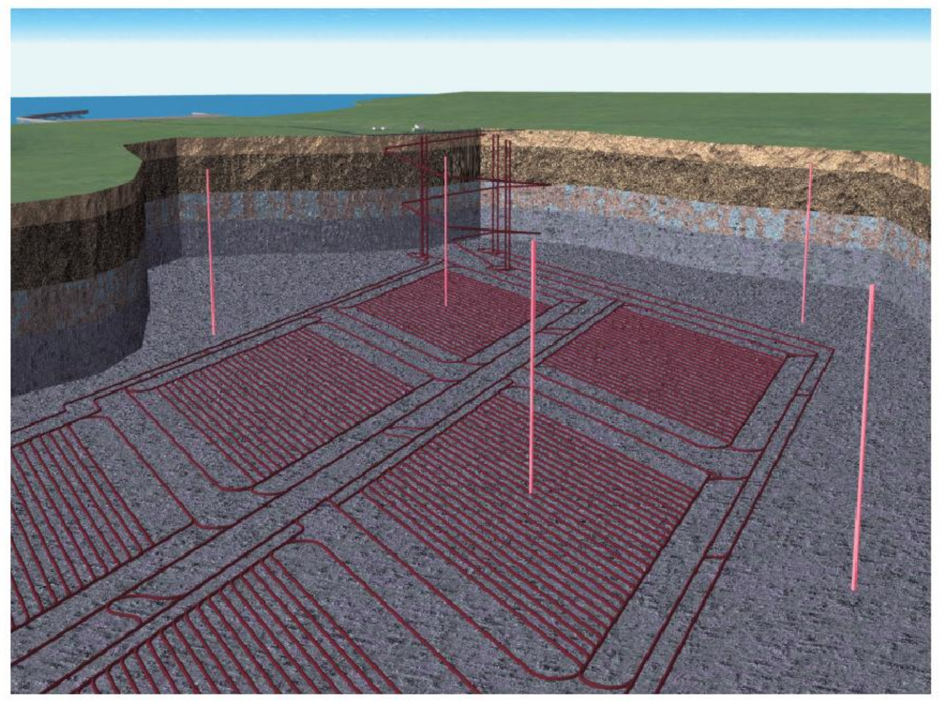
The surface facilities are completely removed. After removal, a monument or a memorial park can be built.



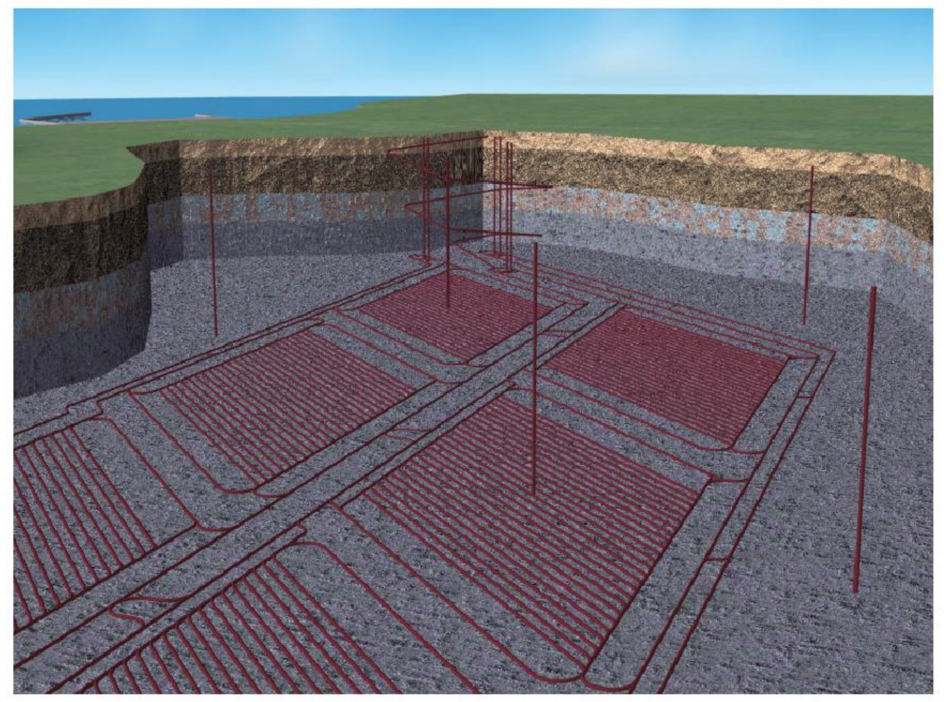
After confirmation of the safety assessment results using additional data, underground facilities including access ramps or shafts are backfilled and sealed.



If necessary, boreholes can remain for monitoring during an institutional control period.



If necessary, monitoring of the underground environment can be continued using the remaining boreholes,



Underground facilities and all boreholes are finally completely sealed.

How are Site Investigations Conducted before Repository Construction?

Literature surveys and surface/underground investigations are conducted in a stepwise manner for confirmation of the Final Disposal Site.

Literature surveys for selection of PIAs based on existing information are aimed at excluding definitely unsuitable areas from consideration.
The surface-based investigation of PIAs for selection of DIAs aims to confirm the results of the literature surveys as well as the feasibility of underground construction.
The underground investigation of DIAs for selection of a repository site aims to confirm suitability of the disposal site and obtain data for repository design and construction.

Applicant areas and their surroundings → **Preliminary Investigation Areas (PIAs)** → **Detailed Investigation Areas (DIAs)** → **Repository Site**

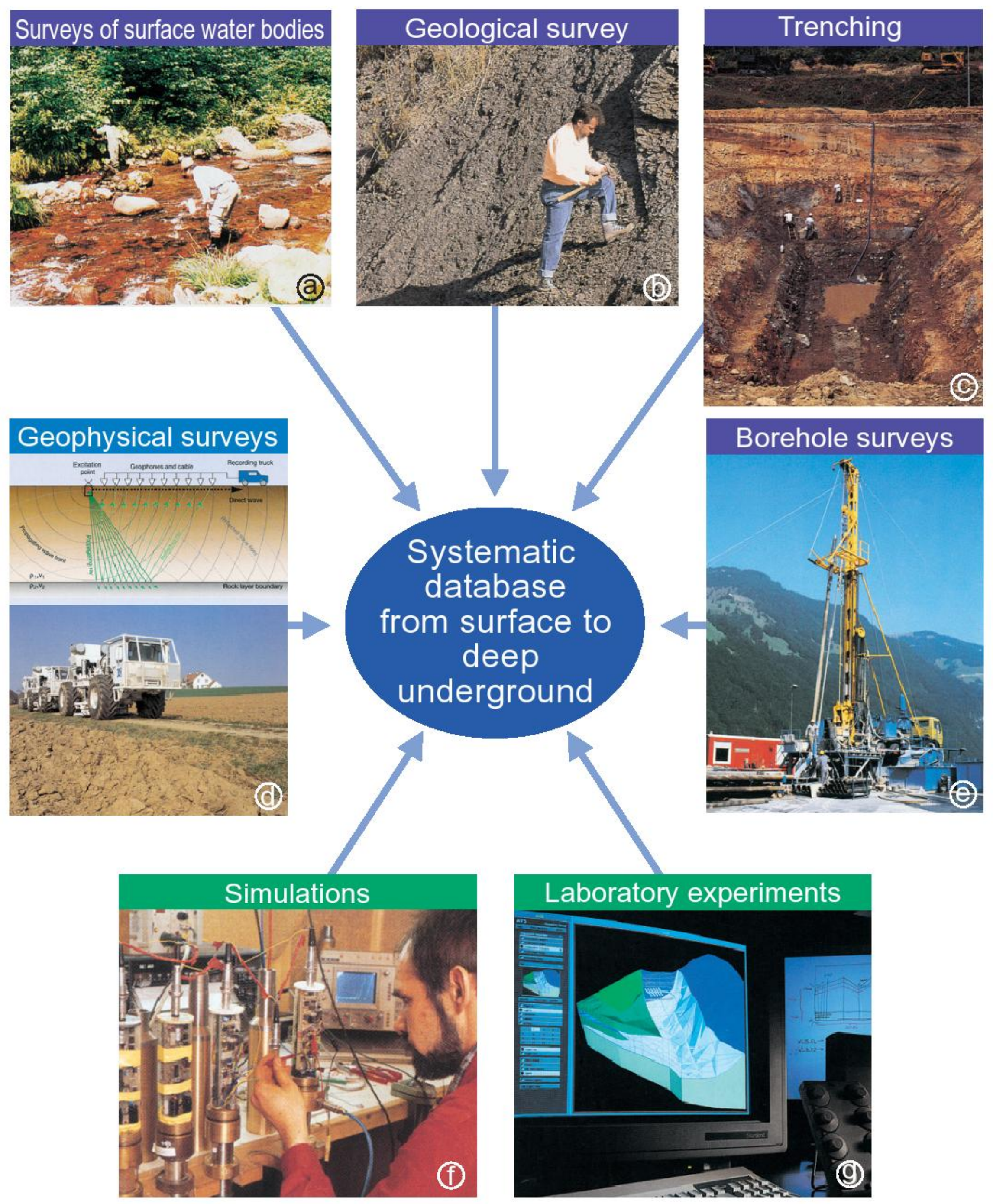
Literature survey

The literature surveys for applicant areas and their surrounding regions are conducted to determine their suitability based on NUMO's "Siting Factors for Selection of PIAs".

Sources including historic records of earthquakes, eruptions, uplift/erosion etc. in the applicant areas, including the surrounding regions, will be used in the literature survey.

Surface-based investigations

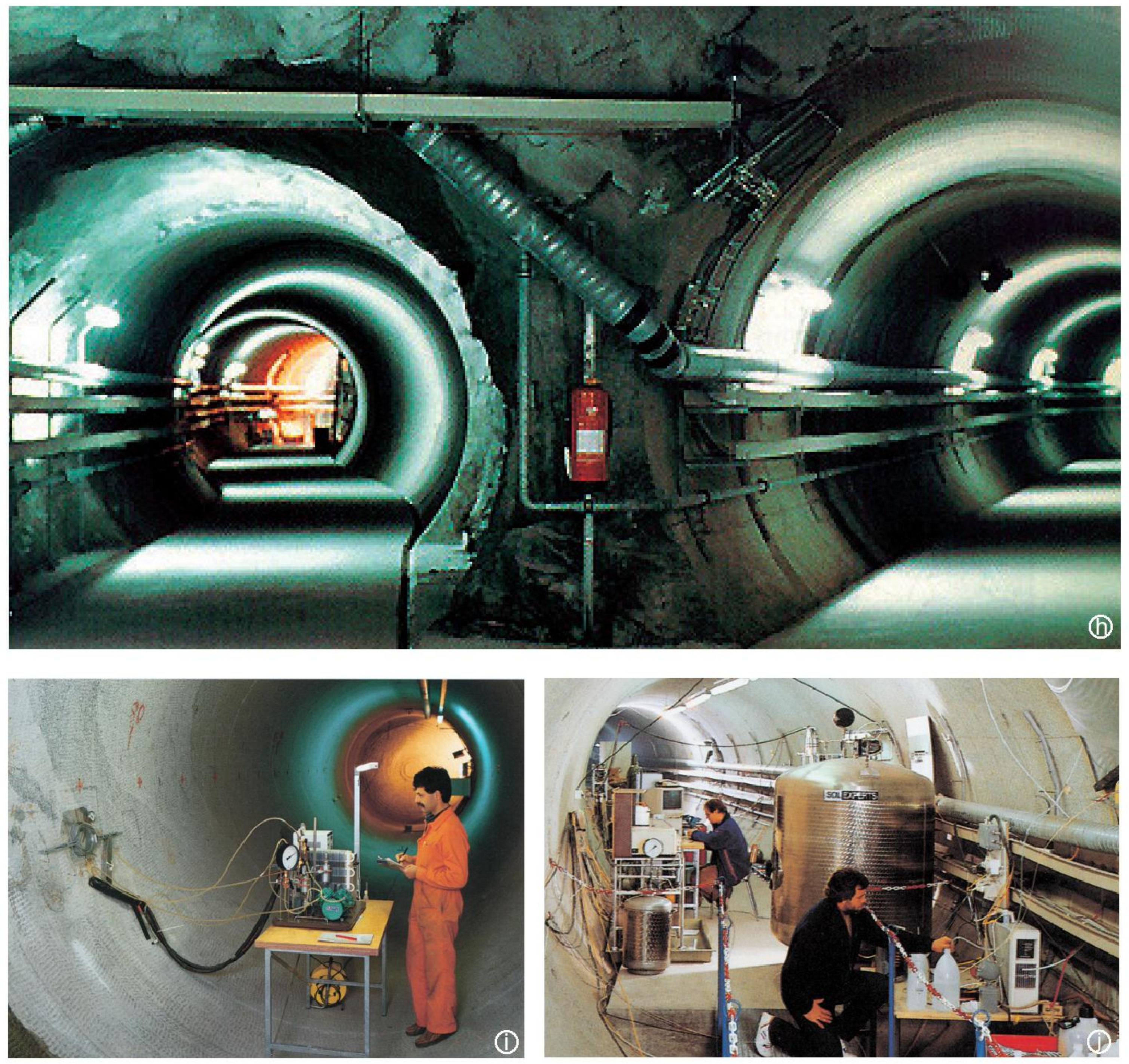
Surface-based investigations are conducted to obtain data on geological structure, hydrology and geochemistry of groundwater, mechanical properties of the rock formation, etc. This will provide a systematic database from the surface to deep underground. The investigation include surveys of surface water bodies, geological surveys, geophysical surveys, borehole surveys and trenching.



Surface-based /underground investigations

Together with surface-based investigations, the subsurface is characterized in more detail through investigations in an underground test facility.

Underground investigations



Repository Site

Data acquisition is continued during the construction and operational phase at the repository site in order to confirm the results of the safety assessment performed for the license application at the time of repository closure.

Photos: courtesy of:
ⓐMETI
ⓑNagra taken from Nagra Bulletin No.31 (1997)
ⓒCRIEPI
ⓓNagra taken from Nagra Bulletin No.33 (2000)
ⓔNagra taken from Nagra Bulletin No.24 (1994)
ⓕNagra taken from Nagra Bulletin No.24 (1994)
ⓖNagra taken from Nagra annual report 1993 (1993)
ⓗNagra taken from Nagra Bulletin 10 years GTS (1994)
ⓘNagra taken from Nagra Bulletin Special Edition (1998)
ⓙNagra taken from Nagra annual report 1995 (1995)

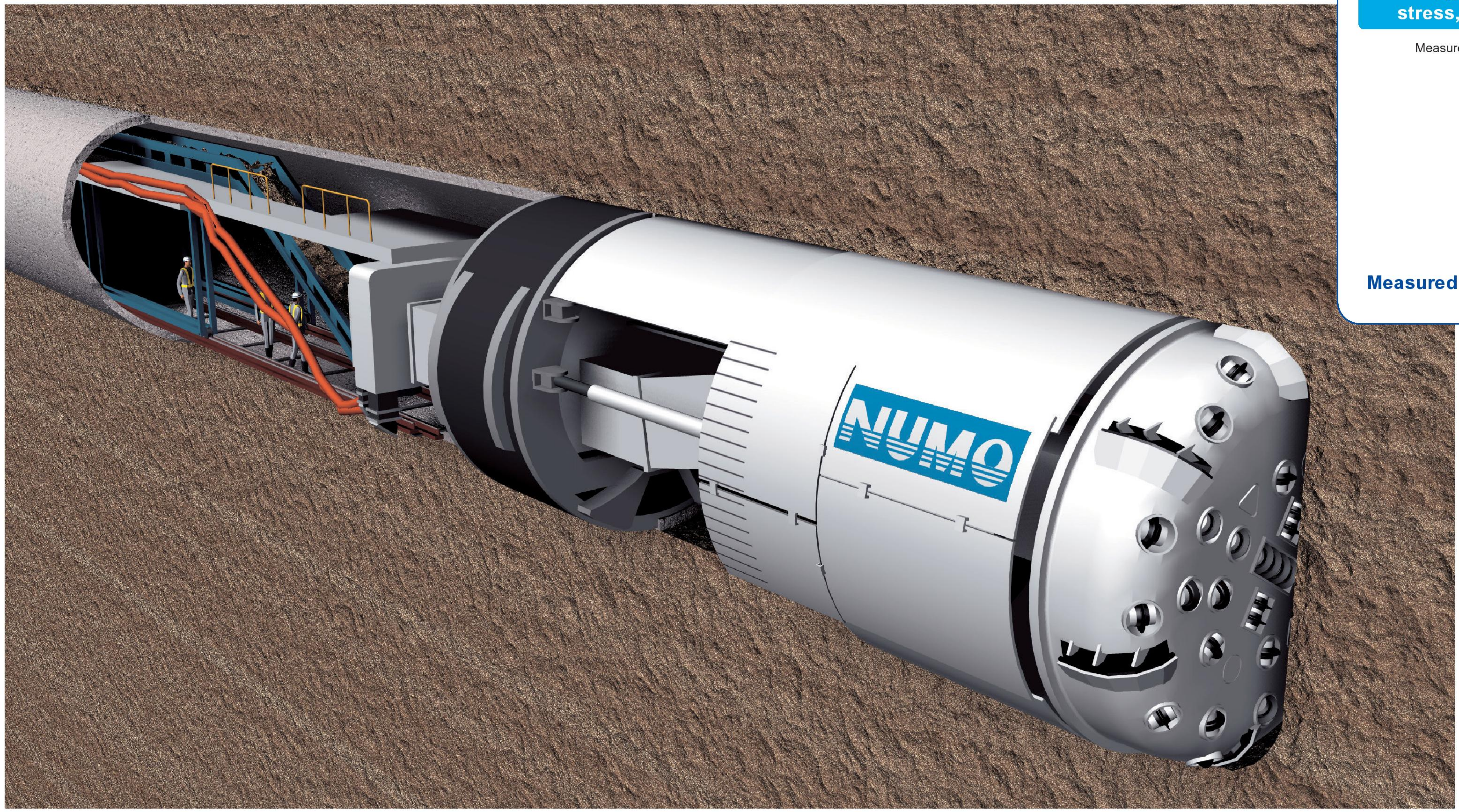
How is a Repository Constructed?

After the selection of the Final Disposal Site, the repository will be constructed following approval of the license application. Current technologies can be applied for construction.

At the Final Disposal Site, construction of the repository starts following approval of the licensing application.
After land development, construction of the surface facilities including private roads is carried out, followed by construction of the underground facilities. For drilling tunnels, a Tunnel Boring Machine (TBM) can be used, which allows a safer and shorter period of construction.
Current technologies as used in nuclear facilities and underground construction can be applied for construction of both surface and underground facilities.

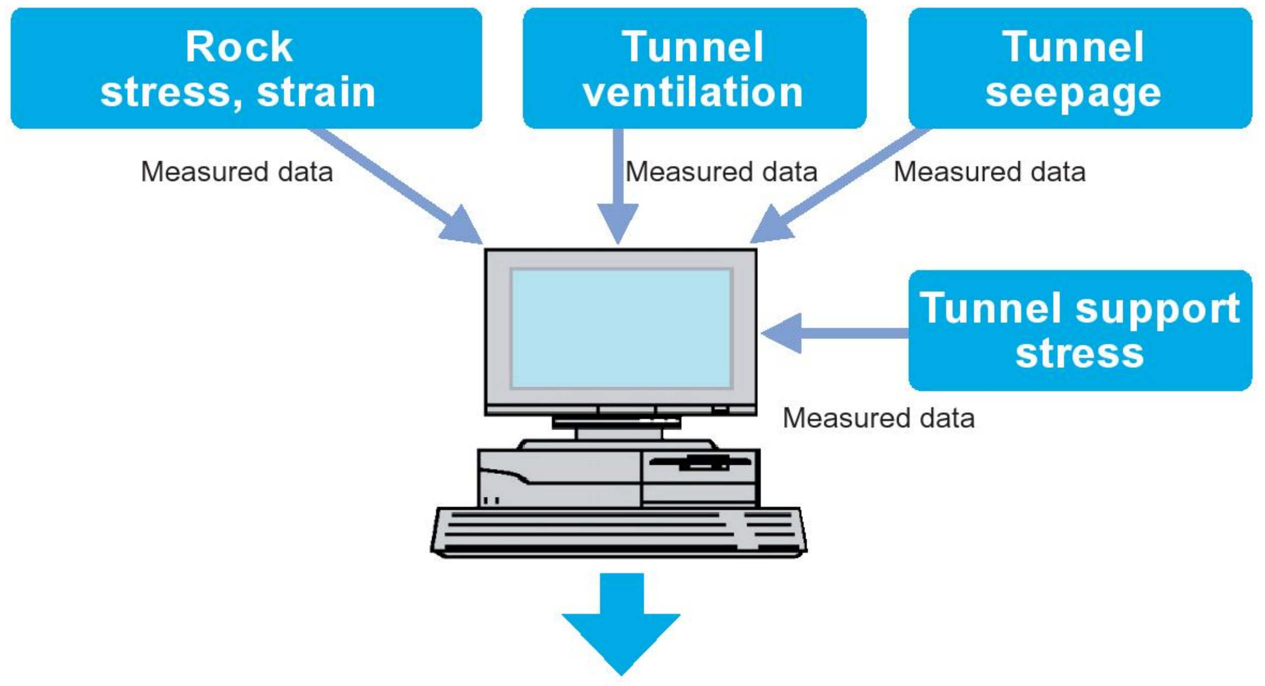
Construction of disposal tunnels

The TBM excavates hard rock using a rotating cutter fixed at the front of the machine. Compared with conventional excavation methods using blasting, a TBM works more efficiently and is superior in terms of noise and vibration reduction.



Ensuring safety of construction

Tunnel construction is carried out ensuring safety by continuous measurement of parameters such as stress field, ventilation, seepage, etc.



Measured data are used for feedback to ensure the safety of the construction work

View of disposal tunnel (left) branching off an access tunnel

How is HLW Transported to the Repository?

HLW transportation to the repository is by ship/vehicle, and has already been demonstrated using current technology for transportation of returned waste from overseas.

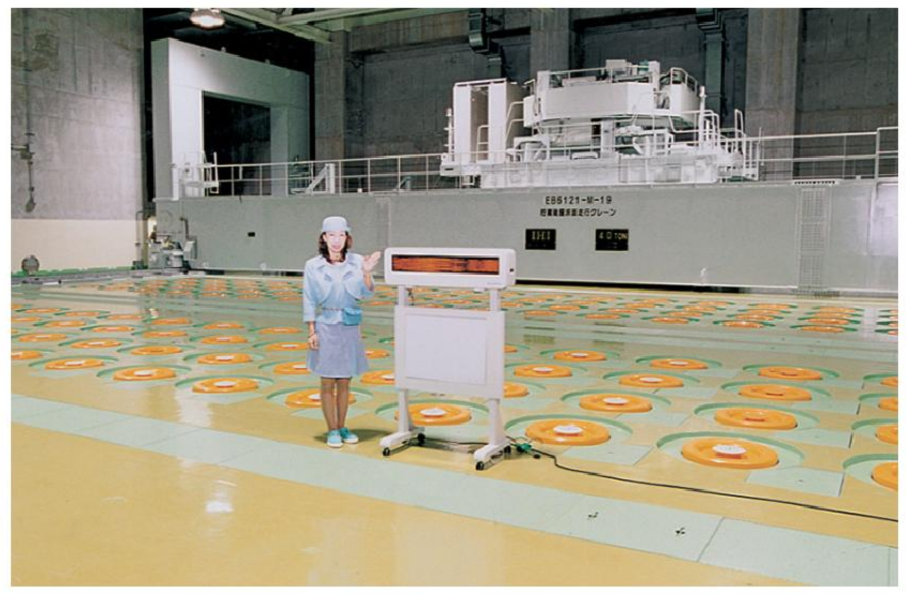
Vitrified HLW packaged at the interim storage center is transported to the repository by ship and/or truck. The transportation method depends on the location of the repository site.

In the case of transport by sea, a specially designed ship is used to ensure safety by taking account of potential accidents. Road transportation vehicles are also specially designed to ensure safety by anticipating accidents which could arise.

Such ships and trucks are already used routinely in transportation of returned HLW from overseas.

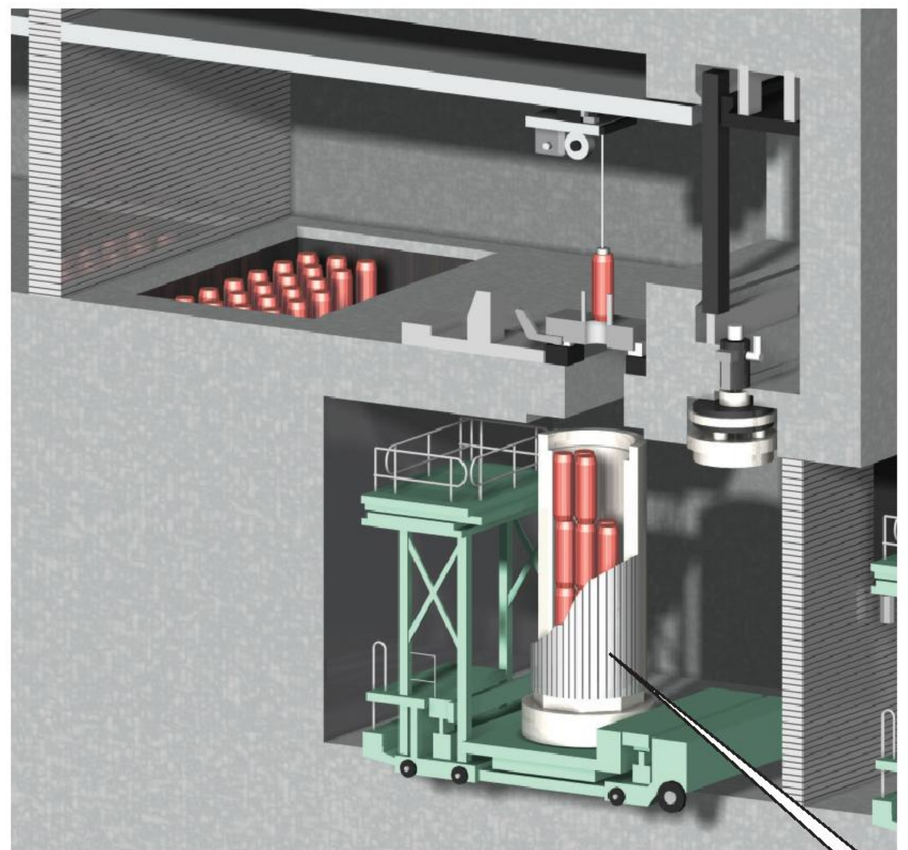
Transportation of vitrified waste

Interim storage & packaging for transport



Rokkasho (Aomori, Japan) HLW Storage Center

Photo:courtesy of JNFL

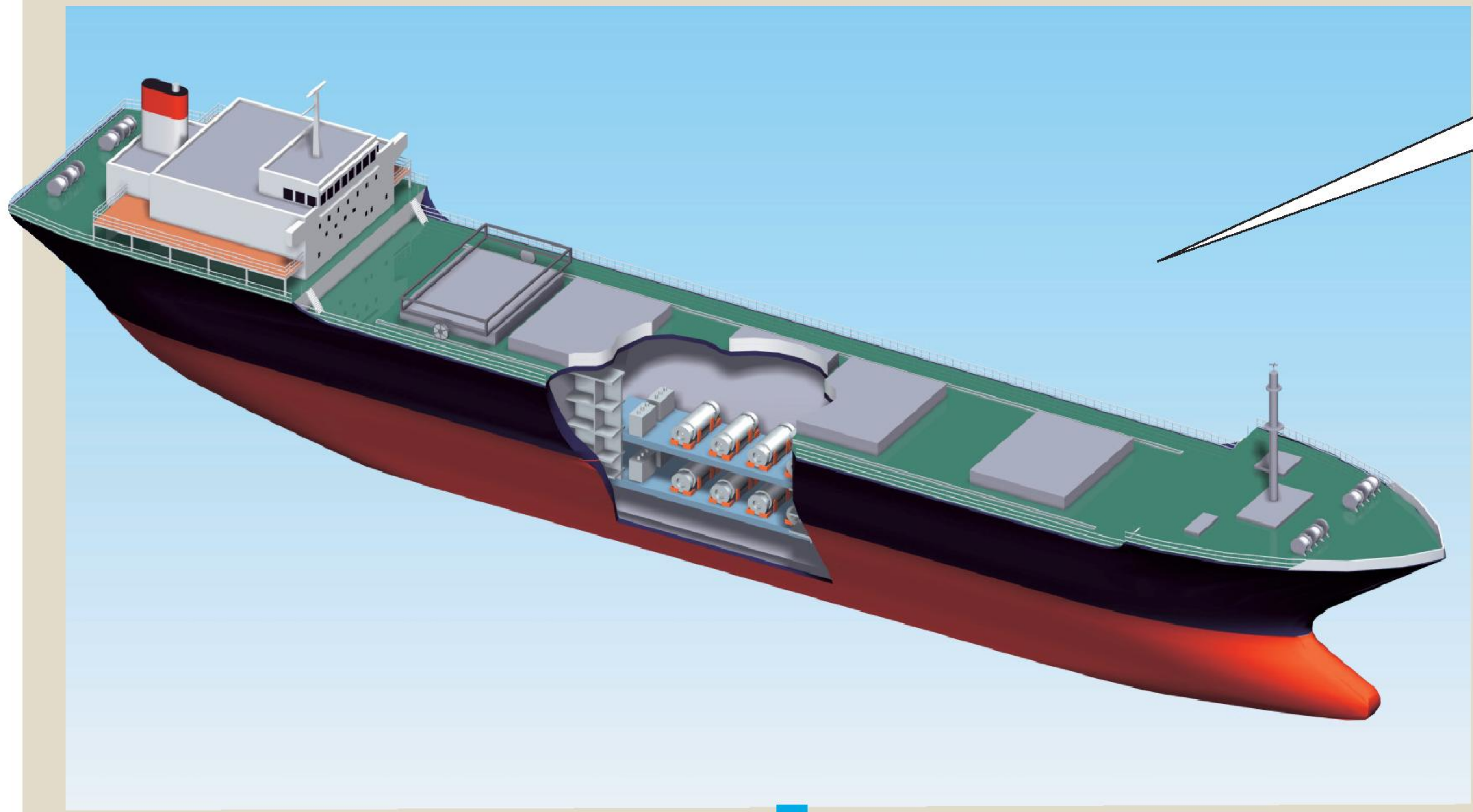


Vitrified HLW is transferred into a transport cask by remote handling.

Transport cask

Specially designed taking account of anticipated accidents: impacts, fire, etc.

Transportation



Transport ship

Specially designed taking account of anticipated accidents:

- double skinned hull
- equipment for prevention of collisions
- fire prevention and control system, etc.

Even in the case of ship transportation, use of a specially designed vehicle is required for HLW transport from the nearest harbor to the repository.

from the nearest harbor

Road transport vehicle

Specially designed to ensure safety by anticipating possible accidents: equipment for preventing dislodging/falling of a transport cask and dual braking systems.

The vehicle is also designed to run on both private and public roads.

Reception at the repository

Vitrified waste is delivered to the waste reception and encapsulation plant.

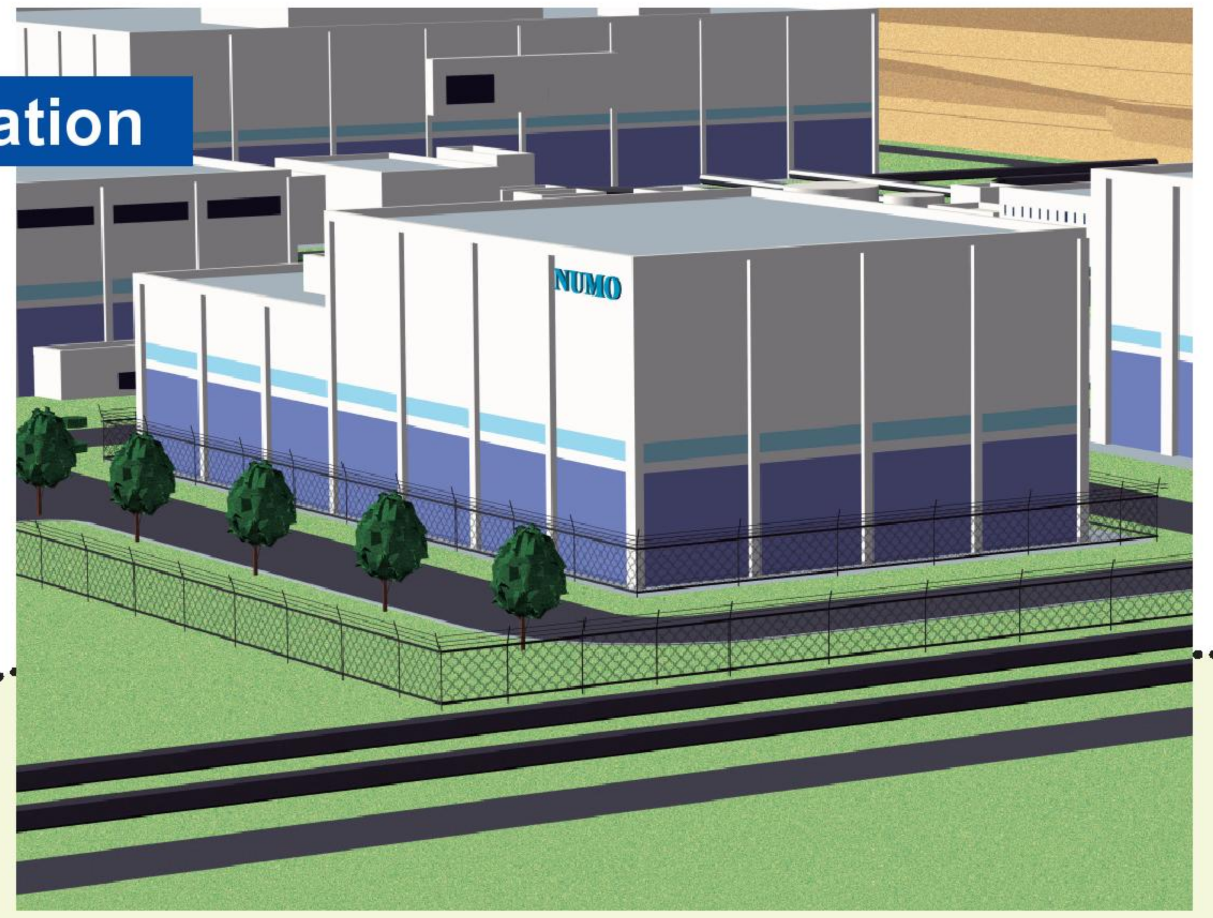
How is HLW Treated in the Surface Facilities?

Vitrified HLW is encapsulated using remote handling technology.

Following reception of the transport cask and subsequent cask inspection, the vitrified HLW is removed from the cask and then encapsulated. These processes are carried out in well shielded areas by remote handling to avoid radiation exposure of workers. The radiological impact of these processes on the environment will also be below regulatory limits.
The facility is designed taking account of possible events such as dropping of vitrified HLW canisters, earthquakes and fire.

Waste reception and encapsulation

Vitrified HLW is received at the waste reception and encapsulation plant.

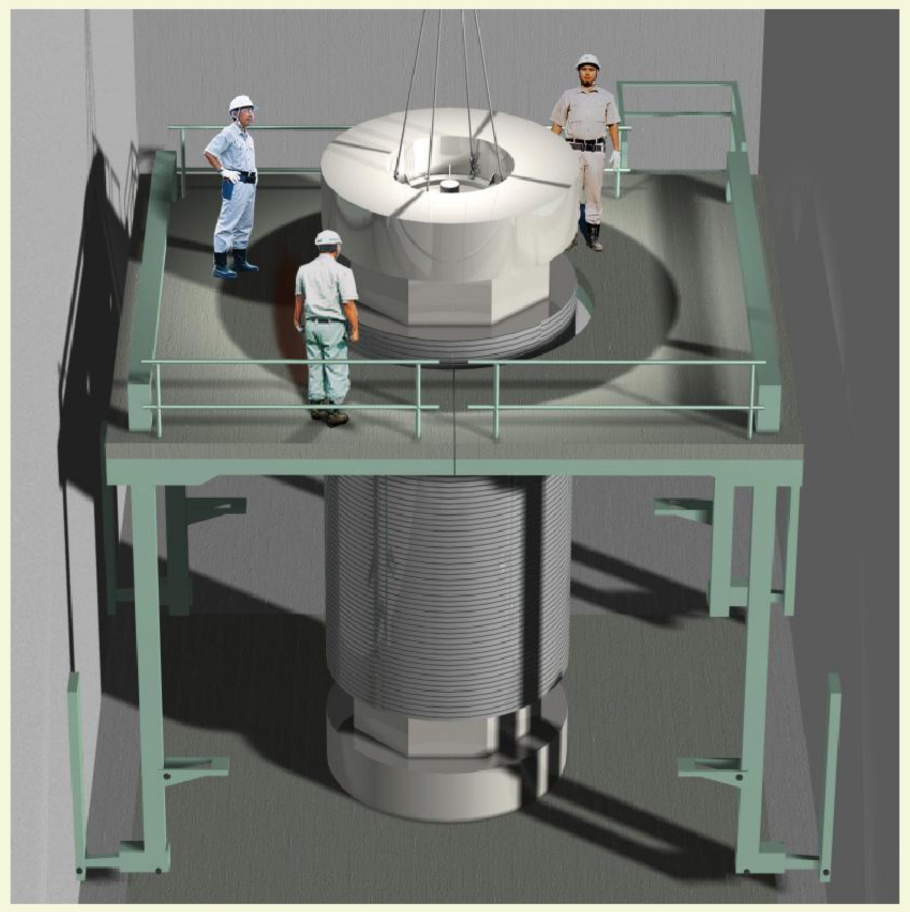


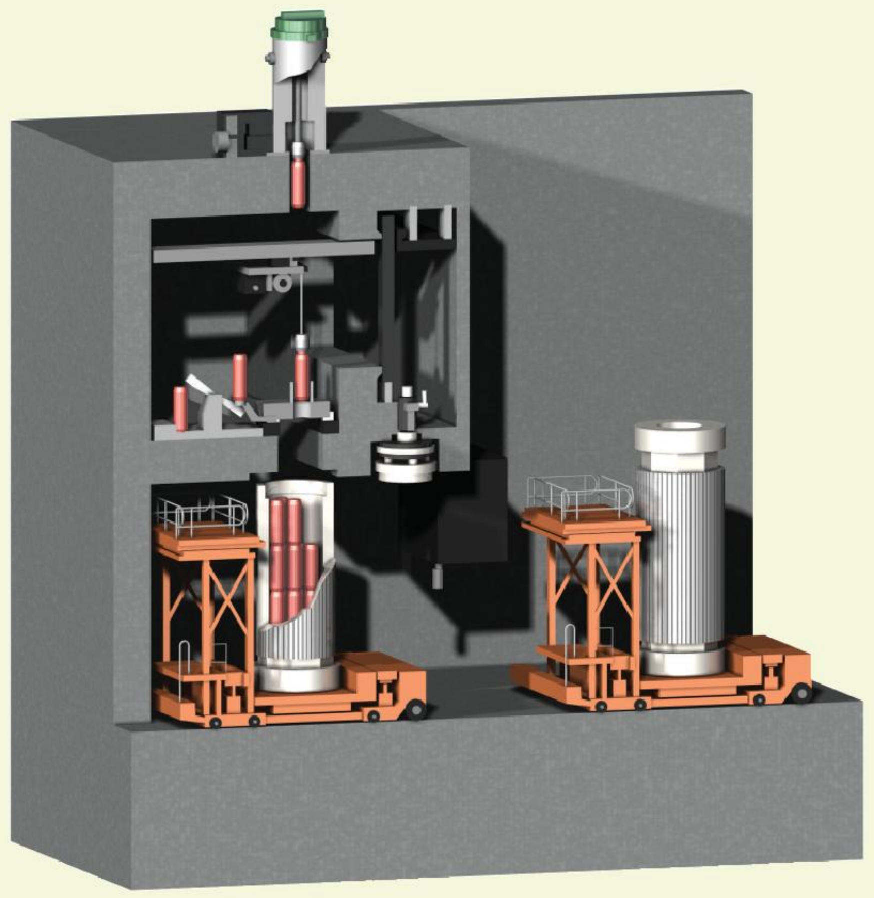
Transfer to the underground facilities

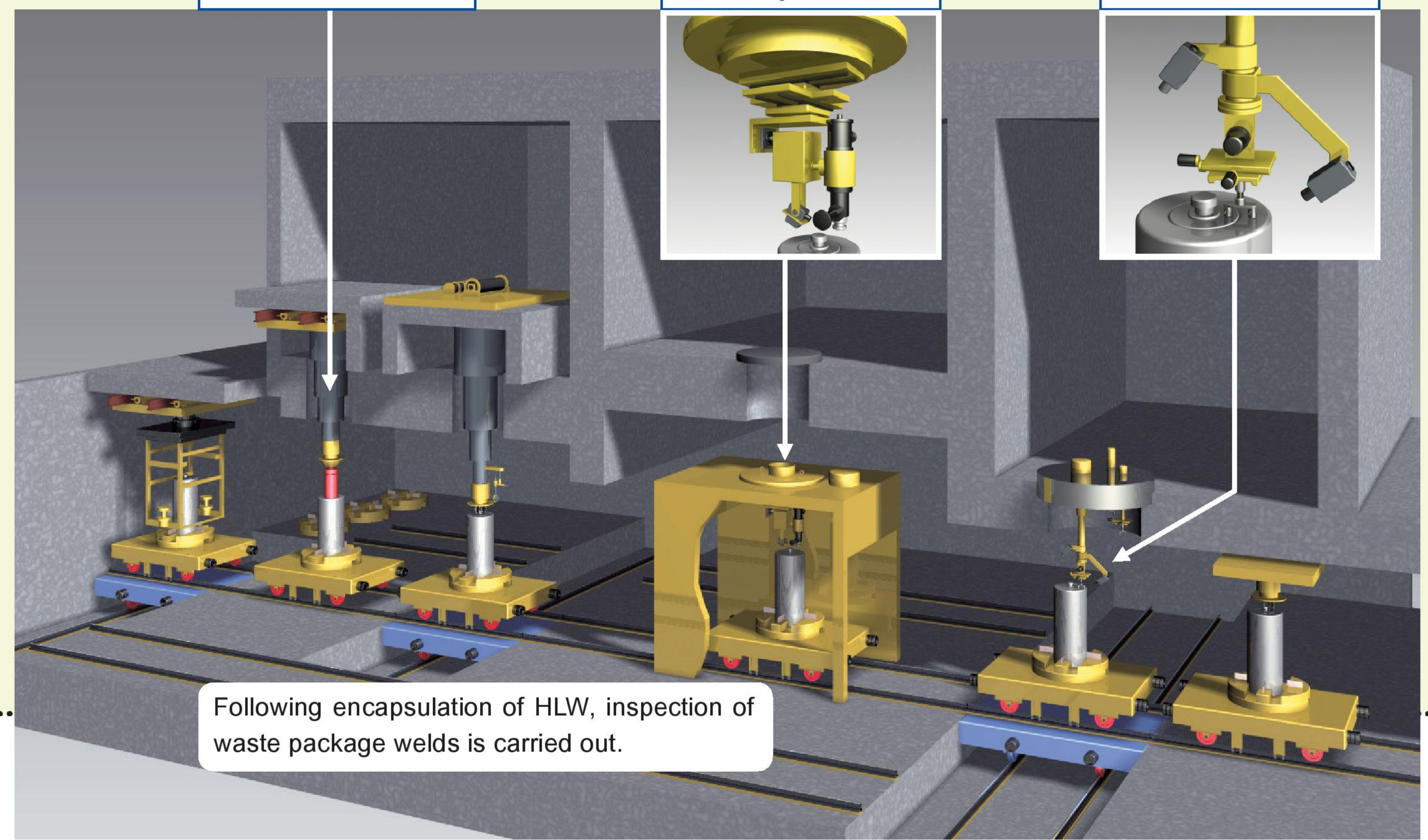
Entrance of the access ramp

Waste packages are transferred through the access tunnel to the underground facilities.

① Cask inspection → ② HLW canister unloading and inspection of canisters → ③ Encapsulation → ④ Welding of overpack lid → ⑤ Inspection of waste package







Following encapsulation of HLW, inspection of waste package welds is carried out.

How are Operations Conducted in the Underground Facilities?

Waste packages are emplaced in disposal pits or tunnels. The construction, operation and backfilling processes are carried out in parallel.

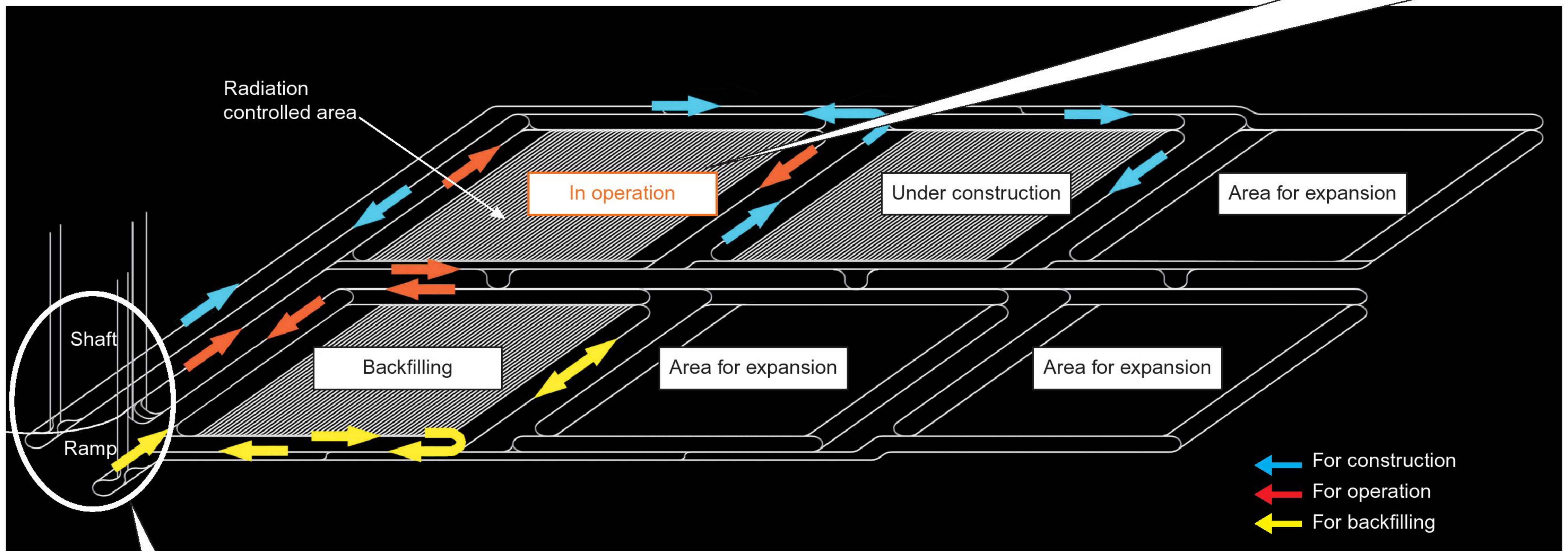
Waste packages are emplaced in disposal pits or tunnels by remote handling after transfer underground. Potential accidents are taken into account when designing the procedures so as to ensure safe operations.

Because of radiation protection requirements, emplacement of waste packages is carried out in a separate panel to construction and backfilling of disposal tunnels, which are carried out in parallel.

The planned annual emplacement rate is 1,000 canisters.

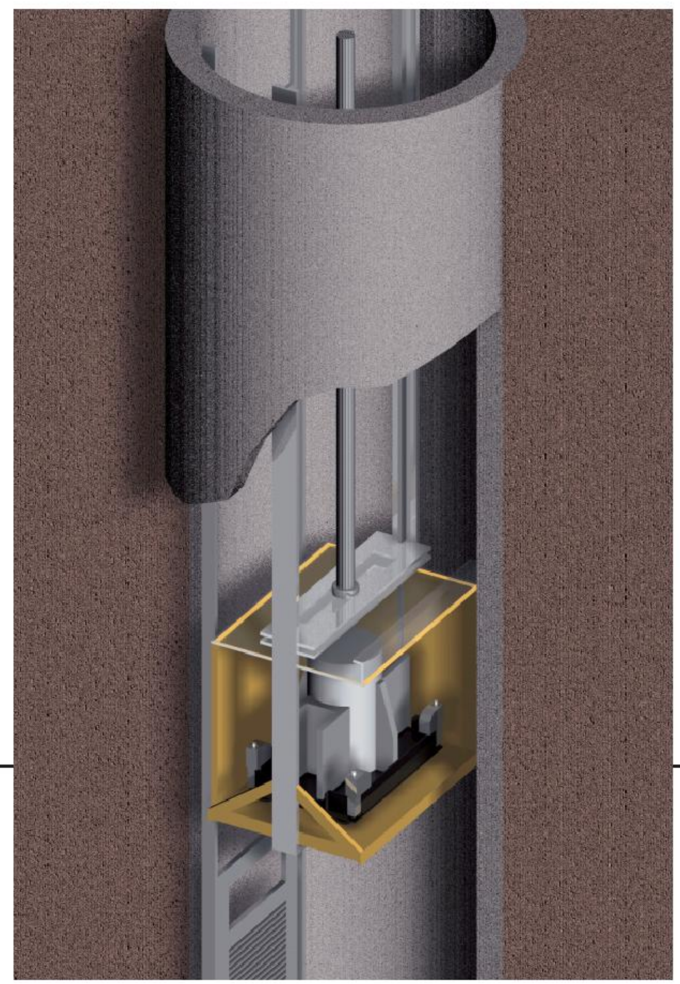
Example of repository operation

Construction of disposal pits or tunnels, emplacement of waste packages and backfilling of disposal tunnels are carried out in parallel in each separate panel.

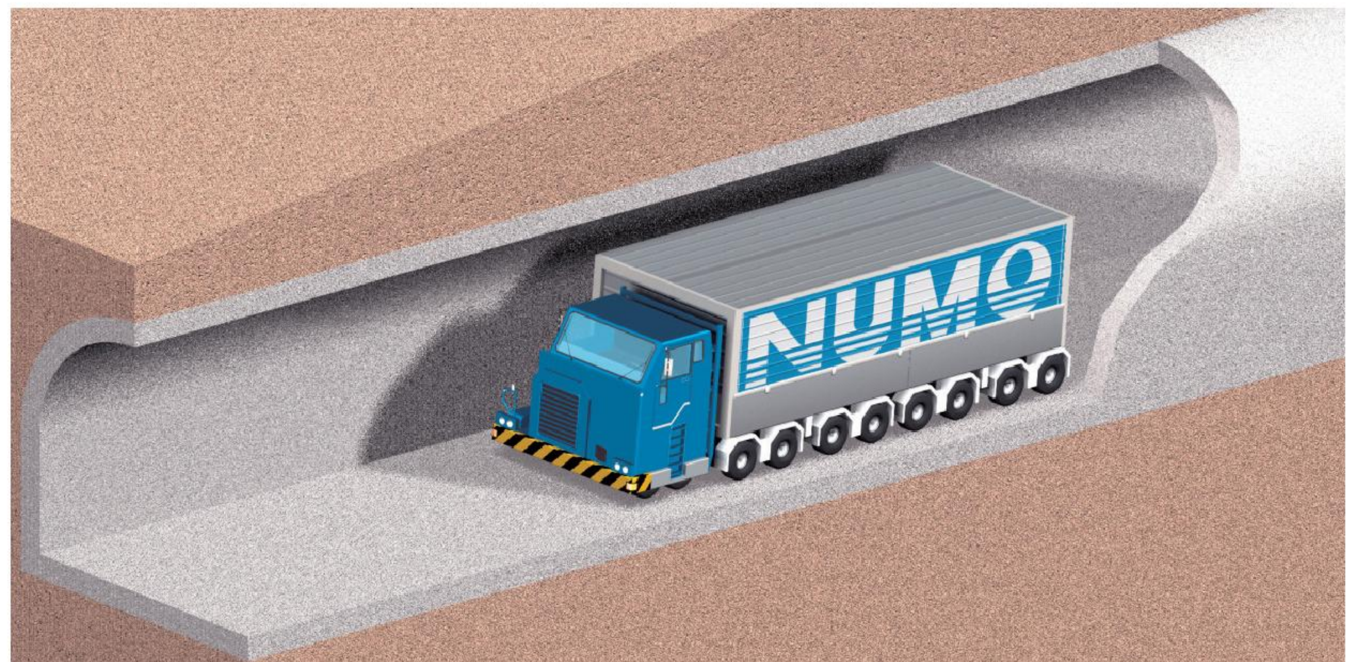


Transfer to the underground facilities

A specially designed elevator or trailer is used



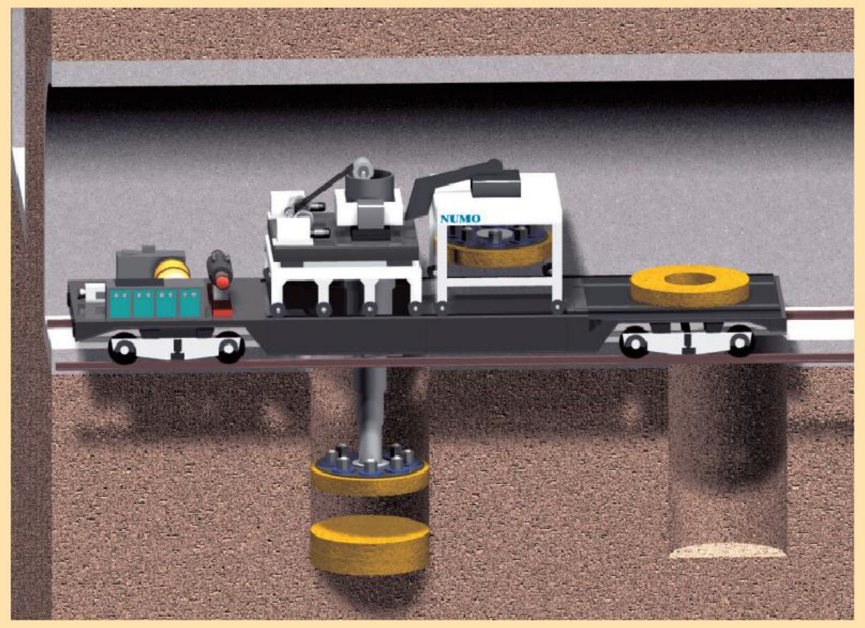
Shaft elevator



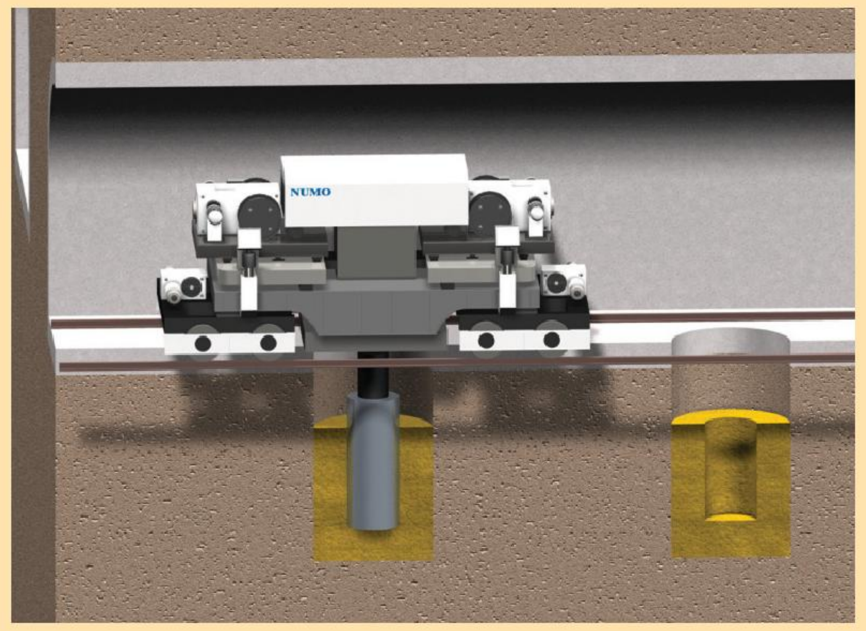
Transfer trailer for access ramps

Emplacement of vitrified HLW (example of vertical emplacement)

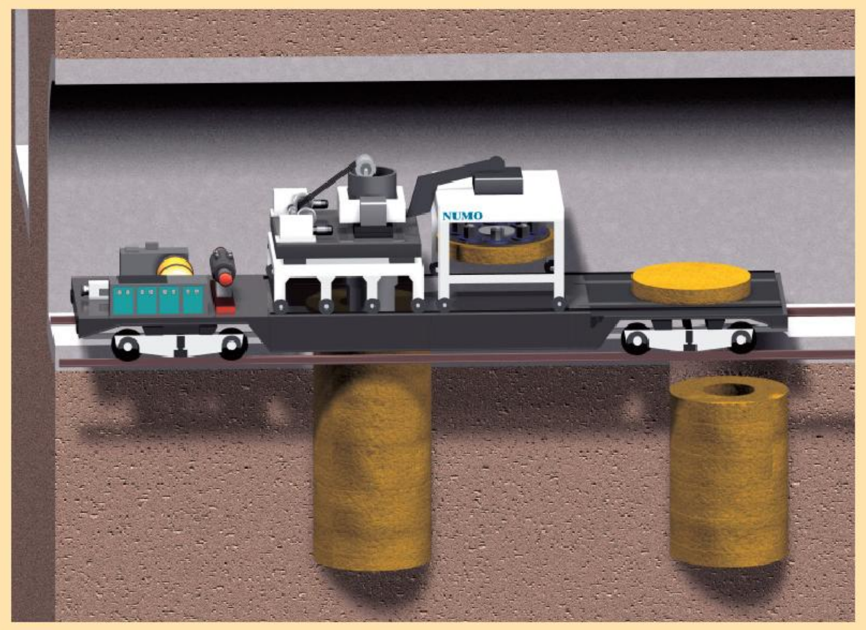
Emplacement of buffer



Emplacement of HLW



Emplacement of upper part of buffer

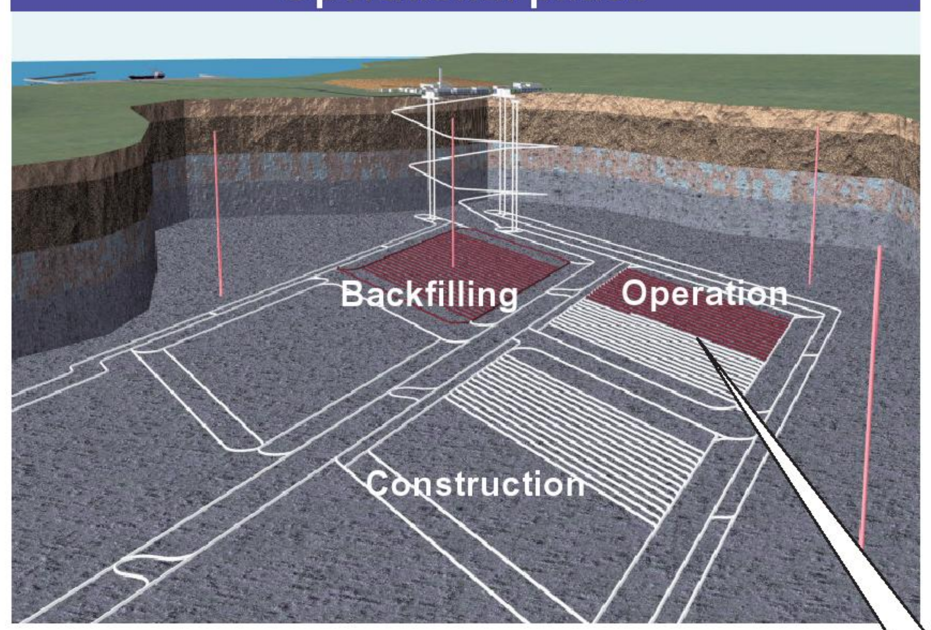


How is a Repository Backfilled?

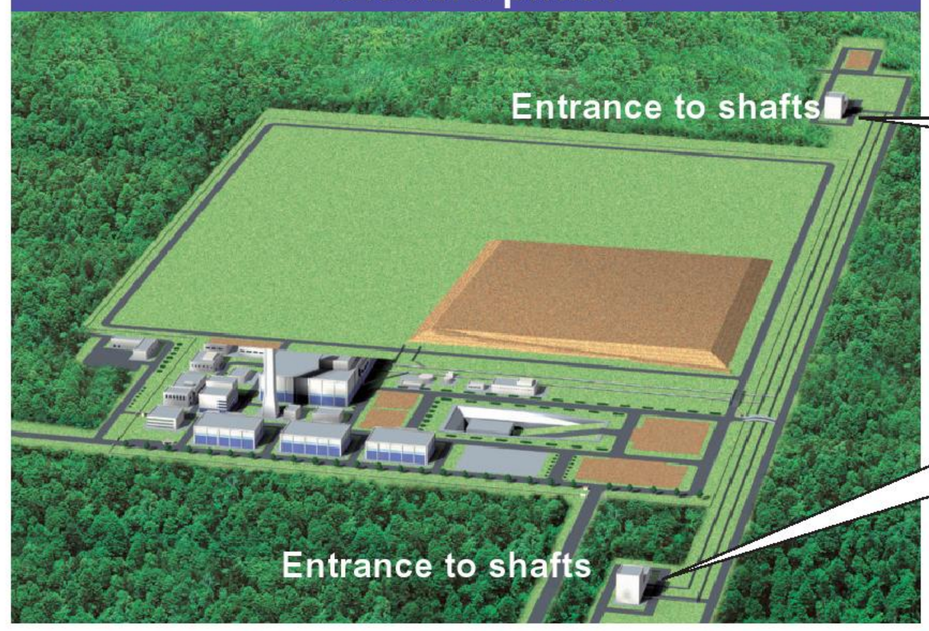
Applying current civil engineering technologies, disposal tunnels and shafts are completely backfilled and sealed.

Disposal tunnels are backfilled after emplacement of waste packages. At the time of repository closure, shafts and access tunnels are also backfilled. Backfilling is carried out using current civil engineering technologies.
Backfill materials are made from mixtures of excavated rock spoil and bentonite.
Backfilling methods depend on the design of tunnels and shafts.

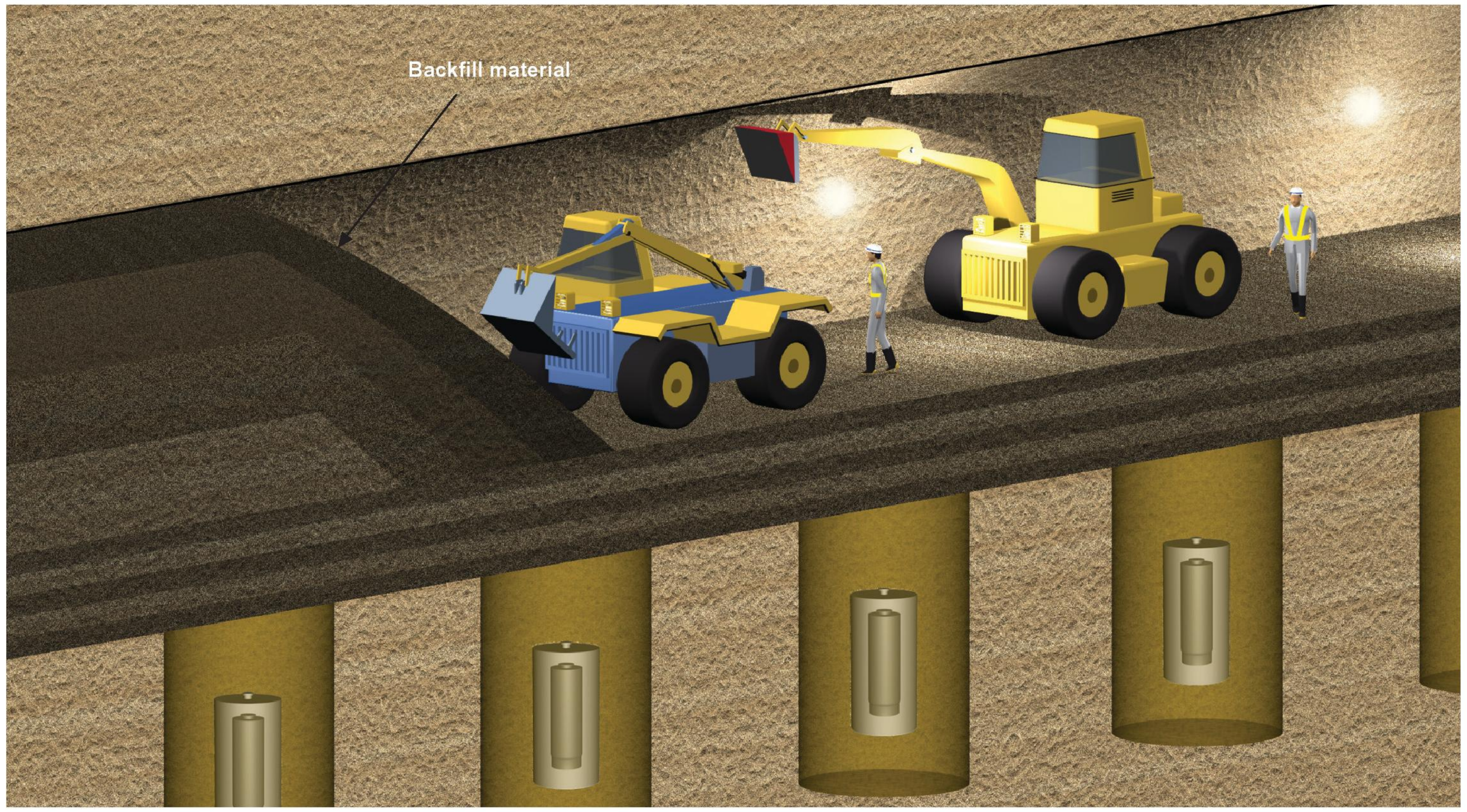
Operational phase

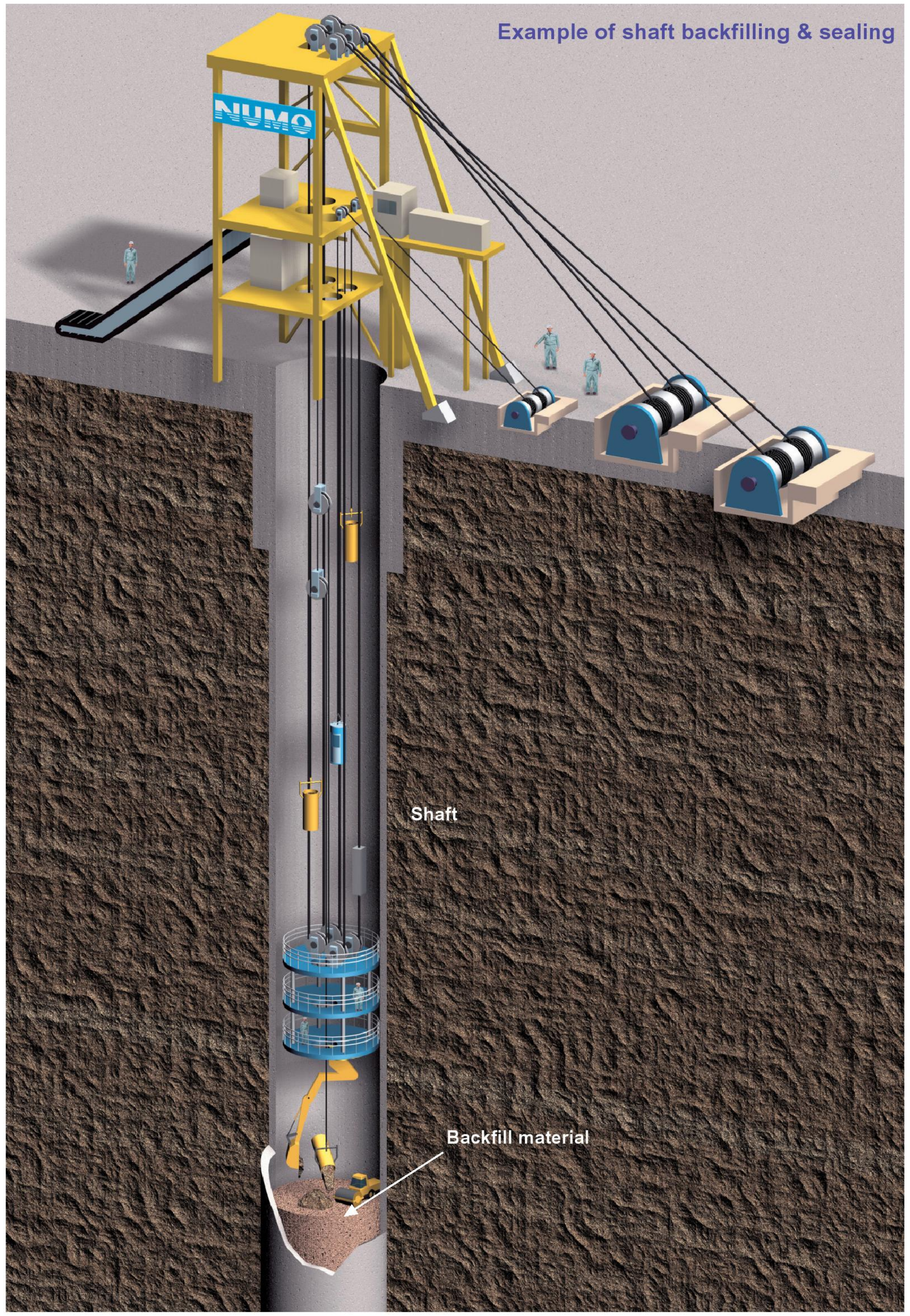


Closure phase



Example of disposal tunnel backfilling





How are Environmental Protection and Operational Safety Ensured?

Environmental protection measures are devised to minimize the impact on the natural environment of the repository and its operation. Operational safety measures are devised to ensure the safety of workers from radiation and possible accidents.

An environmental impact assessment is carried out prior to implementation. Based on the results, appropriate measures are taken to minimize impacts on the environment at all stages of repository development.

In the repository concept, radiation protection for both the public and workers is taken into account by considering all possible activities. The concept is then authorized on the basis of a license application which states the appropriate measures to be taken.

For repository operation, appropriate measures for the safety of workers also take possible accidents into account.

The above measures should be sufficiently flexible to be able to adapt to changes in circumstances in the future, e.g. by making use of updated technology.

The effectiveness of these measures can be confirmed by appropriate monitoring activities.

Surrounding environment

Protection measures for the environment

Air

- air quality
- meteorology
- noise/vibration
- smell
- radiation level

Air quality observation facility

Water

water chemistry, sediments and radiation level of:

- groundwater
- river,lake
- marine environment

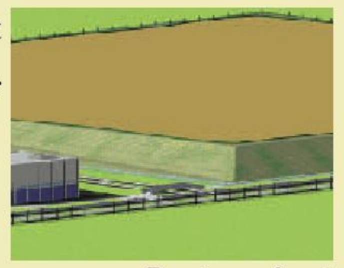
Soil/others

- air quality
- meteorology
- noise/vibration
- smell
- radiation level

investigation

Measures

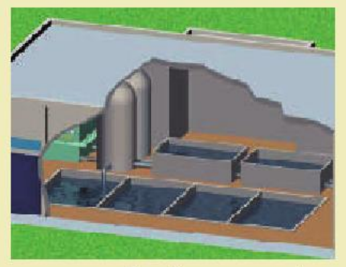
- dustproof equipment
- dust collection filter on ventilation systems
- active use of construction equipment with low noise, low vibration
- protection measures for specific eco-systems



eg. Dustproof net

eg. Biotope

- water purification by settling ponds and other drainage processing facilities
- building and rock spoil storage area harmonized with landscape
- measures against traffic disruptions



eg. Drainage water processing facility

eg. Greening

- no reuse of contaminated soil
- no surface discharge of untreated drainage water

- reuse of rock spoil as backfill material
- effective use of timber from felled trees
- reduction of waste volumes and recycling

ex. Reusing rock spoil as backfill material

investigation

Fauna/flora/eco-systems

- species, distribution, natural habitat and growth etc.

fauna investigation

Landscape/social environment

- natural environment, population, industry, land use, traffic density, pollution, etc.

Industrial/general waste

- waste generated by operation

Remediation of the site after repository closure

Post-closure environmental remediation

Preservation and regeneration of the natural environment

Working environment

Radiation protection

Phenomena potentially leading to radiological impacts on the environment and workers

- radiation from vitrified HLW
- damage to HLW due to accidental dropping
- release of radioactivity from HLW shortly after emplacement

anticipated

Measures

- radiation shielding
- remote handling
- procedures designed to prevent accidents with vitrified HLW, e.g. during earthquakes, etc.
- QA for design, manufacturing and construction of overpack and buffer
- transport ship: double-skin hull, collision prevention and fire control systems
- transport vehicle: equipped with dual braking systems and fall prevention system for the transportation cask
- radiation protection management for workers, etc.

Operational safety

Consequences of human activities and natural phenomena which could jeopardize workers

- ventilation failure
- rock fall / tunnel collapse
- power failure
- fire
- flooding, etc.

anticipated

Measures

Ensuring:

- ventilation
- drainage
- evacuation pathway
- emergency power supply
- fire proofing and fire control system
- preventative measures against the consequences of other natural phenomena, e.g. earthquakes causing rock fall
- continuous measuring of parameters such as stress field, ventilation, seepage for tunnel drilling, etc.

Photos: courtesy of Tokyo Elec. Power Co., METI and Chubu Elec. Power Co.

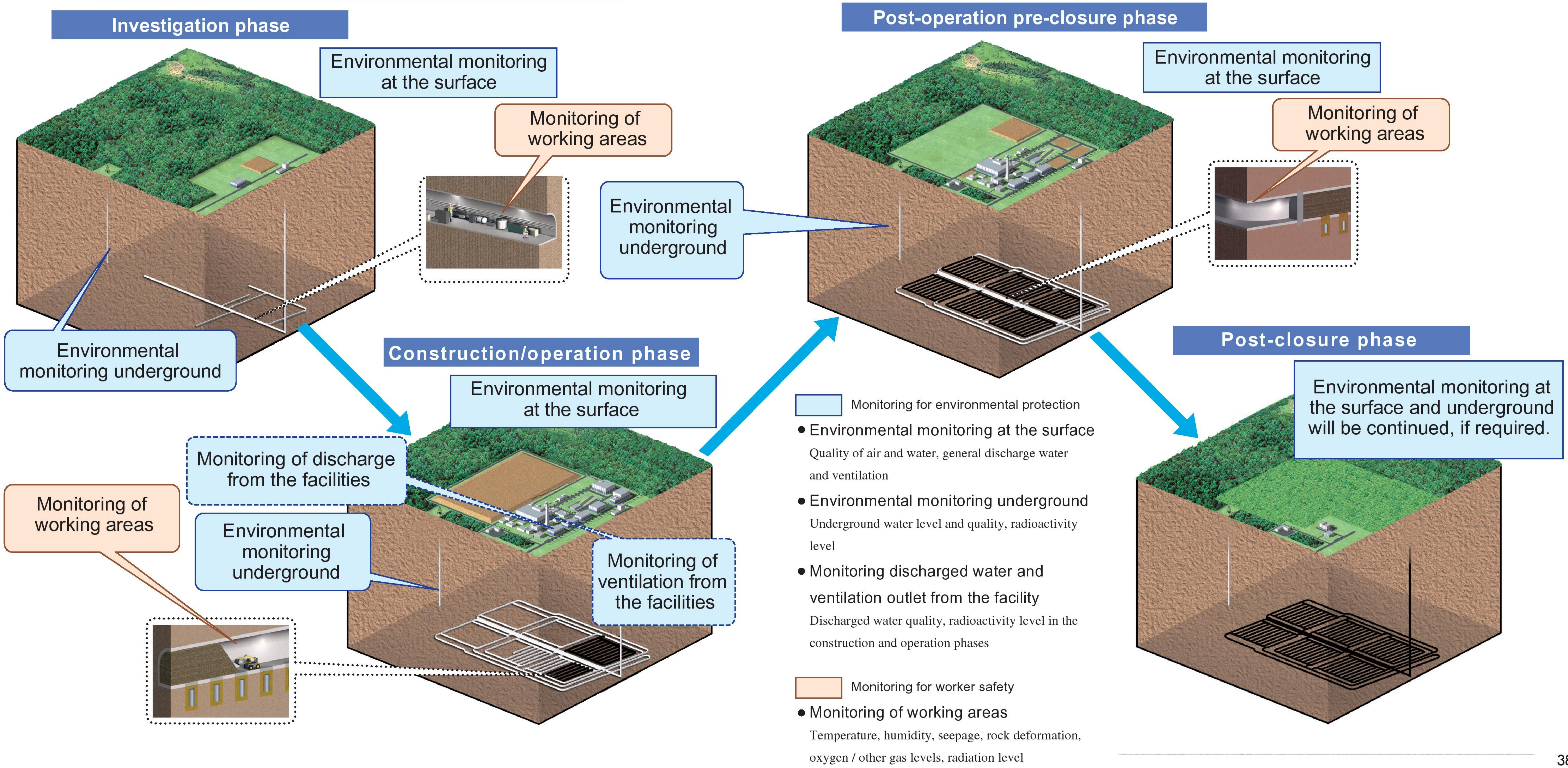
Environmental and radiation protection as well as operational safety are confirmed by appropriate monitoring activities carried out continuously from siting to repository closure and, if necessary, during a post-closure period.

In the event that a perturbation is detected, appropriate countermeasures are taken immediately after identifying its cause.

Monitoring results are open to the public to show that the appropriateness and effectiveness of the above protection measures will be continuously checked.

If necessary, environmental monitoring of the underground will continue after the post-closure phase, through monitoring at the surface and in boreholes.

The effectiveness of protection measures can be checked by monitoring



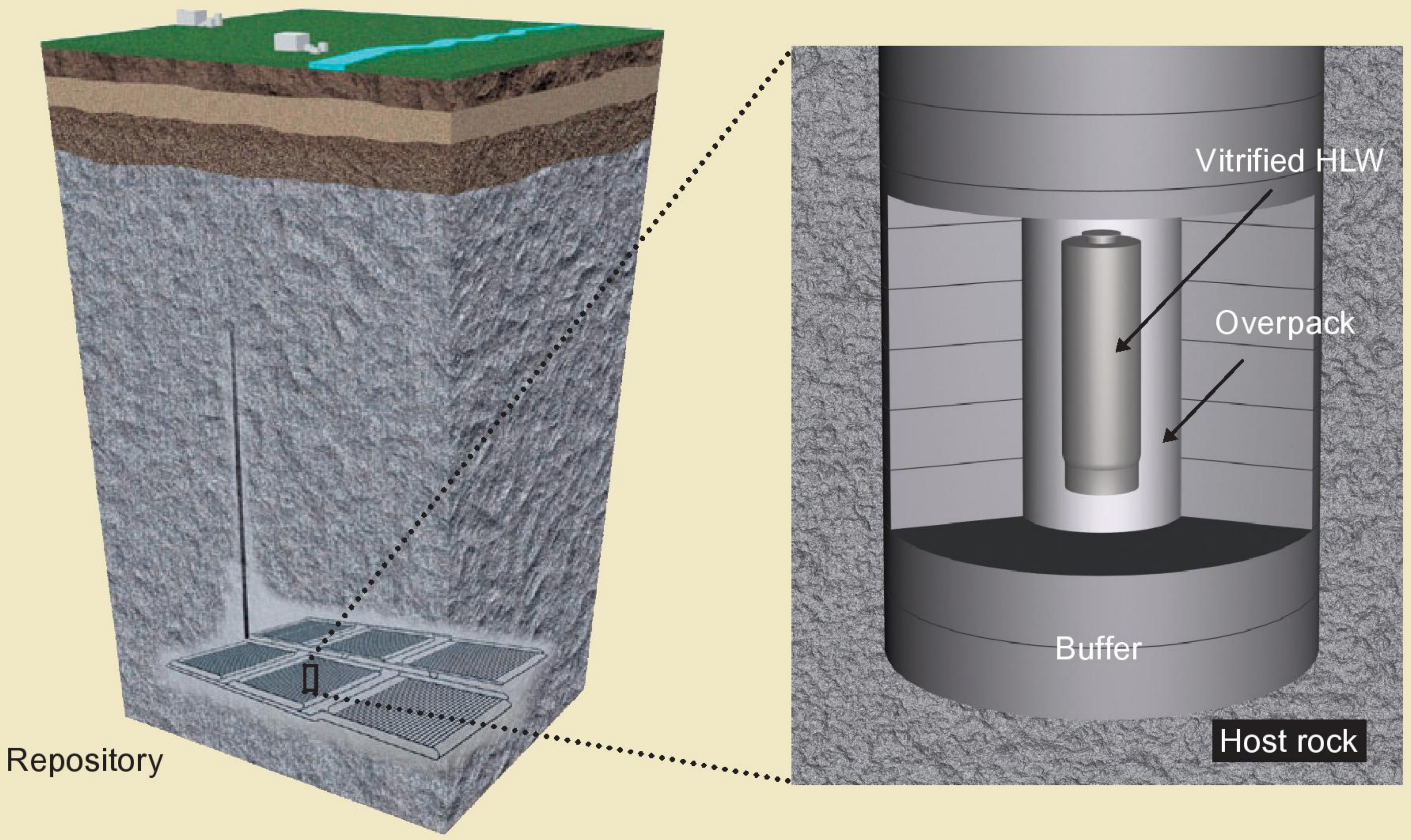
How is the Long-Term Safety of the Disposal System Ensured?

Selection of a disposal site with stable conditions combined with an appropriate repository design. An assessment of the performance of the repository system is used to demonstrate long-term safety.

To ensure long-term safety, a rigorous stepwise selection procedure for identifying a suitable site in a stable geological environment is carried out. A repository designed to take account of the features of the site is then constructed at sufficient depth to ensure isolation over long periods. Finally, the EBS and HLW are emplaced to meet rigorous quality checks.
Performance of the disposal system is assessed, based on sound scientific and technical knowledge, by considering what can happen to the repository after closure that may lead to potential impacts on the human environment. The long-term safety can be judged in terms of whether the results of the safety assessment are in compliance with safety standards. This is confirmed through the government's safety review for the license application prior to construction of the repository.
At the time of repository closure, it is required that the results of safety assessment be confirmed by taking account of additional data obtained from the construction and operational phases.

Construction of the repository in a stable geological environment

Measures for the long-term safety of a geological disposal system



Selection of a Final Disposal Site with stable conditions

- Site selection in a stepwise manner
- Transparent decision-making throughout the site selection process

Appropriate design and construction of the repository

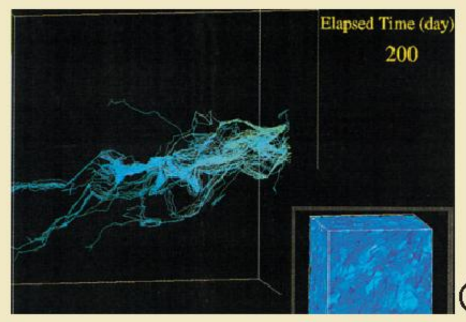
- Construction more than 300 m underground
- Overpack: designed to provide complete containment of vitrified HLW and prevent water contact for the period when radioactivity and heat generation are high; rigorous QA for manufacturing.
- Buffer:designed to provide low permeability, high absorption of radioactive materials, protection of waste package, etc.; rigorous QA for manufacturing and construction.

Assessment and compliance with safety standards

The primary concern is that radioactive material dissolved from the vitrified HLW will be transported to the surface environment. Based on scientific and technical knowledge obtained from the literature, experiments, field tests/investigations and calculations, the behavior of the radioactive material and its impact on humans can be estimated by computer calculations. It is important to confirm that the maximum impact on humans is below the regulatory safety standards even though it occurs in the far future.

Computer simulations


ⓐ

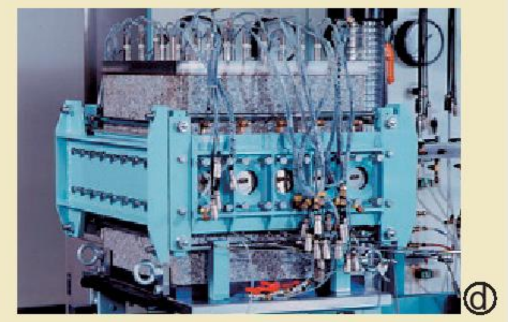


ⓑ

Experiments


ⓒ

Experiment using simulated underground chemical conditions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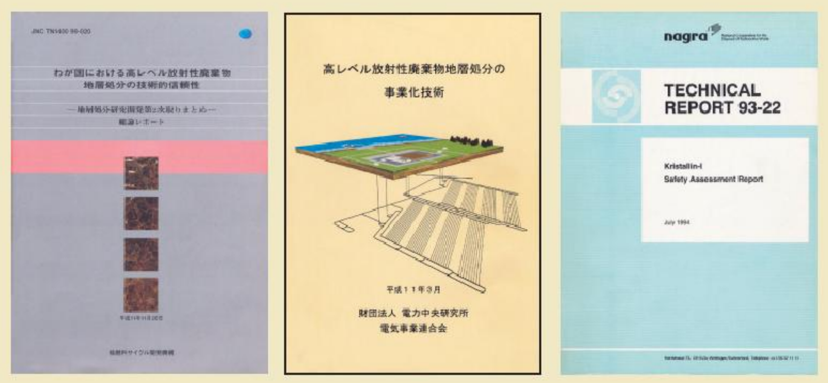
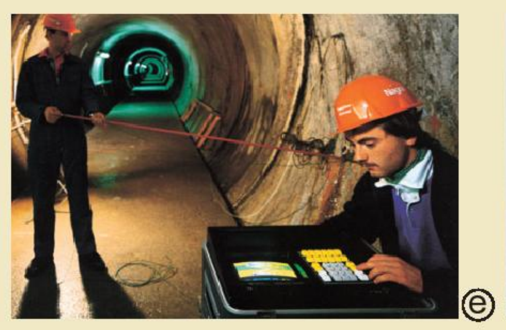
Experiment using simulated underground stress field

Literature



Field tests and investigations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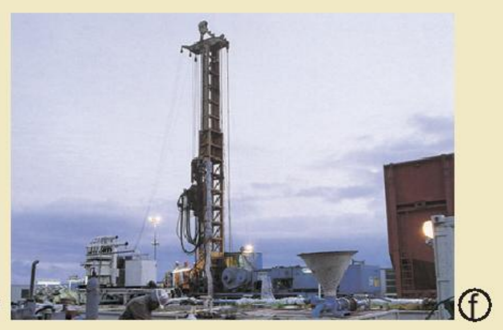
Tests/investigations in underground tunnel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Investigations using borehole

Estimation of transport of radioactive material to the human environment

Estimated radiological impacts on humans

Safety standards

Assessment of long-term safety

(Photos:ⓐ〜ⓓ courtesy of JNC, ⓔ,ⓕ courtesy of Nagra:taken from Special Edition (1998) and Nagra Bulletin No.2(1990).)

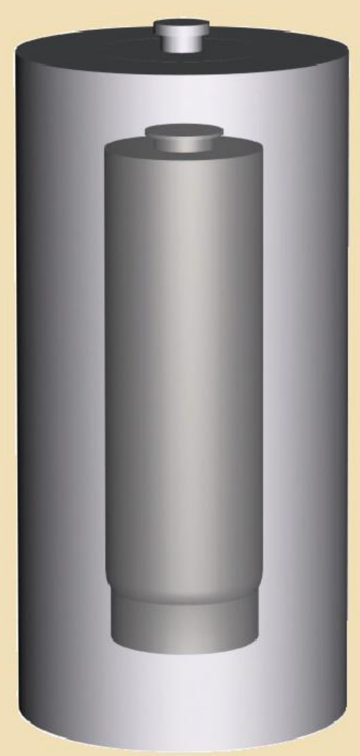
What can Happen if Radionuclides are Released into Groundwater?

The multi-barrier system limits release of radioactivity. Even if radioactivity is released into the human environment in the future, the amount will be extremely low.

The overpack provides complete containment of vitrified HLW for more than 1,000 years so that short-lived radioactive materials decay away.

Even if the glass makes contact with water immediately after overpack failure, the amount of radioactivity released into the water is extremely low and it takes a long time for it to reach the human environment. The radioactivity further decreases during this period, so that the amount released into the human environment is far less than that of naturally occurring radioactive materials.

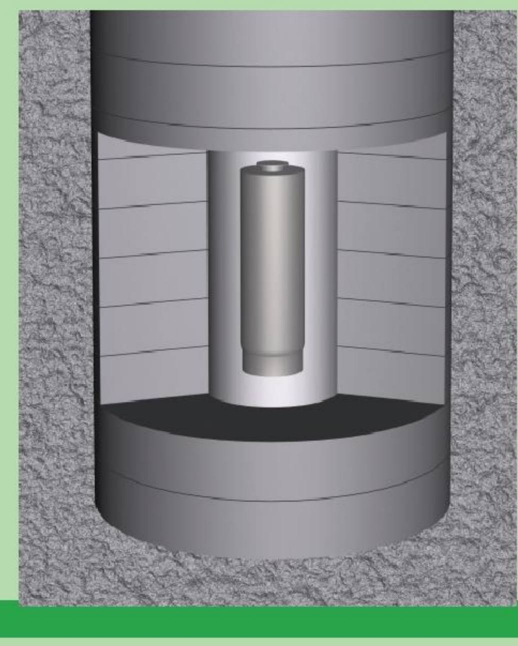
Predicted evolution of the geological disposal system



At least 1000 yrs...

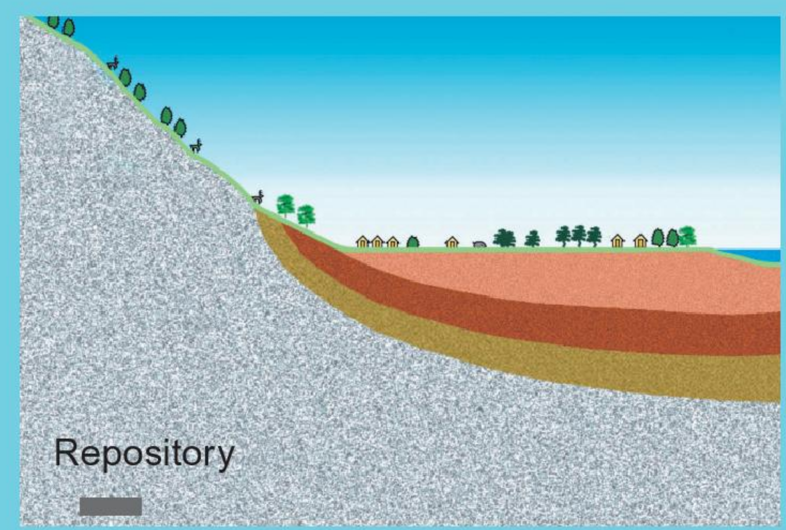
The carbon steel overpack is unlikely to be breached because of very slow corrosion underground. This provides complete confinement of the vitrified HLW for over 1,000 years.

A few tens of thousands of years...



- Even if the glass makes contact with water after overpack failure, the amount of radioactivity released from the glass is extremely low and it takes more than a few tens of thousands of years for the glass to completely dissolve
- In addition, radioactive materials are absorbed onto the buffer and rock, so that their movement is slowed.

A few hundreds of thousands of years....



- It can take more than a few tens of thousands of years for deep groundwater to return to the surface.
- Since movement of dissolved radioactive materials is slowed by absorption onto the rock, it takes longer for them to reach the surface.

After a few hundreds of thousands of years...

Even if radioactivity is released into the human environment, the amount is far less than that of naturally occurring radioactive materials found in soil and river water, etc.

Generation | 100yrs | 1,000yrs | 10,000yrs | 100,000yrs

Decrease in radioactivity

Short-lived radioactive materials decay completely during the period of overpack containment.

Most of the long-lived radioactive materials decay either in the glass or in the buffer and surrounding rock so that the amount released into the human environment is extremely low.

Very long-lived radioactive materials from HLW also decay during migration; most of these are finally released into the human environment but the total inventory is extremely low.

How Does the Radiological Impact of Geological Disposal Affect Our Lives?

There are no significant impacts on our lives during either the operational phase or the post-closure phase.

The repository is operated with appropriate controls so as to ensure no significant radiation impact on the environment.
Even if radioactivity is released into the human environment after closure of the repository, the estimated radiological impact on our daily lives would be extremely low compared with normal exposure arising from natural radiation.

Radiological impact due to geological disposal

Operational phase

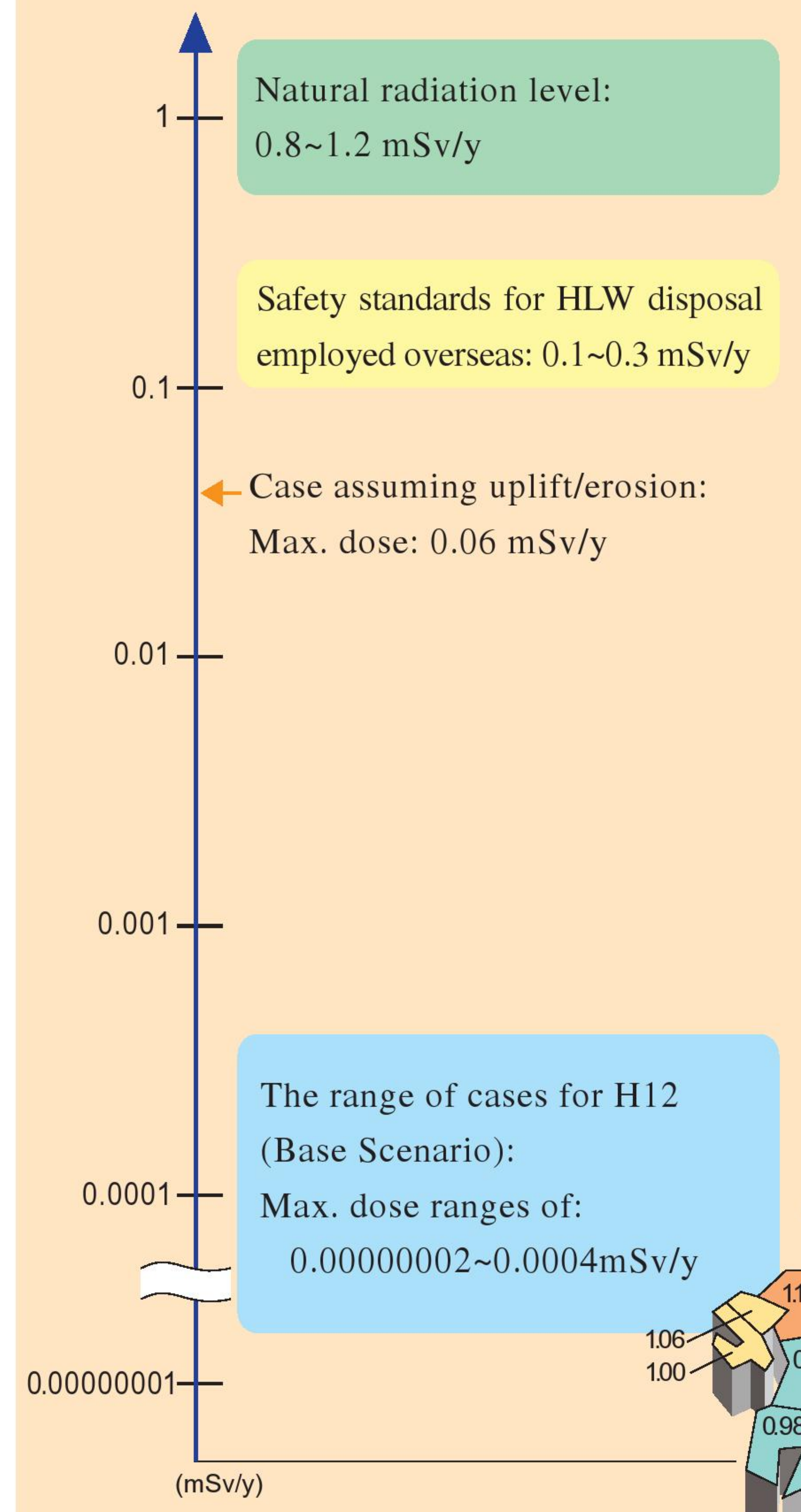
Like other nuclear facilities, repository operation, including transportation of vitrified waste, is carried out in a controlled manner with rigorous safety management and never leads to exposures exceeding the regulatory protection levels.

Post-closure phase

Even if radioactivity is released to the human environment in the future, as is considered in JNC's H12 Report (Japan Nuclear Cycle Development Institute, 2000), its impact on human beings is extremely low.
According to the H12 calculations, for a repository built in the range of geological environments which occur in Japan, the maximum calculated doses are between 0.00000002~0.0004 mSv/y. These are approximately 1/2,000 ~1/50,000,000 of the natural radiation level in Japan (0.8~1.2 mSv/y).
Even in an extreme case, assuming uplift of the repository and eventual erosion at the surface, the maximum calculated dose is only 0.06 mSv/y.
The above results are also below the range of safety standards employed overseas (0.1~0.3 mSv/y).
The Japanese safety standards for HLW disposal will be set by the regulatory authority at later stage.

Extremely low compared with natural radiation levels

Estimated impacts in post-closure phase



Natural radiation levels

We are exposed to natural radiation in our daily life.

In our daily life, we are exposed to natural radiation from rocks and soil, cosmic rays and intake of naturally occurring radioactive materials. This fact will remain the same in the future.
The natural radiation level varies in different places and according to lifestyle, with ranges of 0.8~1.2mSv/y (difference : about 0.4mSv/y). However, the impact on our health arising from these regional and habitual differences is negligible.

Natural radiation levels in Japan

(National Institute of Radiological Sciences, 1988)

The figure shows natural radiation levels from rock and soil, cosmic rays and ingestion of foodstuffs in each region. (note : inhalation of radon, which also depends on different places and habits, is not included in the figure).