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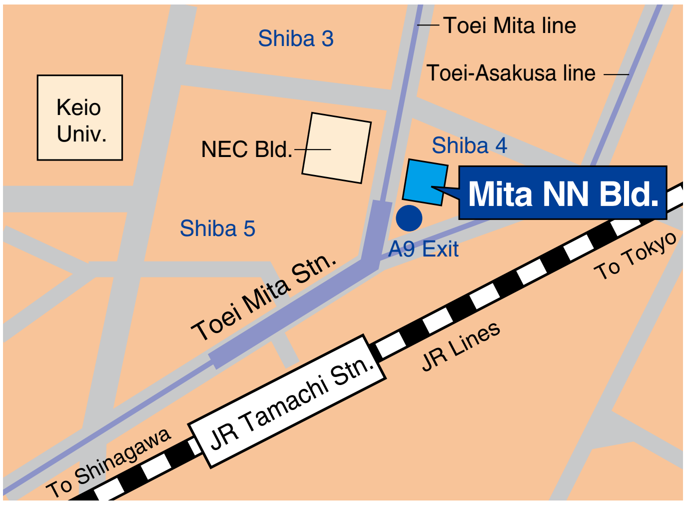

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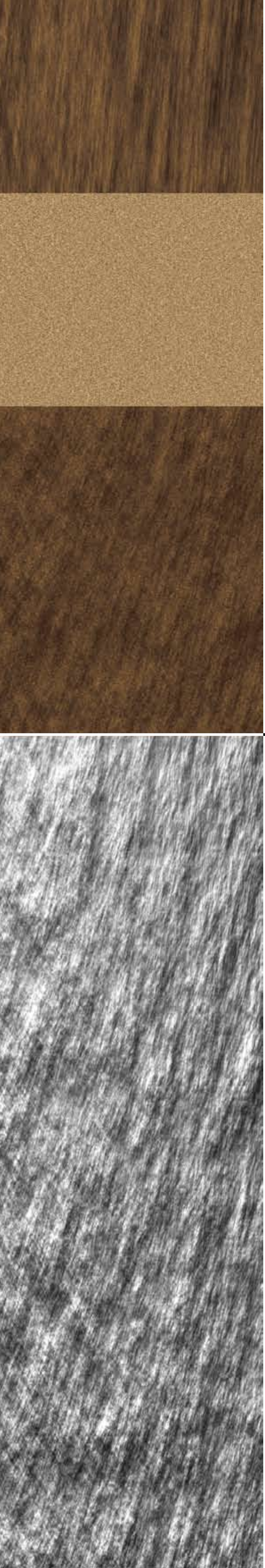

Geological Disposal of TRU Waste

September, 2008

NUMO
原子力発電環境整備機構

Contents

1 Introduction

Approximately one-third of Japanese electricity production depends on nuclear power, which plays a key role as a sustainable energy source due to stability of uranium supply and provision of clean energy without carbon dioxide emissions, thus reducing global warming.

From the viewpoint of effective utilization of energy resources in Japan, a policy of recycling nuclear fuel is supported as a fundamental strategy. Re-usable materials such as uranium and plutonium are recovered from reprocessing of spent fuel.

During reprocessing, low-level radioactive waste (LLW) with low heat production and long half-lives (TRU waste*) is generated in addition to high-level radioactive waste (HLW)*note1. HLW and some TRU waste require to be disposed in deep geological formations in order to isolate them from our living environment over long time periods.

* TRU waste: LLW generated during reprocessing and MOX fabrication. "TRU" comes from transuranium elements, i.e. elements with atomic numbers higher than that of uranium.

In addition to its existing mandate for geological disposal of vitrified HLW, NUMO has officially been designated as the implementor of geological disposal of TRU waste*note2, and this brochure introduces the project.

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*note 1: The Specified Radioactive Waste Final Disposal Act defines Class 1 specified radioactive waste as vitrified high-level radioactive waste extracted or produced from reprocessing of spent fuel. This waste category is referred to as high-level radioactive waste or HLW in this brochure.

*note 2: The Specified Radioactive Waste Final Disposal Act defines Class 2 specified radioactive waste as TRU waste requiring geological disposal. This waste category is referred to as TRU waste in this brochure.

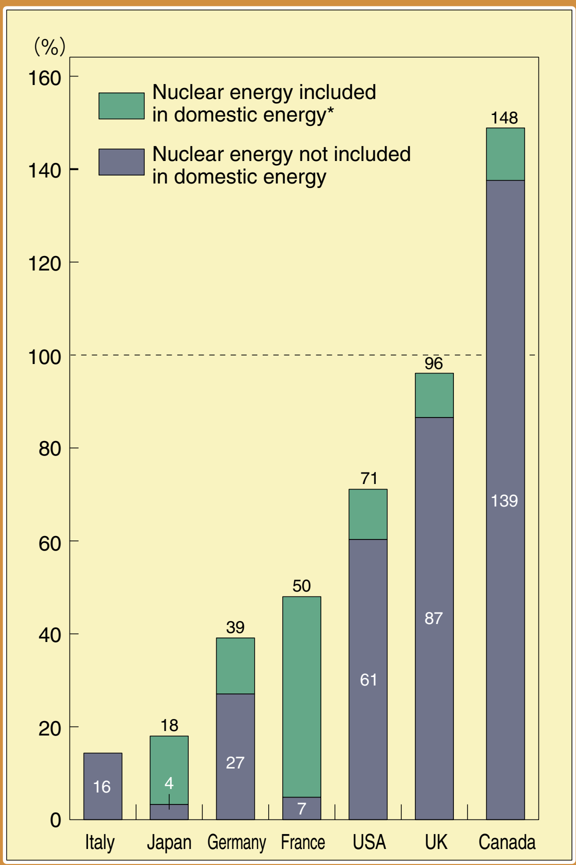
2 Features of nuclear power generation

Nuclear power plays an important role in Japan, where mineral resources are limited.

Approximate one-third of the country's electricity production is supplied by nuclear power plants.

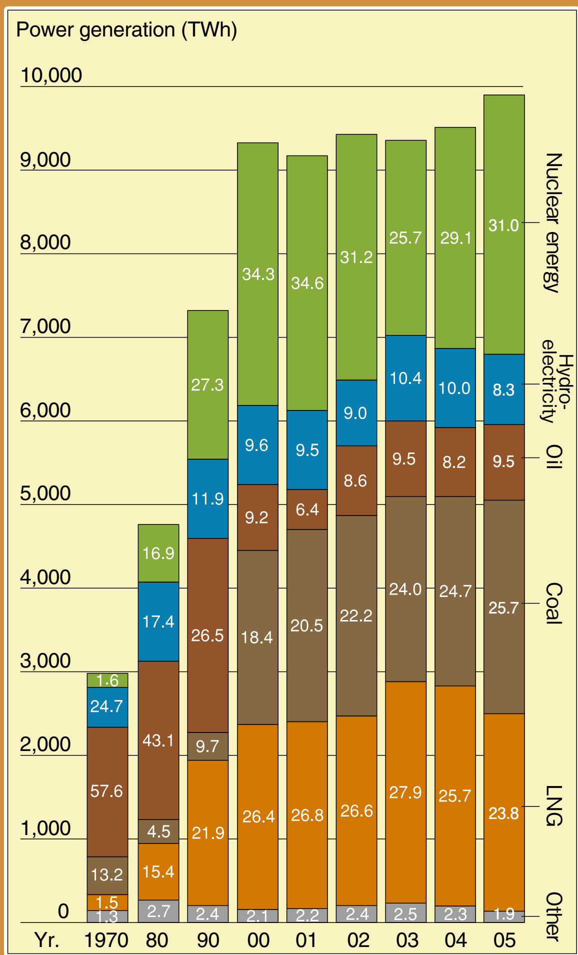
Self-sufficiency of energy supply in major countries

Japan's self-sufficiency in terms of energy supply is lower than that of other major countries.



Source: IEA/ENERGY BALANCES OF OECD COUNTRIES (2003-2004)
* Nuclear fuel is considered as quasi-domestic energy, because uranium is reusable for a long time once imported.

Historical trend of Japan's power generation by source



(note)
1. This figure shows power generation by 10 electricity utilities.
2. Others include LPG and geothermal power.
3. Figures do not necessarily total 100% due to rounded numbers.
Source: Agency for Natural Resources and Energy "Outline of Electric Power Development, 2006"

In terms of self-sufficiency of energy supply, Japan can generate only 4% of its total requirement through hydropower and geothermal energy. Even including nuclear power, only 20% of energy consumption can be supplied domestically. Currently, approximate one-third of Japan's electricity production relies on nuclear power, which is important from an environmental perspective as it emits no carbon dioxide. Considering the entire process through construction, operation and decommissioning of power plants, carbon dioxide emission is extremely low and, in terms of sustainability, it is therefore a very important power source.

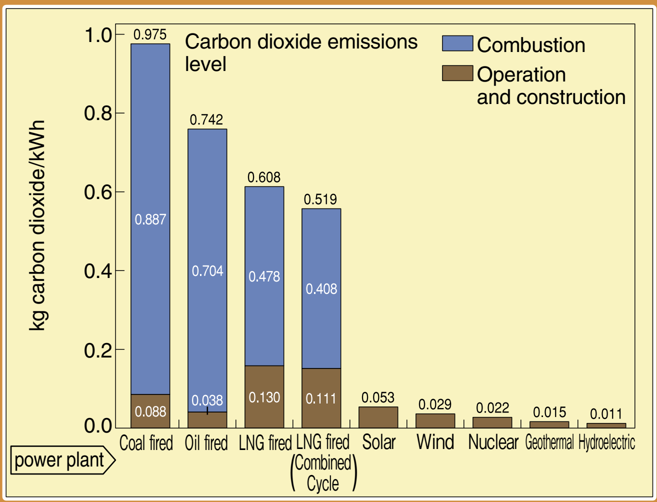
Although the uranium used as fuel for nuclear power production can also be considered as a limited resource, like oil, the possibility of recycling spent nuclear fuel by reprocessing is beneficial in terms of ensuring a secure energy source over long time periods. Nuclear power generation is therefore an important component of sustainable economic development, which at the same time protects the environment of Japan.

Carbon dioxide emission by energy source

Nuclear power plants do not emit carbon dioxide in the power production process. For the life cycle of a power plant, from construction and decommissioning, the total carbon dioxide emission is low compared to other power sources. Although solar, wind, geothermal and hydroelectric power emit almost no carbon dioxide, the power supply from these sources is not stable as it depends to a large extent on climate or location.

(note)
1. The carbon dioxide emission is calculated from the total energy consumed in mining, plant construction, fuel transport, refining, plant operation and maintenance, etc., as well as burning of fuel.
2. Data for nuclear power include reprocessing of spent fuel in Japan, use of MOX fuel in thermal reactors (assuming reprocessing once) and disposal of high-level radioactive waste.

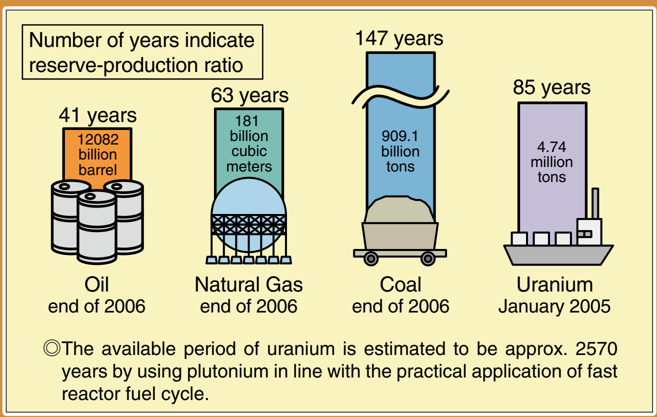
Source: CRIEPI Report 2000.03/2001.08 in Japanese



Reserves of global energy resources

Although the uranium used for nuclear power generation is a limited natural resource, its efficiency can be increased considerably by reprocessing. This contributes to ensuring a long-term, secure energy supply.

Source: BP Statistical Review of World Energy 2007 URANIUM 2005

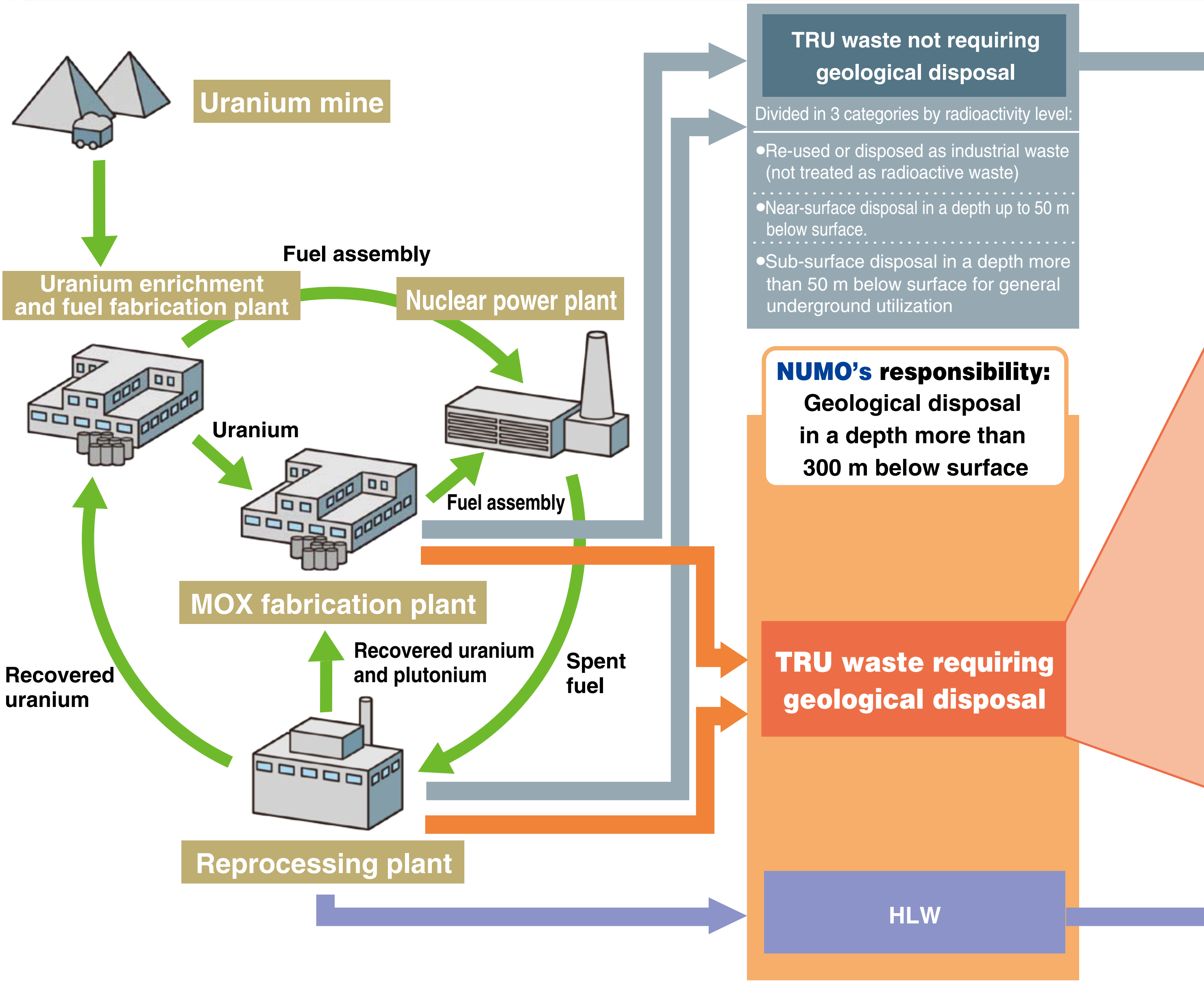


3 Overview of TRU waste requiring geological

●What is TRU waste?

TRU waste that requires geological disposal is generated by reprocessing and MOX fuel fabrication.

NUMO is responsible for geological disposal of TRU waste, as well as high-level waste.



This diagram shows radioactive waste generated by reprocessing and MOX fabrication.

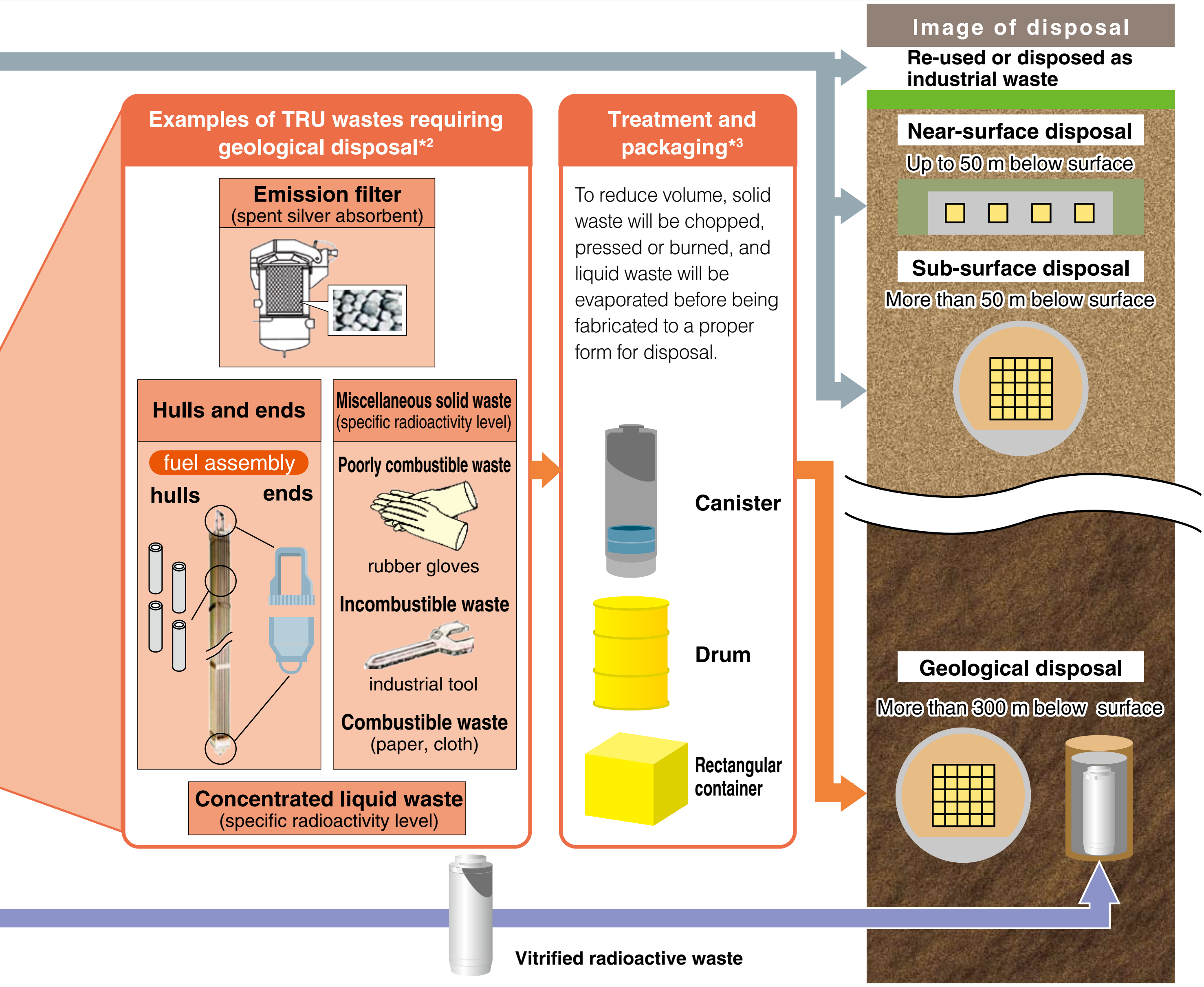
disposal:

In Japan, where natural energy resources are limited, nuclear fuel cycle policy is promoted to ensure effective recycling of materials such as uranium and plutonium recovered by reprocessing of spent fuel. Besides high-level waste, reprocessing also produces low-level waste with lower heat generation and activity levels.

Of this low-level waste, waste with specified concentrations of radionuclides with long half-lives requires to be disposed in a geological repository, as is the case for high-level waste. This ensures the required long-term isolation from the human environment.

TRU waste is also generated by the operation of MOX fuel fabrication plants*1 and by the decommissioning of both reprocessing and MOX fabrication plants. NUMO will implement geological disposal of TRU waste. The total volume of TRU waste requiring geological disposal is expected to be around 18,100 m^3.

*1 MOX (mixed oxide) fuel fabrication plant: a fuel fabrication plant that uses uranium and plutonium from reprocessing.



*2 Details are provided in Appendix 1 *3 Packages according to waste properties are described in Appendix 2

3 Overview of TRU waste requiring geological

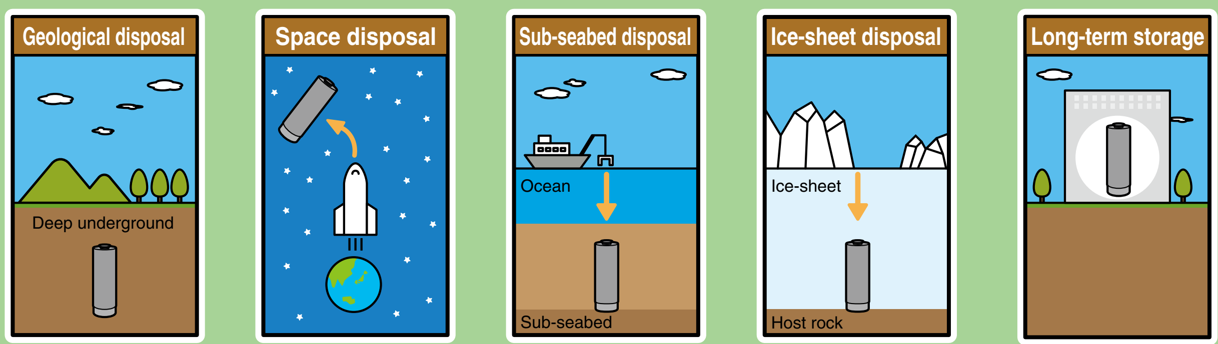
●Characteristics of geological disposal

Various concepts have been considered for isolating radioactive waste from the human environment for several tens of thousands of years.
Geological disposal is considered to be an effective method for confining radioactive waste for a very long time due to the inherently favorable isolation features of the deep underground environment.

Why geological disposal?

●Alternative concepts considered

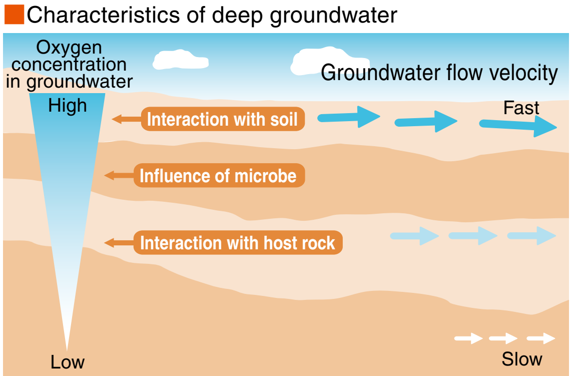
No need of long-term measures				Need of long-term measures



Geological disposal	Space disposal	Sub-seabed disposal	Ice-sheet disposal	Long-term storage
Using the favorable containment features provided by the deep underground environment	Problematic with current space technology	Prohibited by international political and legal agreements covering the seabed	Prohibited by international political and legal agreements covering the Antarctic	Imposes undue burdens on future generations

Characteristics of confinement in deep underground

■Characteristics of deep groundwater



Radioactive substances can be contained for a long time in a reducing environment with slow groundwater flow.

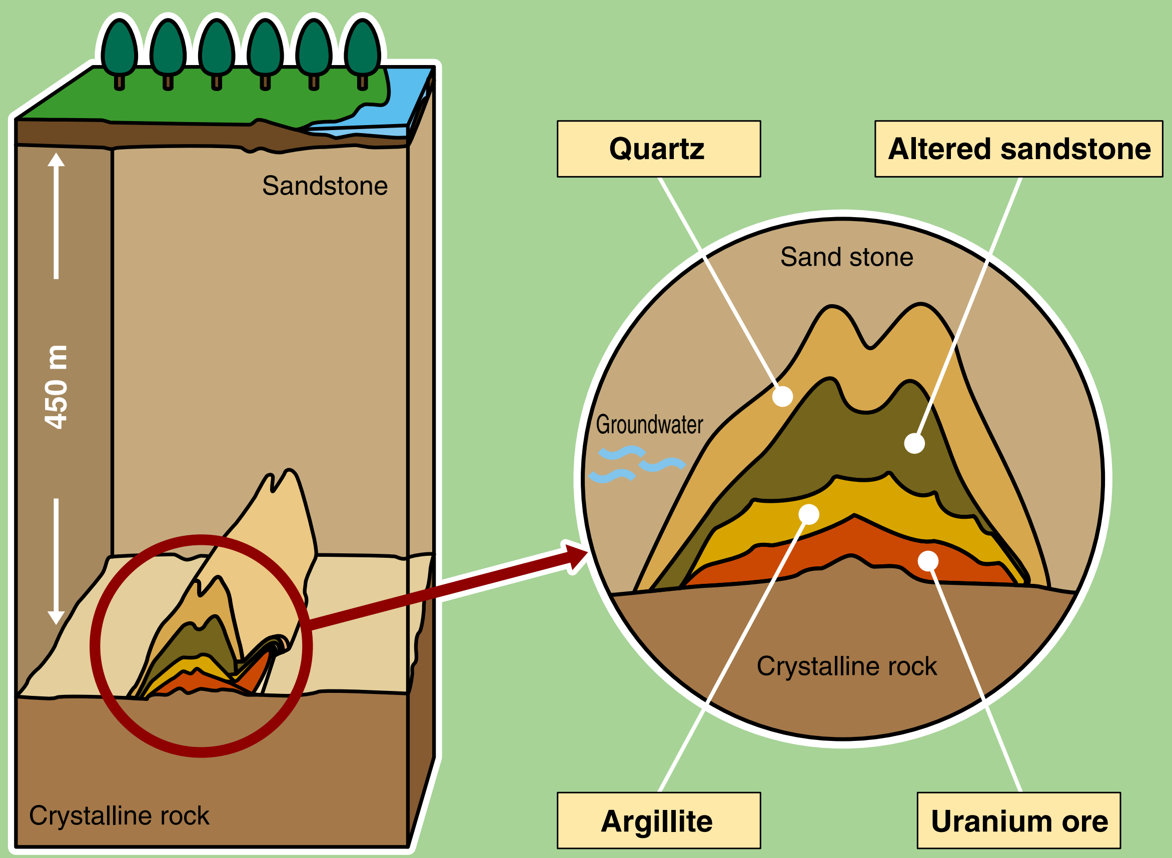
Deep meteoric water has a low oxygen content due to interactions with the host rock and consumption by microbial reactions. The deep underground environment is chemically stable and there is virtually no dissolution or corrosion of metals. Dissolved substances also migrate extremely slowly because of the slow groundwater flow rate (e.g. several mm/year).

disposal:

Although management of waste with active human intervention appears to provide the required security and safety, it is difficult to ensure that such institutional management can be maintained for the necessary timescales of tens of thousands of years until radioactivity levels have decayed sufficiently. A range of concepts for disposing of radioactive waste have been reviewed by international authorities.
Of the concepts examined, disposal in a stable, deep geological environment is acknowledged worldwide as being the most safe option that does not rely on active human management. The deep underground environment has favorable properties for disposal such as slow groundwater flow and reducing conditions that limit the dissolution of radionuclides. Geological formations also have the ability to retain substances dissolved in groundwater and thus to retard their transport and confine them in the geological environment.
This ability of the geological environment to confine radioactive substances has also been demonstrated by studying natural examples, so-called natural analogues. At Cigar Lake in Canada, for example, a uranium deposit that was formed about 1.3 billion years ago has been preserved in a stable condition and shows no traces of radioactivity at the surface that can be distinguished from natural background radioactivity.

Example of a natural analogue

The uranium ore deposit at Cigar Lake has remained isolated for more than 1300 million years since its formation. Underground conditions led to isolation of the radioactive substances for an extremely long time period.



3 Overview of TRU waste requiring geological

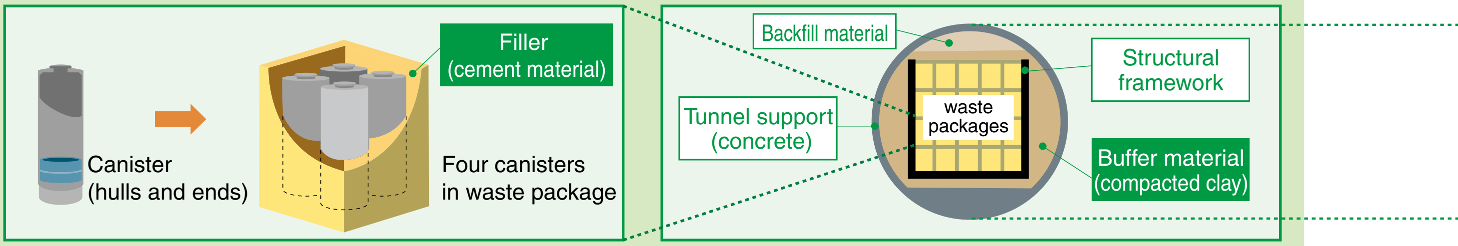
●Geological disposal system of TRU waste

In the geological disposal system, long-term safety is assured by the engineered barrier system designed in accordance with the property of waste and the natural barrier provided by the geological environment.

On this page, hulls and ends are presented as examples of TRU wastes with relatively high heat generation and radioactivity levels requiring geological disposal.

Barrier system of TRU waste in geological disposal

Example of the engineered barrier system



Filler (cement material)

Retardation of radionuclide migration

Waste canisters will be placed in a large container to form a waste package, which is infilled with cement material to immobilize the waste. The cement material has sorbing properties and can retard the migration of radionulides.

Buffer material (compacted clay)

Retardation of groundwater flow and radionuclide migration

The structural framework in which the waste packages are emplaced is surrounded by buffer material consisting mainly of a natural compacted clay such as bentonite. The buffer material has a low permeability and sorbing properties and can retard the migration of radionulides.

Comparison of radioactivity and heat generation of HLW and TRU requiring geological disposal

The value of radioactivity and heat generation of hulls and ends right after disposal:1

	Period	HLW	TRU for geological disposal
Radioactivity	Shortly after disposal	80	1
	After 1000 years	0.2	0.008
Heat generation	Shortly after disposal	130	1
	After 1000 years	2	0.04

Radioactivity and heat generation of hulls and ends are equivalent to those of HLW after 1000 years.

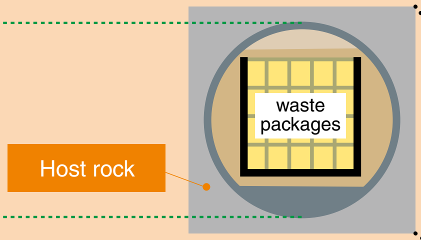
disposal:

HLW and TRU waste requiring geological disposal will be disposed in deep underground in a stable host rock formation. The waste is classified* according to its property, and the engineered barrier design takes this classification into account. The system consisting of the engineered and natural barriers isolates the waste from the human environment for very long time periods.

Because of its high heat generation and high radioactivity levels, HLW will be encapsulated in a metal overpack to prevent contact with groundwater for at least 1000 years. For TRU requiring geological disposal, its highest heat generation and radioactivity levels are equivalent to those of 1000-year-old HLW, thus an overpack is therefore not required.

* Details of classifcation are provided in Appendix 2.

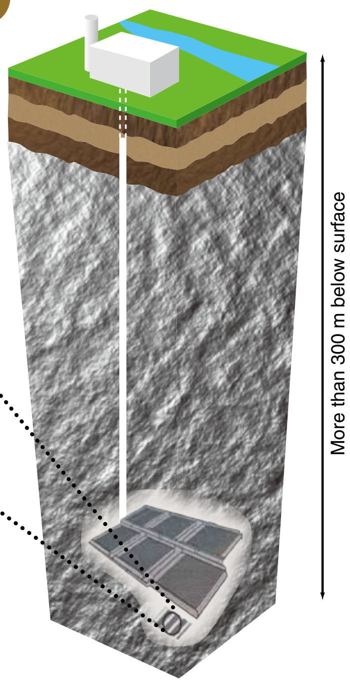
Natural barrier



Host rock

Retardation of radionuclide migration

Radionuclide migration in the deep underground environment is extremely slow because of slow groundwater flow, diffusion and sorption in the host rock

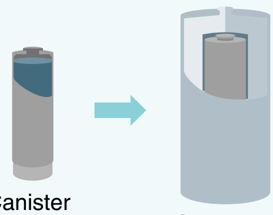


Repository

Radioactive substances are confined by a system consisting of engineered and natural barriers more than 300 m below ground surface. Even if radionuclides are dissolved in groundwater, it takes extremely long times to migrate to the biosphere. Any radionuclides that reach the biosphere will have decayed to insignificant levels and will have no impact on the human environment.

Comparison of engineered barriers

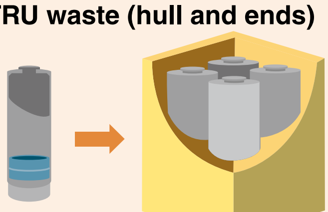
HLW



Canister
(vitrified waste)
diameter: 40 cm
height: 130 cm

Overpack
thickness: 19 cm

TRU waste (hull and ends)



Canister
(hulls and ends)
diameter: 40 cm
height: 130 cm

Waste package
in packs of four
1.2 m×1.2 m×1.6 m (height)

Shape and size of the canister/package are just an example.

3 Overview of TRU waste requiring geological

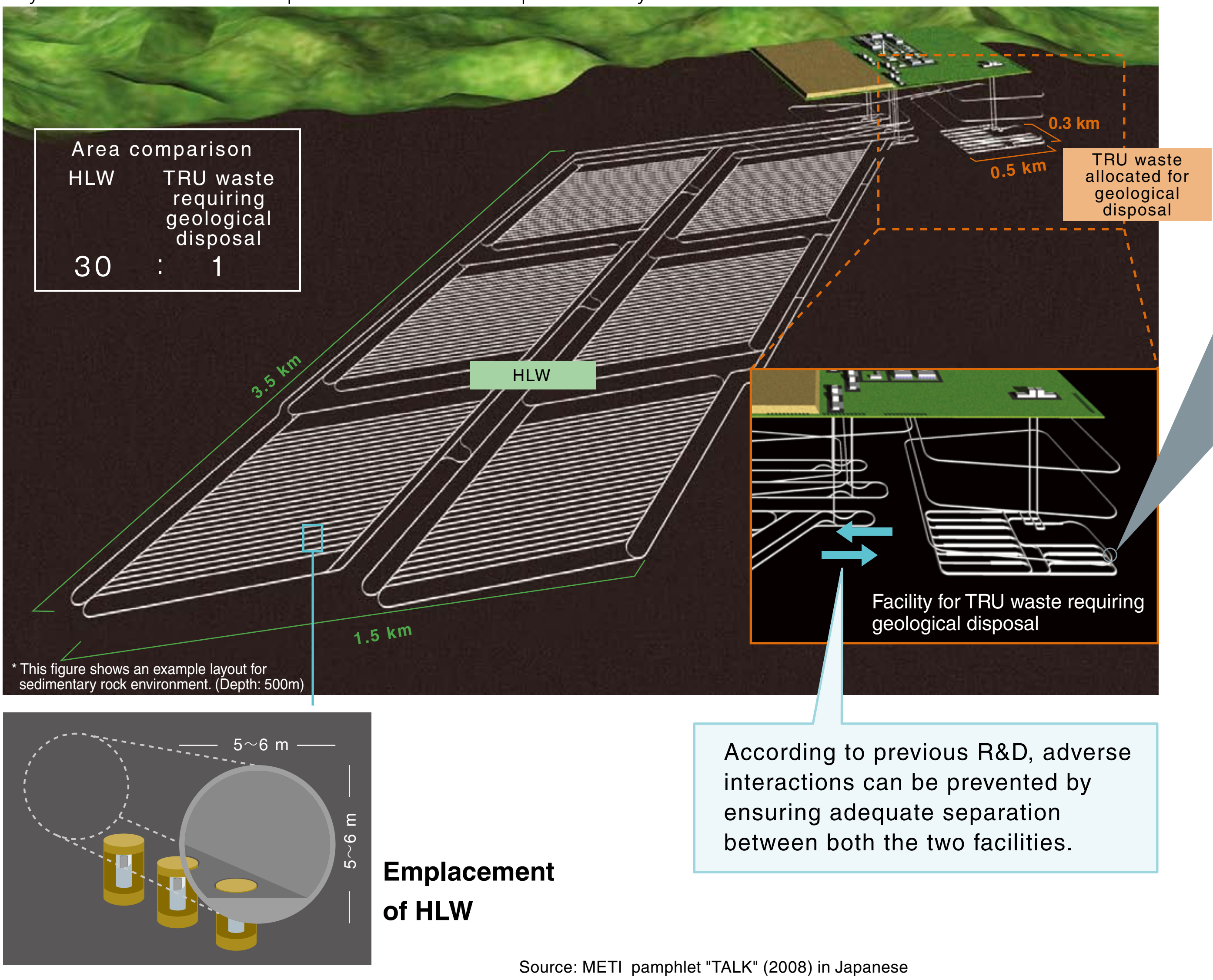
●Geological disposal system of TRU waste

The disposal facility for TRU waste requiring geological disposal will be designed and constructed taking into account the diversity of waste properties.

Although components of the disposal facility are the same as those of HLW, the scale of underground facilities will be much smaller.

Layout example of disposal facilities

Layout in the case of co-disposal with the HLW disposal facility



Emplacement of HLW

According to previous R&D, adverse interactions can be prevented by ensuring adequate separation between both the two facilities.

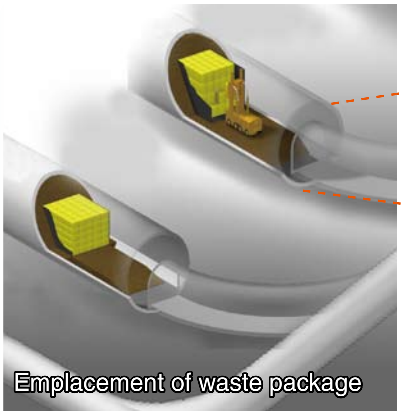
Source: METI pamphlet "TALK" (2008) in Japanese

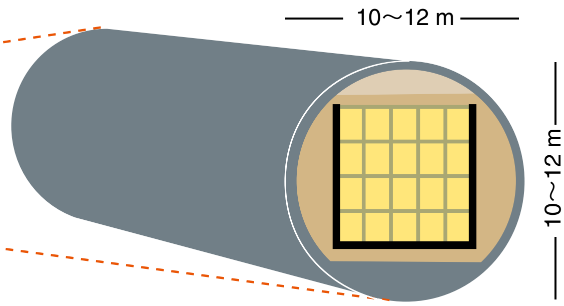
disposal:

The engineered barrier system and the layout of the underground installations for the TRU disposal facility will be designed in accordance with the diversity of waste properties. As well as the HLW repository, the TRU disposal facility will consist of main tunnels, access tunnels and surface facilities.

LLW produces much less heat than HLW, and high density emplacement in large cross-section tunnels is therefore possible. Although the total volume of TRU waste requiring geological disposal is greater than that of HLW, the scale of the underground facilities will be around one-thirtieth of that for HLW as the latter requires sufficient pitch between waste containers due to the high heat generation.

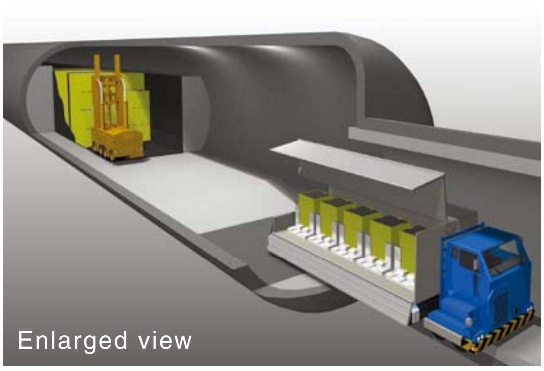
Disposal facilities can be constructed in a range of environments that meet specific geological requirements.
Disposal facilities for TRU waste can be co-located with facilities for HLW on the condition that the host community accepts this arrangement.





Geological disposal of TRU waste

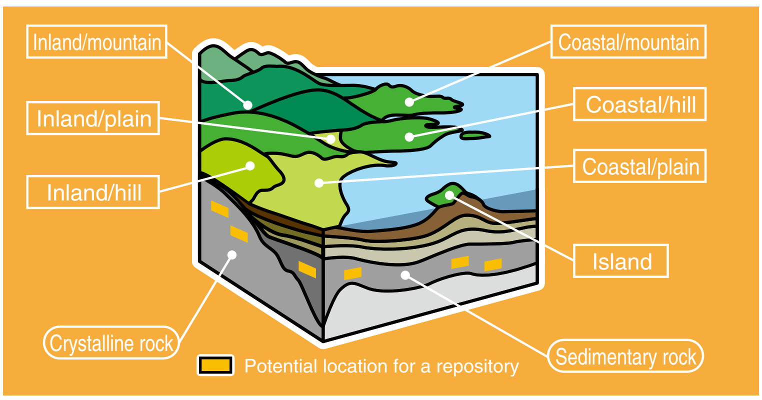
TRU waste can be emplaced with high density because of its low heat generation. The waste will be classified depending on its property, and the engineered barriers will be designed based on this classification.



Stable waste packages are transported to the underground facilities and emplaced with appropriate safety measures.

Range of siting environments

The repository will be designed and constructed taking into account characteristics of the siting environment, such as geography, topography and geology. In the case of a coastal site, the repository can be constructed beneath the seabed.



4 Schedule of disposal and site selection procedure

The site selection procedure for a TRU waste repository is conducted in the same way as a HLW repository.

Site selection will be carried out in three stages, always respecting opinions of local communities.

Schedule of geological disposal project

Open solicitation → Application* → Literature Survey → Selection of Preliminary Investigation Areas (PIAs) → Preliminary Investigation → Selection of Detailed Investigation Areas (DIAs) (Around 2013) → Detailed Investigation → Selection of a repository site (Around 2028)

*The government can nominate the site for literature survey, taking account of opinions of local communities. In this case, mayor will express whether they will accept the proposals or not.

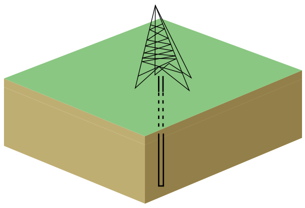
Stepwise site selection process

A final repository site will be selected via a three-step site selection process.

All Japan

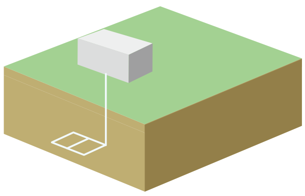
Call for volunteer municipalities to host a repository

PIAs



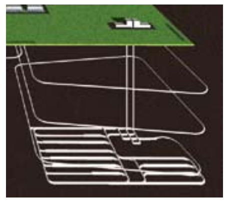
Explorations such as borehole survey

DIAs



Measurements and tests in underground investigation facilities

Repository site



Repository construction

Selection of PIAs

■**Investigation areas:**
Volunteer areas and their surroundings
■**Investigation methods:**
Literature surveys
■**Objectives:**
- To confirm that there is no record of significant movement in geological formations due to earthquakes, fault activity, igneous activity, uplift, erosion and other natural phenomena,
- To verify the low likelihood of significant movement in the future due to natural phenomena (such as earthquakes and so on)

Selection of DIAs

■**Investigation areas:**
PIAs
■**Investigation methods:**
Borehole surveys, geophysical prospecting, etc. (preliminary investigations)
■**Objectives:**
To confirm that:
- The geological formations for hosting the repository and their surroundings are stable;
- There is no obstruction for excavating drifts;
- Potential adverse impacts on underground facilities due to groundwater flow and so forth are small

Selection of a repository site

■**Investigation areas:**
DIAs
■**Investigation methods:**
Detailed surface explorations, measurements and tests in underground investigation facilities (detailed investigations)
■**Objectives:**
To confirm the feasibility of repository construction based on the physical and chemical properties of the selected geological environment

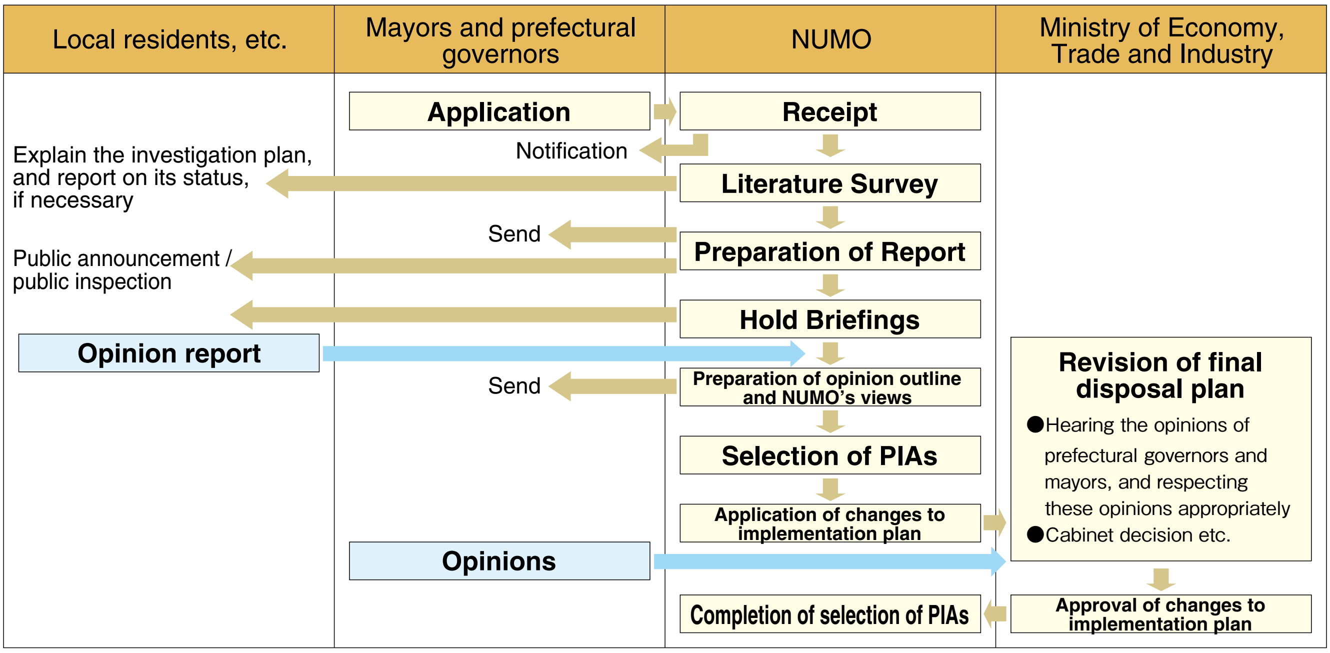
In order to ensure the transparency of the project and respect opinions of local communities, NUMO has adopted an open solicitation approach to find volunteers of areas to explore the feasibility of constructing a final repository.

Selection of a site for constructing the repository will take place in three stages following confirmation of the volunteer area's geological conditions, such as the occurrence of volcanoes and active faults. The results of investigations in each stage will be documented in a report, and an opportunity will be given to local communities to express their opinions.

Reflecting opinions of local communities

Opinions of local communities will be reflected in the project of each stage.

●**Procedure for selection of PIAs** (Selection of detailed investigation areas and selection of site for repository construction will follow the same procedures)



5 Siting factors for selecting Preliminary Investigation

In order to ensure the safety of geological disposal, candidate sites for Preliminary Investigation Areas should be located where there is no significant influence from volcanic or fault activity.

Siting factors for selecting Preliminary Investigation Areas (PIAs)

■What are siting factors?

The goal of selecting PIAs is to identify areas for conducting preliminary investigations and excluding areas that would clearly be unsuitable for repository construction, based on data and information obtained through literature surveys.

The siting factors for selecting Preliminary Investigation Areas are items to be examined when selecting PIAs. A literature survey will be carried out based on the result of the assessment of the siting factors. Siting factors consist of legal requirements (Evaluation Factors for Qualification) and favorable factors for additional assessment (Favorable Factors).

Evaluation Factors for Qualification

●Factors used to evaluate compliance with legal requirements for PIAs

1. Earthquake and fault activity
2. Igneous activity
3. Uplift / erosion
4. Unconsolidated Quaternary deposits
5. Mineral resources

Nationwide evaluation factors

●Factors used to assess the suitability of PIAs based on consistent nationwide criteria (active faults and Quaternary volcanoes)

Site-specific Evaluation Factors

●Factors used to assess the suitability of PIAs based on literature surveys for volunteer areas and their surroundings.

Favorable Factors

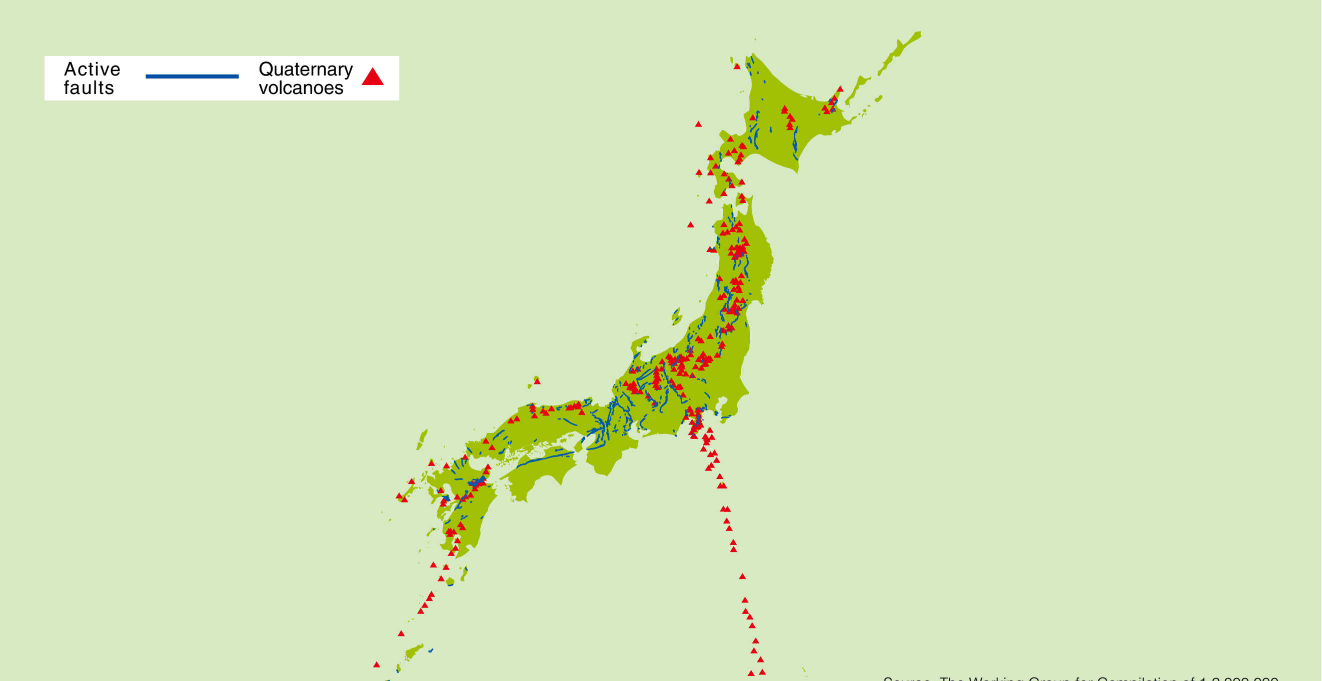
●Factors used to assess the characteristics of PIAs comprehensively and comparatively for areas where compliance with legal requirements has been confirmed.

1. Properties and conditions of geological formations
2. Hydraulic properties
3. Investigation and assessment of the geological environment
4. Natural disasters during construction and operation
5. Procurement of land
6. Transportation

Areas

In Japan, there are frequent volcanic and earthquake activities and fault movement, and there has been much research on these natural phenomena. According to the research, volcanic and fault activities are focused in particular areas. By avoiding such areas, suitable sites for repository construction can be found. Stable rock formations where there is less influence from natural phenomena that could compromise the safety of a repository can be found throughout Japan.

●Distribution of active faults in land areas and quaternary volcanoes



Source: The Working Group for Compilation of 1:2,000,000 Active Faults Map of Japan (1999); Committee for Catalog of Quaternary Volcanoes in Japan(1999)

Prior confirmation of geological conditions

■Prior confirmation of geological conditions for the volunteer area.

Before conducting a literature survey, NUMO will confirm whether or not the volunteer area satisfies the geological conditions set out below. If the results of this prior confirmation show that the area does not satisfy the conditions, the area will not be considered for a literature survey.

●Geological conditions

- **Excluded are locations with active faults that are indicated in nationwide literature based on, for example, aerial surveys for land or acoustic surveys for marine areas.**
- **Excluded are areas within a radius of 15 km of volcanic centers, considering the possibility of wide-ranging magmatic activity over the next several tens of thousands of years.**

6 Outreach scheme

It is important to develop a long-term relationship with local communities to ensure smooth implementation of the disposal project.
Acting as a member of the local community, NUMO will work together with local residents to create favorable conditions by respecting long-term visions and needs of the community.

Aspects of the disposal project and outreach to local communities

Geological disposal is an extremely long-term project. It is therefore important to develop an outreach scheme tailored to the situation in a volunteer area, to promote regional development and to improve the welfare system of the local community.
NUMO will formulate plans for outreach schemes that connect the geological disposal project with the vision of the local communities and will implement these plans in collaboration with the Japanese government* and the electricity utilities.

Final disposal project
This highly public project cannot be implemented without development of an outreach scheme.

Building a long-term working relationship

Municipalities
Pursuing co-existence and joint benefits enhances long-term project development

NUMO's position
NUMO will integrate itself into the municipality and will ensure that the project delivers the maximum benefit to all local communities.

Approach for outreach scheme planning

NUMO's four approaches for outreach scheme planning

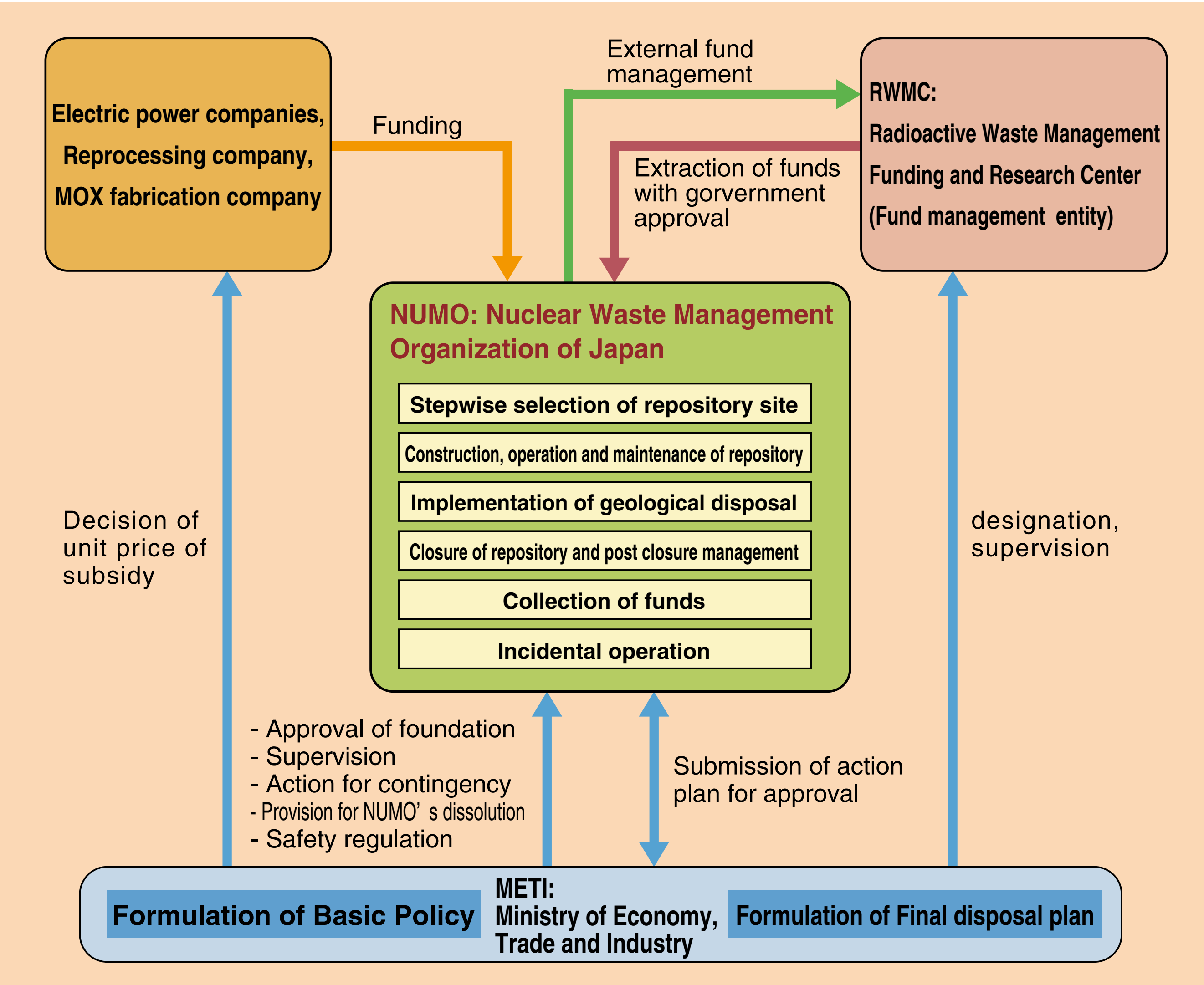
- Building a relationship with the local community through formulation and implementation of a long-term regional vision
- Implementation of the project in a way that ensures sustainable regional development
- Formulating an outreach scheme that can respond to changes in the local situation
- Implementation of activities aimed at promoting mutual understanding with local communities

※When literature survey is launched, various local support funds will be granted by the government.

7 Basic framework of geological disposal

NUMO will implement the disposal project safely in collaboration with the Japanese government and electricity utilities.

NUMO was established by the 'Specified Radioactive Waste Final Disposal Act' to implement the safe disposal of HLW with the cooperation and support of the Japanese government and the electricity utilities.
In addition, licensing and approval by the government are required at certain stages of the project, including construction, operation, closure and termination of the project based on legislation regulating nuclear source materials, nuclear fuel materials and reactors.
Particularly for the closure of the repository, the implementation plan has to be submitted to the government before licensing, and confirmation by the government will be required.



8 Current status in foreign countries

Many countries are planning or implementing geological disposal. In particular, Switzerland, France, Belgium and Germany have programs for co-disposal of high-level waste (vitrified HLW and spent fuel) and low-level waste destined for geological disposal.

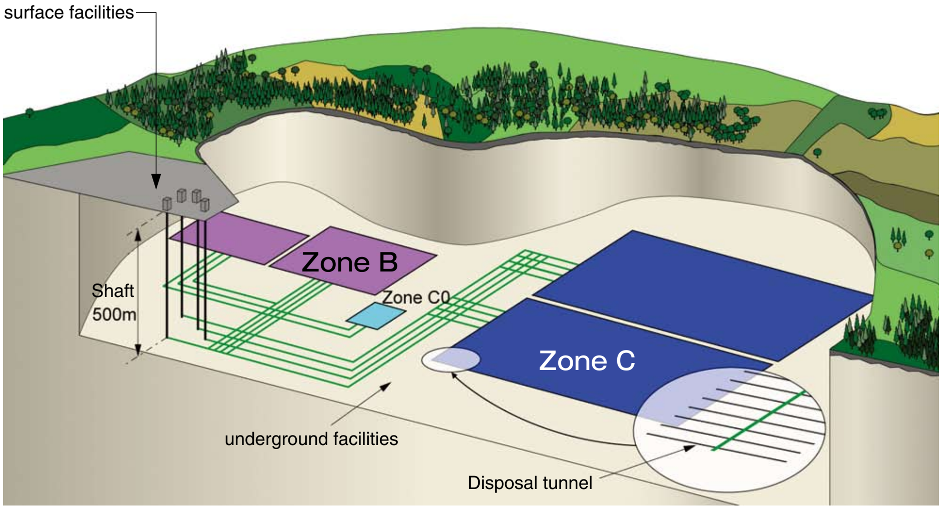
Current status regarding disposal of LLW requiring geological disposal

Country	Waste type	Disposal	Implementer	Earliest operation
Switzerland	Long-lived intermediate-level waste (ILW), HLW (spent fuel and vitrified HLW)	Co-disposal	NAGRA	Around 2040
France	Category B waste, HLW (vitrified)	Co-disposal	ANDRA	Around 2025
Belgium	Category B waste, some category C waste, HLW (spent fuel, vitrified HLW)	Co-disposal	ONDRAF/NIRAS	Not decided
Germany	Heat-generating waste, part of HGW, HLW (spent fuel and vitrified HLW)	Co-disposal	BfS	Around 2030
USA	TRU waste	Sole disposal	DOE	In operation

Co-disposal concept in France

Zone B: category B waste (including LLW for geological disposal)

Zone C: HLW



Source: Dossier 2005 Argile (2005)

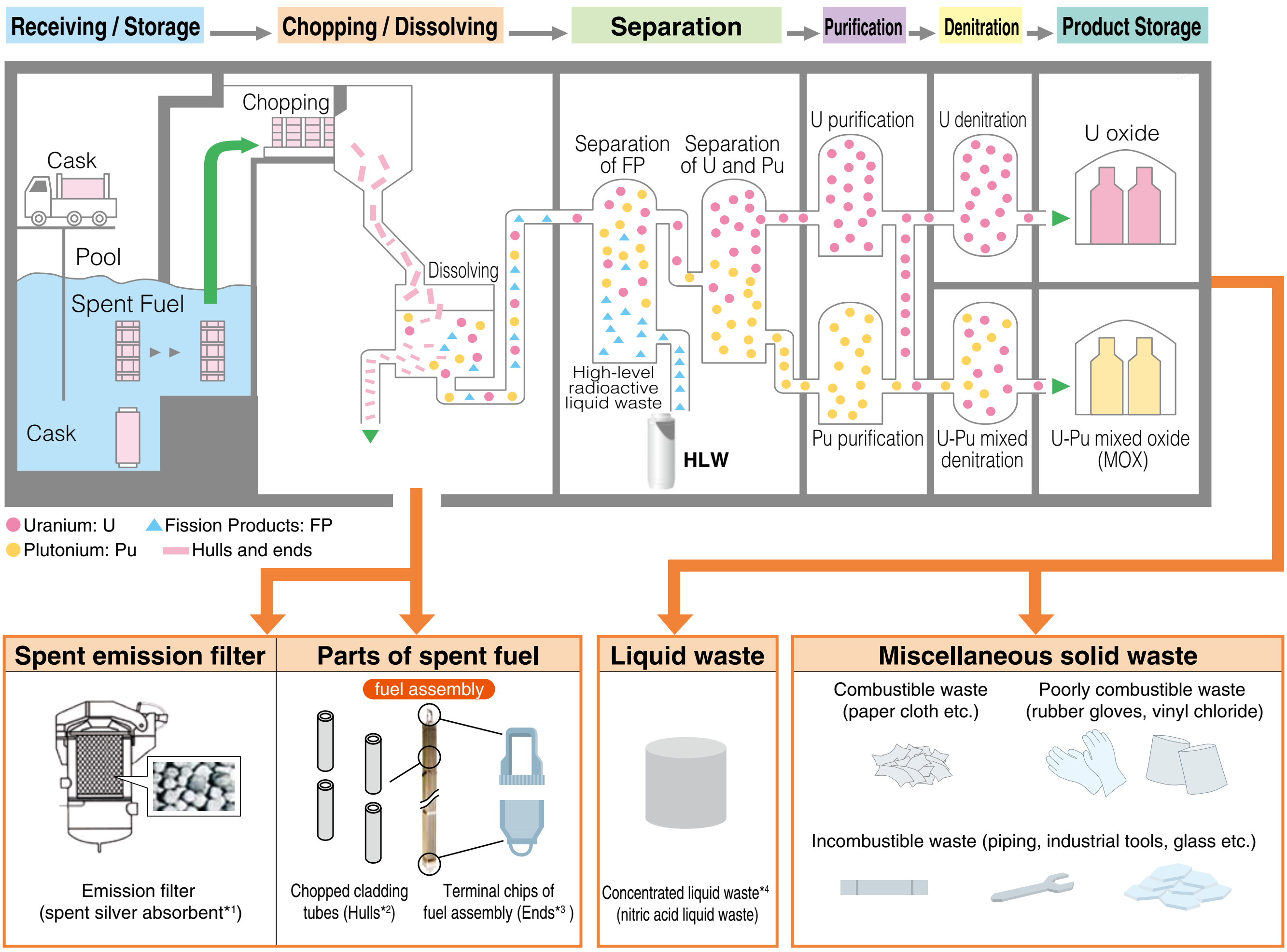
Appendix 1
Generation of TRU waste requiring geological disposal

LLW is generated during operation and decommissioning of reprocessing plants and MOX fuel fabrication plants.

During reprocessing, uranium and plutonium are recovered from spent fuel after the fuel has been chopped and dissolved. Highly active liquid waste is then solidified into a stable form (HLW).

TRU wastes requiring geological disposal, such as hulls and ends, emission filters (spent silver absorbent), concentrated liquid waste and miscellaneous solid waste, are produced by a range of processes.

Waste generation in the reprocessing plant



Some of concentrated liquid waste and miscellaneous solid waste that have specific level radioactivity require geological disposal.

*1 Spent silver absorbent:
Emission filters making use of the chemical sorption properties of silver for absorbing iodine generated during the chopping and dissolution of spent fuel.

*2, *3 Hulls and ends:
Ends are parts of the spent fuel assembly that are excluded during the process of chopping and dissolving the spent fuel. Hulls are the residues left after chopping and dissolution of fuel assemblies.

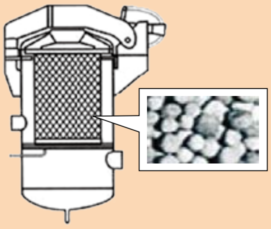
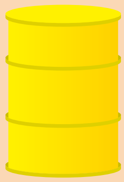
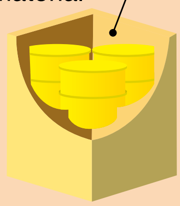
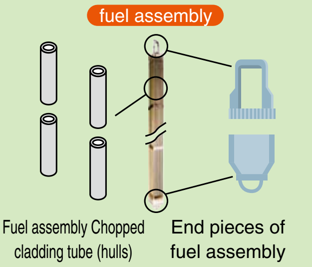
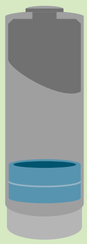
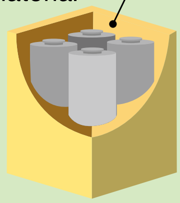
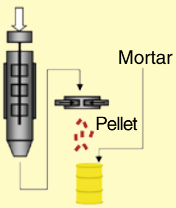
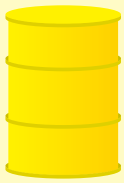
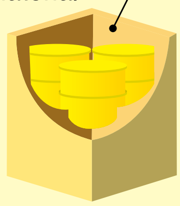
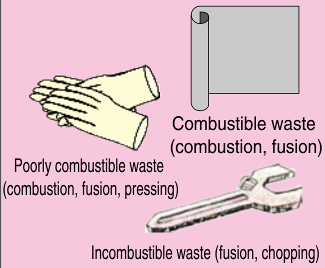
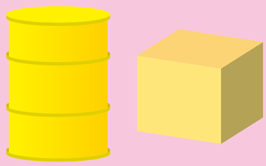
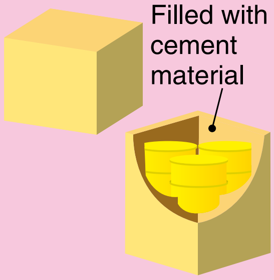
*4 Concentrated liquid waste:
Produced from acid recovery, solvent regeneration, decontamination and analysis; solidified after treatment such as evaporative concentration.

Source: METI pamphlet "TRU"

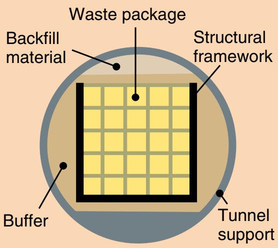
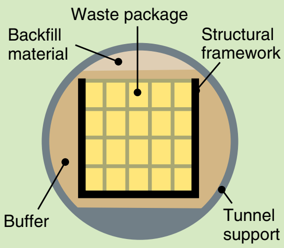
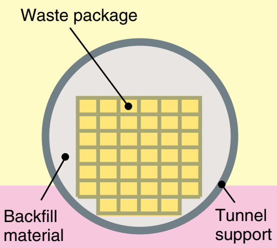
Appendix 2
Categories of TRU waste requiring geological disposal

LLW is generated during operation and decommissioning of reprocessing and MOX fabrication plants. This waste is classified and packaged after volume reduction by chopping, compaction, combustion, fusion and concentration. The waste is classified according to its property, and the layout of the disposal tunnels is based on this classification.

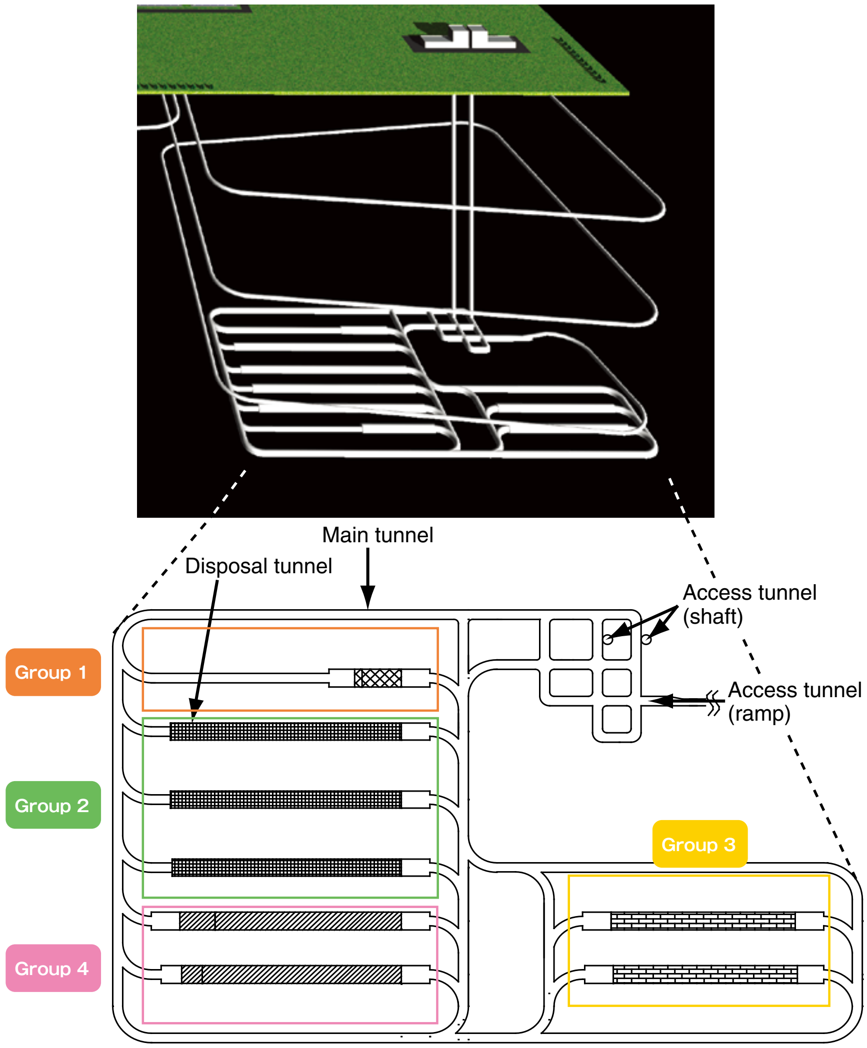
Grouping Table

Group	Waste type	Feature	Waste form (example)	Waste package
1	Emission filter, etc. (spent silver absorbent) 	Includes large amounts of radioactive iodine (I-129) with a long half-life and poor sorption properties. The total volume is small.	Drum  Solidification with cement material	Filled with cement material 
2	Hulls and ends 	Includes large amounts of radioactive carbon (C-14) with a long half-life and poor sorption properties. Relatively high heat generation.	Canister  Encapsulating pressed hulls and ends	Filled with cement material 
3	Concentrated liquid waste etc. (radioactivity level is higher than specific level) Nitric acid liquid waste  Process example of nitric acid liquid waste	Includes large amounts of nitrate that can have an effect on the properties of the engineered barriers.	Drum  Solidification with mortar and asphalt	Filled with cement material 
4	Miscellaneous solid waste (radioactivity level is higher than specific level) 	No features like groups 1-3	Drum and rectangular canister  Solidification with cement material	Filled with cement material 

Source: METI pamphlet "TALK" etc.

	Cross section of disposal tunnel	Repository scale*
	 Select buffer material which can restrict movement of groundwater	About 300 m^3
	 Select buffer material which can restrict movement of groundwater	About 6,100 m^3
		About 5,500 m^3
	Select backfil material which can restrict movement of groundwater	About 7,100 m^3

Layout of underground facilities



Waste packages will be classified into four groups which will be emplaced in different locations. The layout of the disposal tunnels and the distance between tunnels will be designed taking account of the mutual influence of the different waste groups that can affect tunnel stability, heat generation and the effects of nitrate.

*The above scale includes extra 5% of estimated waste generation volume, considering possible fluctuation of future waste generation (19,000 m^3 to the estimated waste volume, 18,100 m^3).