Tentative translation

Dialogue Meeting between Students of Nagaoka University of Technology and Seniors of SNW of AESJ,
December 17, 2024 at Nagaoka University of Technology, Nagaoka

Keynote Speech

"How should we dispose of high-level radioactive waste (HLW)?"

- I want everyone to be able to think and express their own opinions on geological disposal -

December 17, 2024

SNW　Hiromi TANABE

How to dispose of HLW?

Contents

1.The main technical issues

2. Social and technical issues

I will briefly touch on NUMO's own activities and explain national and international trends.

1.The main technical issues

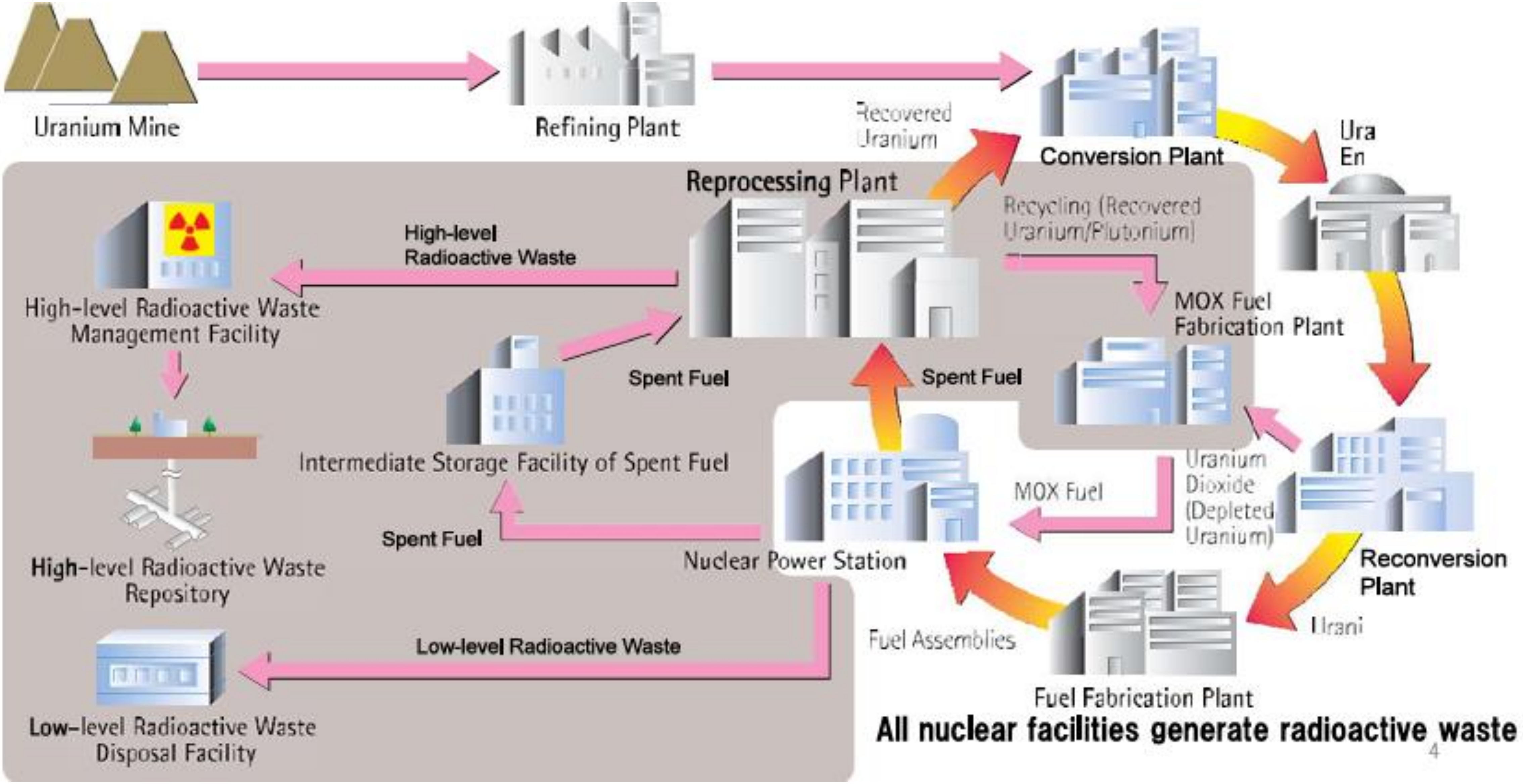
The main technical issues of geological disposal are geological survey, disposal facility design/construction/operation/closure, safety during operation, and long-term safety after closure, which are discussed in detail in lectures and "The NUMO Pre-siting SDM(site descriptive model)-based Safety Case", so I'll touch on it briefly here.

- Geological disposal was selected to ensure the long-term isolation period and containment performance of HLW.

As a reference,

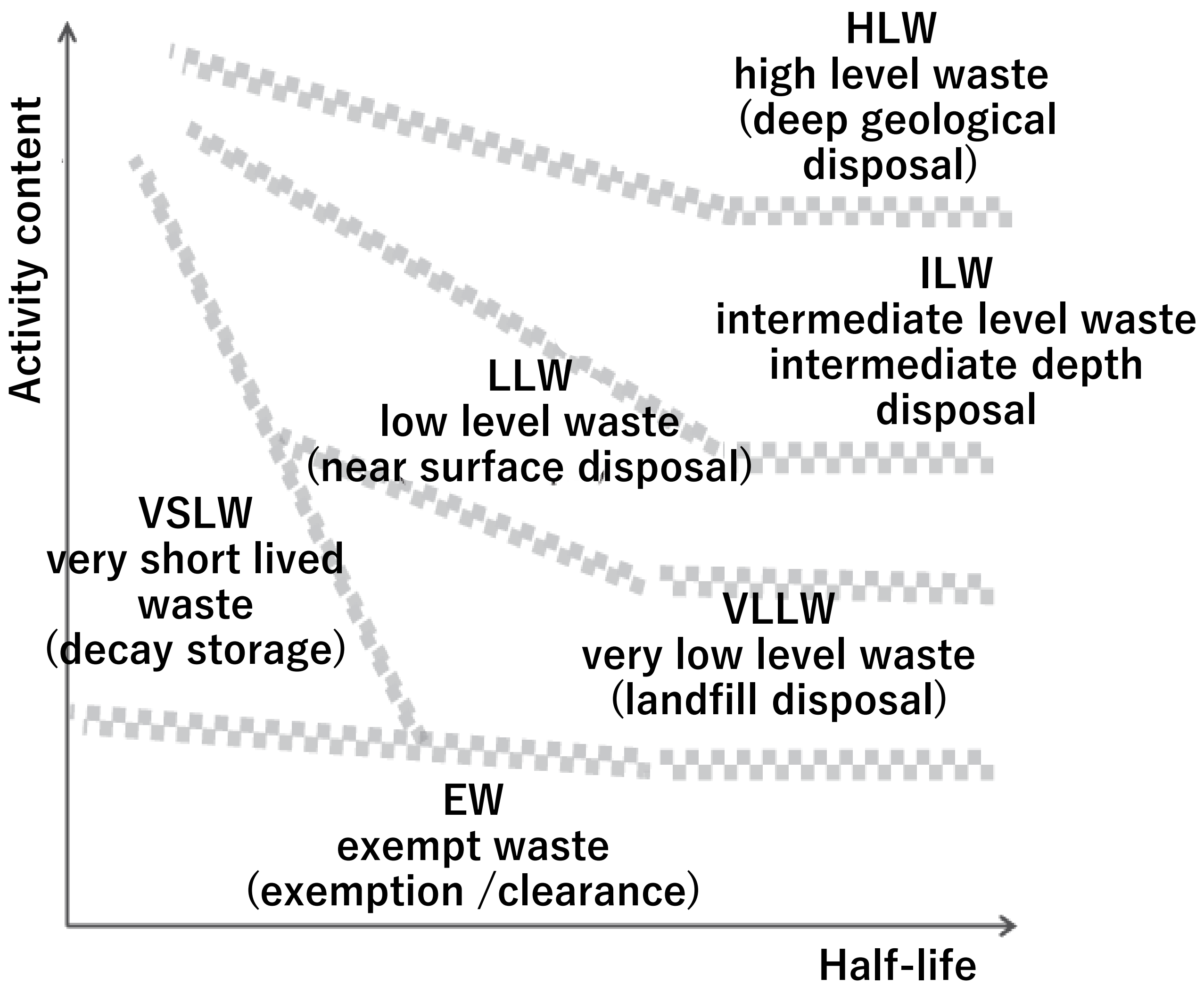
- IAEA, Classification of Radioactive Waste, Safety Standard Series No. GSG-1, 2009.
- Low-level radioactive waste (LLW), that is above clearance levels, but with limited amounts of long lived radionuclides, is suitable for near surface disposal. Near surface disposal requires robust isolation and containment for periods of up to a few hundred years for which active institutional control can be guaranteed and thus human intrusion into the waste can be prevented.

Nuclear Fuel Cycle and Radioactive Waste



Ref.; Dialogue Meeting between Students of Nagaoka University of Technology and Seniors of SNW of AESJ, December 15, 2023 at Nagaoka University of Technology, Nagaoka

Waste classification and management and disposal option



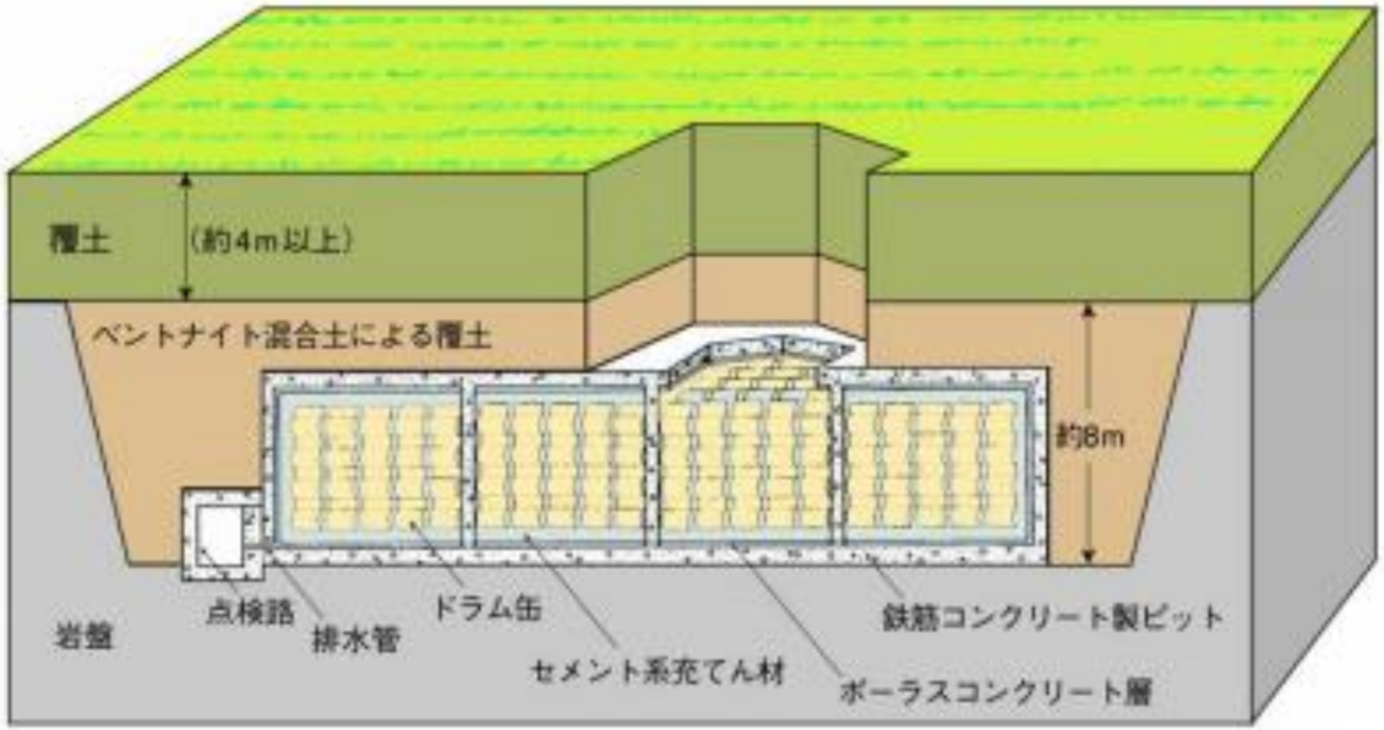
Conceptual illustration of the waste classification scheme

- In general, the higher the radioactive content, the greater the need for radioactive containment and isolation from the living environment.
- Active institutional control contributes to ensuring the safety of near-surface disposal facilities for waste that mainly contains short-lived radionuclides.
- Waste containing a large amount of long-lived radionuclides, in particular, requires higher levels of containment and isolation, and disposal at greater depths.
- The limit value (acceptance criteria) for the amount of radioactive material that can be tolerated for each radionuclide is specified based on the safety evaluation of each disposal site.
- Waste containing extremely short-lived radionuclides can be reduced to below the clearance level by decay storage.
- Management of waste containing amounts of radioactive material below exemption/clearance levels in the lower range on the vertical axis can released without radiological restrictions.

INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, Safety Standard Series No.GSG-1, 2009.

"Containment" and "isolation" are preferred strategy and important in disposal

Low level waste (LLW): Waste that is above clearance levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities. This class covers a very broad range of waste. LLW may include short lived radionuclides at higher levels of activity concentration, and also long lived radionuclides, but only at relatively low levels of activity concentration.



Near surface pit disposal facility of Japan

Ref. White Paper on Nuclear Safety,1999

"Containment" and "isolation" are preferred strategy and important in disposal

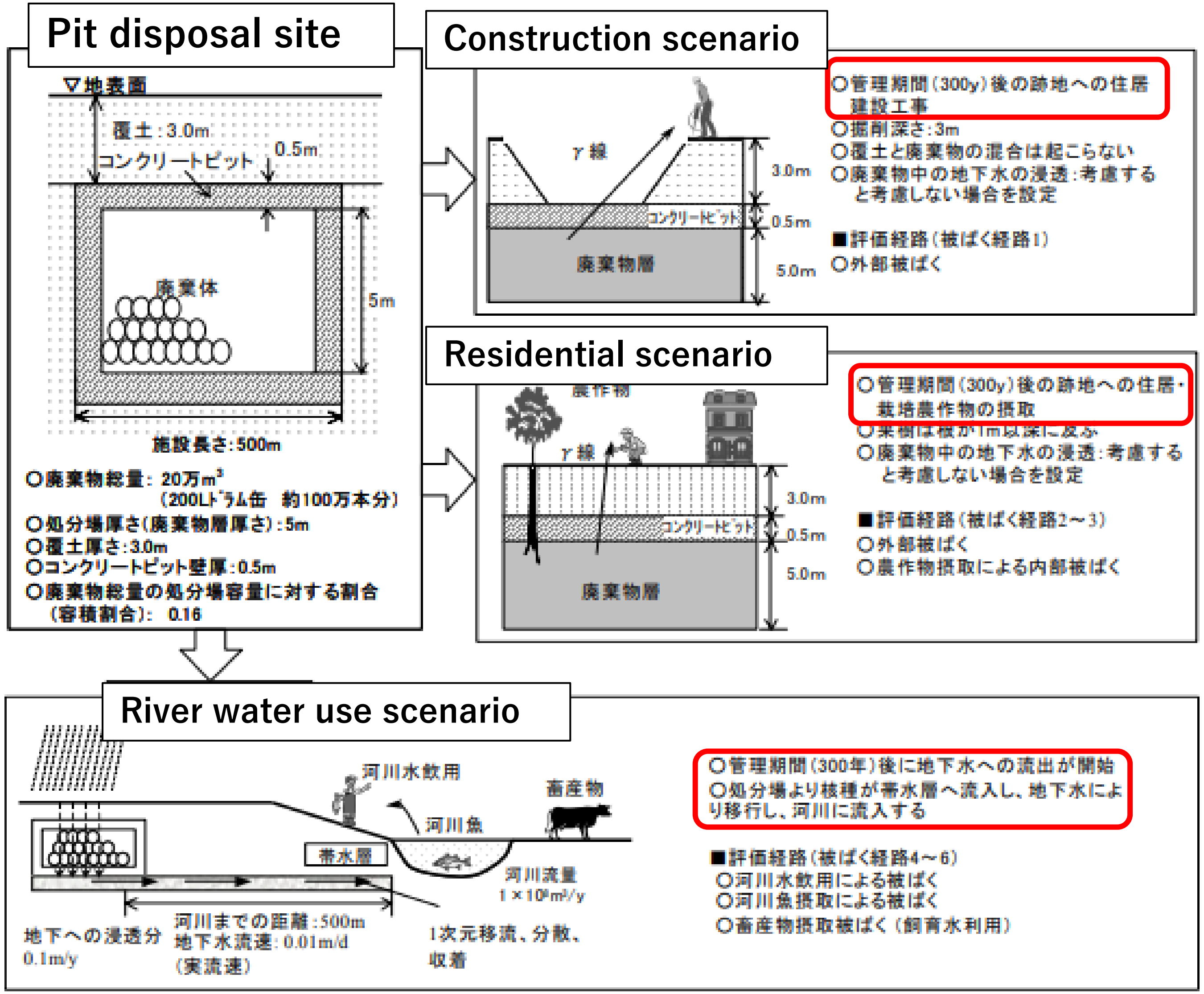


Fig. Conceptual diagram of safety assessment scenario after the end of the active control period

The scenarios of safety assessments are organized in "human intrusion scenarios" and "natural event scenarios" .

Active control period will be set up to prevent radiation exposure due to the construction/residential scenario, in which people intrude the disposal site, for hundreds of years after the waste is emplaced.

⇒International standards require that wastes be isolated from accessible living environments, substantially reducing the likelihood of accidental human intrusion into wastes and any possible impact.

Radiation exposure due to the river water use scenario occurs when radioactive materials leak from disposal facilities into groundwater, flow into rivers, and are ingested by humans as drinking water, river products, and livestock products.

⇒International standards require that the transfer of radioactive materials contained in radioactive waste from waste to accessible living environments be constantly controlled, reduced, or delayed.

The standard dose equivalent concentrations for each radionuclide in pit disposal

You can see that the scenario in which the concentration equivalent to the standard dose is the lowest differs depending on the radionuclide.

If the construction/residential scenario becomes the decision scenario, the control period (isolation) becomes important.

Containment becomes important if the river water use scenario becomes the decision scenario.

Tab. Calculation results of the standard dose equivalent concentrations for each radionuclide in pit disposal (part)

核種	半減期 (y)	基準線量相当濃度（第2次中間報告[30)]）		パラメータ見直しによる基準線量相当濃度（100万本ケース）*1		対象廃棄物の平均濃度(D) (Bq/ton)			対象廃棄物のD/C		
		濃度 (Bq/ton)	決定シナリオ	濃度(C) (Bq/ton)	decision scenario	原子炉	サイクル	原子炉＋サイクル	原子炉	サイクル	原子炉＋サイクル
H-3	1.2E+01	1.5E+16	居住	2.8E+16	居住	9.9E+08	3.1E+08	7.4E+08	3.6E-08	1.1E-08	2.7E-08
Be-10	1.6E+06	—*2		1.4E+11	居住	0.0E+00	4.5E-03	1.7E-03	0.0E+00	3.2E-14	1.2E-14
C-14	5.7E+03	3.5E+09	河川水利用	2.8E+09	居住	3.5E+07	6.5E+06	2.4E+07	1.2E-02	2.3E-03	8.6E-03
Cl-36	3.0E+05	7.8E+06	居住	3.4E+07	居住	2.8E+03	2.0E+04	9.3E+03	8.2E-05	5.9E-04	2.8E-04
Ca-41	1.0E+05	3.1E+08	居住	1.6E+09	居住	3.9E+05	5.5E+02	2.4E+05	2.4E-04	3.3E-07	1.5E-04
Mn-54	8.6E-01	2.3E+13	操業中	3.3E+13	操業中	5.2E+08	2.5E+01	3.2E+08	1.6E-05	7.6E-13	9.7E-06
Fe-55	2.7E+00	3.7E+18	操業中	1.3E+24	操業中	4.8E+09	3.0E+09	4.1E+09	3.6E-15	2.2E-15	3.1E-15
Fe-59	1.2E-01	9.3E+12	操業中	1.4E+13	操業中	2.5E+08	9.1E-02	1.6E+08	1.8E-05	6.6E-15	1.1E-05
Co-58	1.9E-01	3.1E+13	操業中	2.8E+13	操業中	7.9E+08	4.4E+03	4.9E+08	2.9E-05	1.6E-10	1.8E-05
Co-60	5.3E+00	4.1E+12	操業中	6.8E+12	操業中	8.5E+08	5.6E+09	2.7E+09	1.2E-04	8.2E-04	3.9E-04

最大値	下線付きの数値がD/Cの最大値。
1桁	D/Cの最大値となった核種と同じ桁のもの。
2桁	D/Cの最大値となった核種の桁から2桁めのもの。
3桁	D/Cの最大値となった核種の桁から3桁めのもの。

出典：原子力安全委員会、低レベル放射性固体廃棄物の埋設処分に係る放射能濃度上限値について、平成１９年 ５月２１日．

Routes of radioactive materials reaching humans from disposal sites and countermeasures to protect humans from radiation exposure

Routes of radioactive materials reaching humans from disposal sites

- River water use scenario
- Human intrusion scenario

Radioactivity of radioactive material reduces with time

Countermeasures

Make the arrival time to humans as long as possible.

Make the time to leave the disposal site and the transportation time through groundwater as long as possible.

「Containment」

Prevent human intrusion

- Human control of disposal site (Hundreds of years at most)
- Dispose deep underground to reduce the possibility of human intrusion

+

Passive institutional controls (excavation limits, record keeping, marking, etc.)

「Isolation」

Select a disposal option according to the type and amount of radioactive material contained in the radioactive waste.

2. Social and technical issues

The safety issues presented in 1. are the most essential. However, in addition to this, there are various social and technical issues related to geological disposal as some of you already know. Here, I will introduce them in a bird's-eye view as much as possible (in no particular order). I hope that this will be a clue and an opportunity for you to think for yourself and express your opinions on issues that you are interested in, not just these. As mentioned above, I will briefly touch on NUMO's own activities and explain international trends.

Example of issues;
①Nuclear fuel cycle options
②Site selection
③Multiple safety functions by combining engineered barriers and geological formation
④Institutional control after closure of disposal
⑤Reversibility and retrievability (R&R)
⑥Socio-economic issues and countermeasures (how to respond to literature surveys, etc.)
⑦Regulatory system
⑧Uncertainty - Long-term stability of geological formation
⑨Principle of waste minimization
⑩Securing fund for HLW disposal
⑪Situation in other countries

① Nuclear Fuel Cycle Options

From the perspective of efficient resource utilization and reducing the volume and harmfulness of high-level radioactive waste, Japan 's basic policy is to promote the nuclear fuel cycle, which involves reprocessing spent fuel and making effective use of the recovered plutonium and other materials.

Basic Energy Plan (Cabinet decision, July 2018)

	Once-through (direct disposal)	**Light Water Reactor Cycle (Reprocessing)**	**Fast Reactor Cycle (Reprocessing) (*4)**
a. Efficient use of resources	×	10-20% of new fuel can be produced	Greater savings than the light water reactor cycle
b. Volume of HLW	1. Spent fuel	1/4 <Vitrified waste>	1/4 to 1/7 (*5) <Vitrified waste>
c. Reducing the toxicity of high-level radioactive waste (*1)	Approximately 100,000 years <Spent fuel>	Approximately 8,000 years <Vitrified waste>	Approximately 300 years <Vitrified waste>
d. Cost	1.0 (*2) (yen/ kWh) ~	1.5 (*3) (yen/ kWh) ~	No estimates available as this is still in the research and development stage

*1 The period required for the toxicity of waste to decrease to the same level as the total amount of natural uranium used to generate electricity
*2 Calculation by the Atomic Energy Commission (November 2011) (Case of 3% discount rate)
*3 Verification results by the General Energy Survey Power Generation Cost Verification Working Group (May 2015)
*4 Assumes the use of both light water reactors and fast reactors. Fast reactors utilize plutonium extracted from spent fuel from light water reactors.
*5 Improvements will occur depending on the proportion of fast reactors in the total.

Source: Agency for Natural Resources and Energy, Answers to Frequently Asked Questions

①Nuclear fuel cycle options

Regarding the nuclear fuel cycle (LWR cycle), although d. the cost is higher than the direct disposal of spent fuel, there are merits such as b. the amount (volume) of HLW (high-level radioactive waste) is reduced to about one-fourth, c. the period until the potential radiotoxicity of HLW becomes equivalent to that of resource natural uranium is shortened from about 100,000 years to about 8,000 years, and a. effective use of resources.

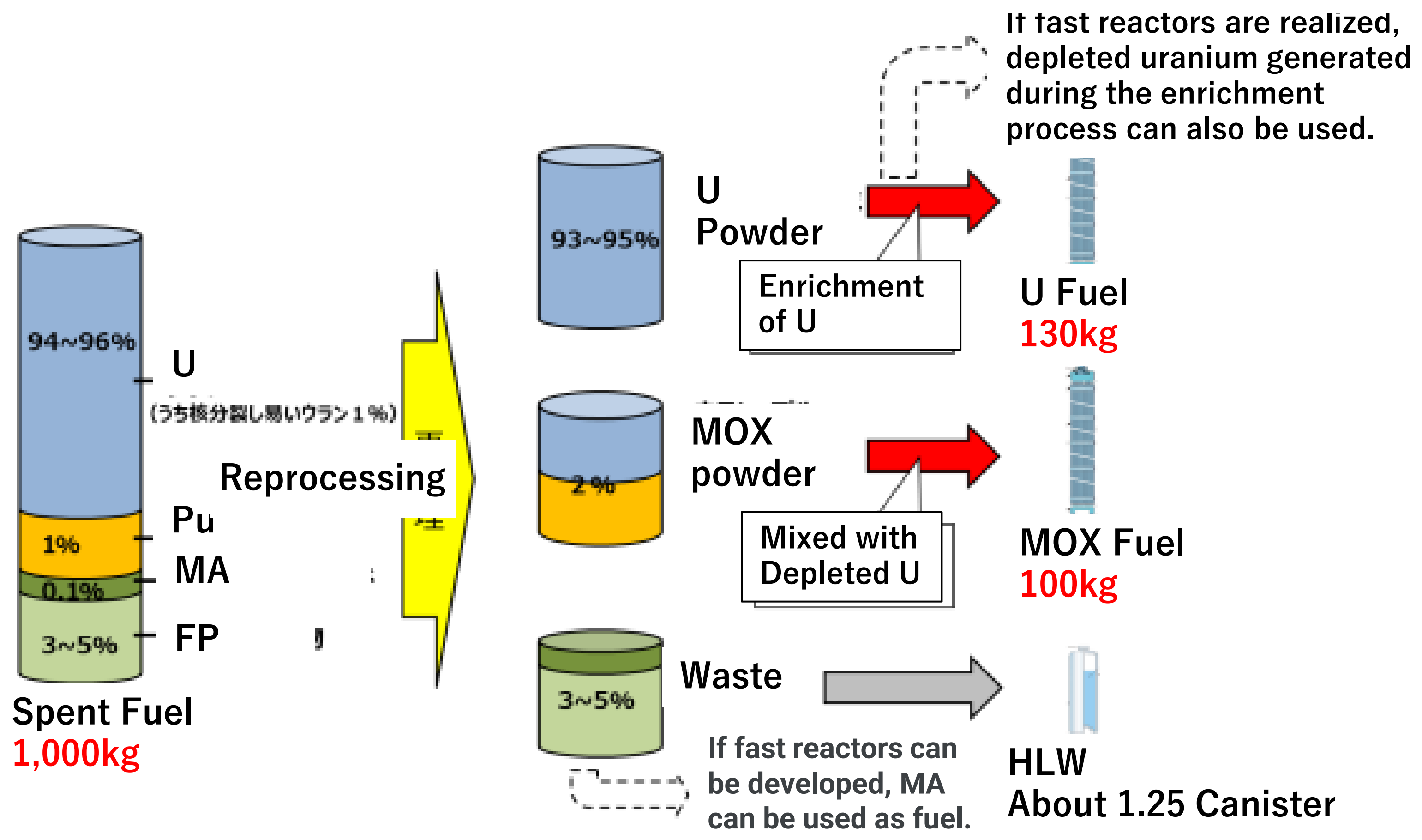
In addition, the realization of the FR cycle will have great effects, such as b. reduce the volume of HLW to about one-seventh of that of direct disposal of spent fuel, c. the period until the potential radiotoxicity of HLW becomes equivalent to that of resource natural uranium is shortened to about 300 years, and a. more effective use of resources.

Ref. Agency for Natural Resources and Energy, answers to frequently asked questions

①a. Mechanism for effective use of resources.

-When reprocessing spent fuel from light water reactors, the recovered uranium and plutonium are used as new fuel. This allows for effective use of resources (10-20%).

-If the fast reactor cycle is established, it will be possible to further effectively use resources.

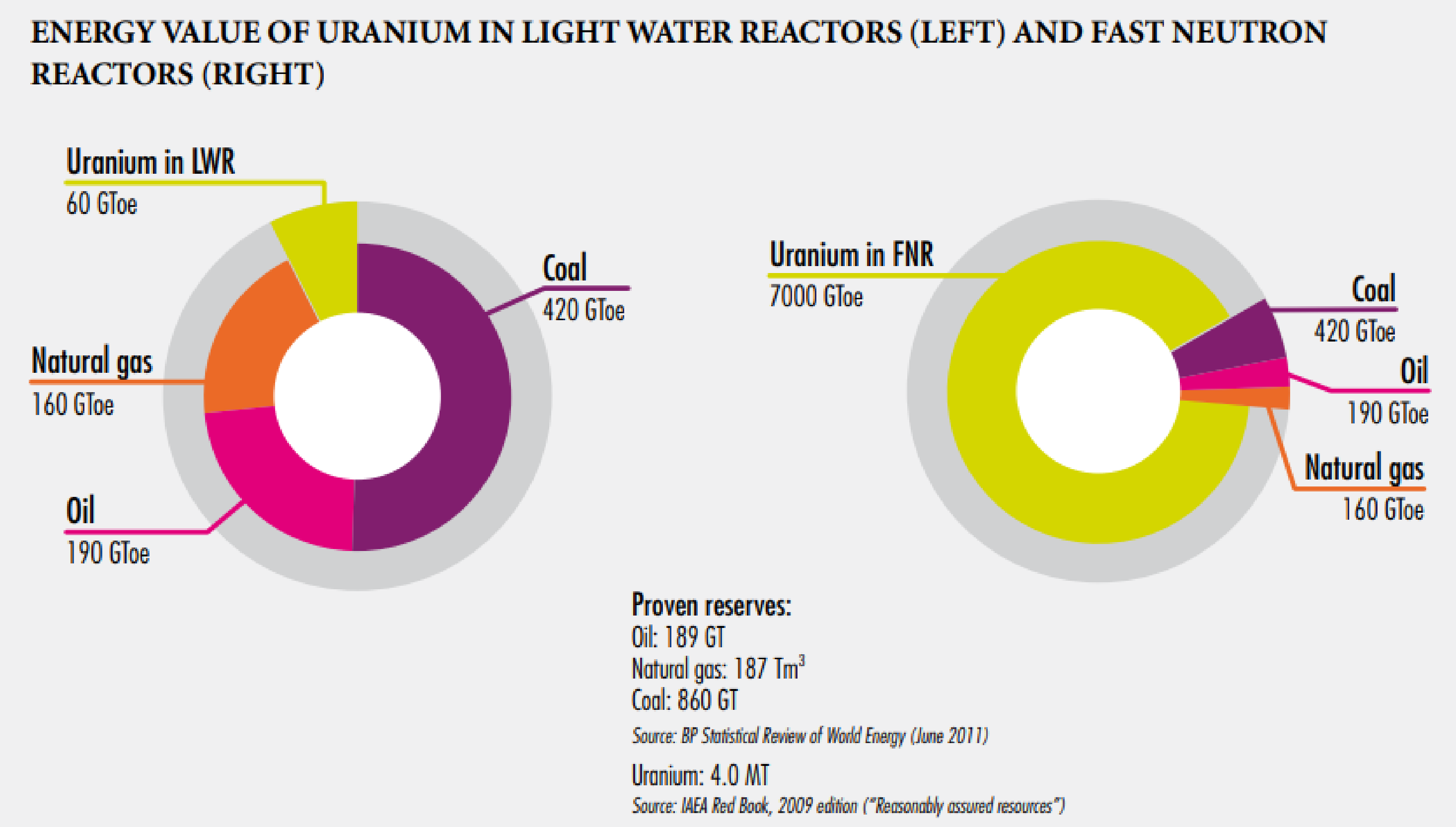


Source: Agency for Natural Resources and Energy, Efforts to Establish a Nuclear Fuel Cycle and Future Considerations, June 25, 2024

①a. Introduction of fast reactors to make effective use of uranium resources

Proven reserves of conventional fossil fuels were estimated in 2011 at 189 billion metric tons of oil, 187 trillion cubic meters of natural gas, and 860 billion metric tons of coal [source: BP Statistical Review of World Energy, 2011]. The proven conventional resources of uranium were estimated at 4 million metric tons [source: IAEA Red Book, 2009]. The figure below represents the energy potential of these resources expressed in billions of metric tons of oil equivalent (GToe):

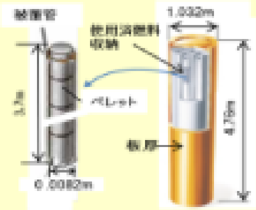
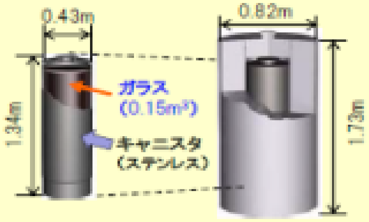
- In the chart on the left, for uranium as utilized today in light water reactors, this amounts to about 7% of the total fossil energy resources.
- The chart on the right corresponds to uranium utilization in fast neutron reactors ; in this case, uranium becomes the first energy resource with a potential 10 times greater than the other fossil resources .



Ref; CEA Nuclear Energy Division, Report on Sustainabel Radioactive Waste Management, Dec. 2012.

①b. Mechanism for reducing the volume of high-level radioactive waste

When reprocessing, the uranium and plutonium that make up the majority of spent fuel are recovered and used, and the volume reduction effect is greater than in the case of direct disposal.

技術オプション / 比較項目	直接処分	再処理	
		軽水炉	高速炉
処分時の廃棄体イメージ	 キャニスタ中の燃料ペレット（PWRの例）（0.103m³） 使用済燃料キャニスタ（3.98m³） 出典：原子力委員会新計画策定会議技術検討小委員会、基本シナリオの核燃料サイクルコスト比較に関する報告書より作成	 ガラス固化体 オーバーパック（0.91m³）	出典：原子力発電環境整備機構、高レベル放射性廃棄物地層処分の技術と安全性 ―「処分場の概要」の説明資料― より作成

シナリオ	概要	処分対象	HLW Volume
Direct Disposal	使用済燃料をキャニスタ（容器）に入れた上で処分。	使用済燃料１トンあたりの体積 ＝4.98立方メートル	1
LWR Cycle (Reprocessing)	キャニスターに充填されたガラス固化体をオーバーパック（金属製容器）に封入した上で処分。	使用済燃料１トンあたりの体積 ＝1.14立方メートル	1／4
FNR Cycle (Reprocessing)	同上	高速炉は、同じ燃料の量で、軽水炉よりも多く発電できるため、単位発電量あたりのガラス固化体の発生量がさらに減少	1／7

※減容化は、単位発電量当たりの高レベル放射性廃棄物の発生量を試算したもの。

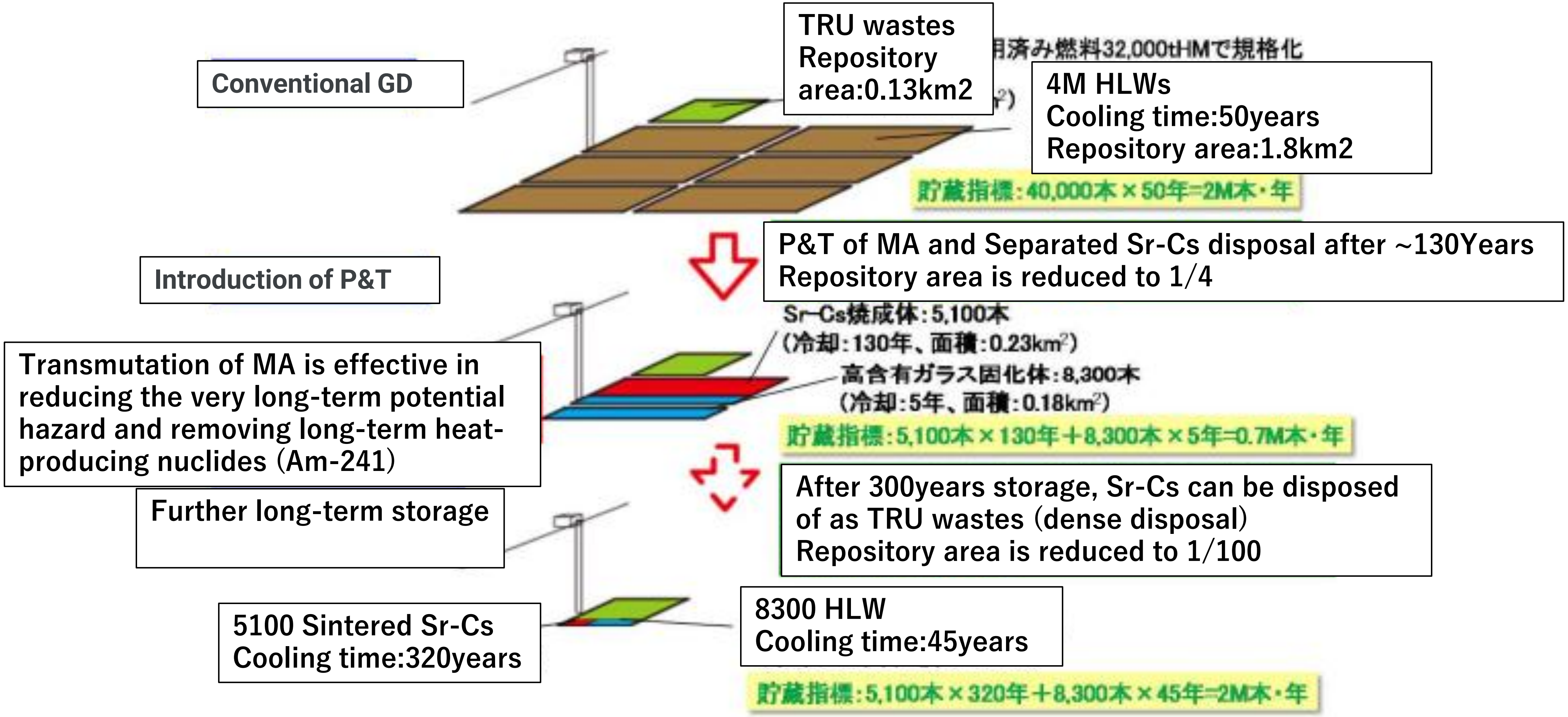
【資料】文部科学省　もんじゅ研究計画作業部会『廃棄物の減容・有害度の低減のために「もんじゅ」等を活用して行うべき研究開発について』（2012年11月）より作成

3

Source: Agency for Natural Resources and Energy, Efforts to Establish a Nuclear Fuel Cycle and Future Considerations, June 25, 2024

①b. P&T may also reduce disposal area (Japanese study)

Dense disposal is possible through a combination of MA P&T and storage of the exothermic nuclides Sr-Cs. (However, existing vitrified waste and vitrified waste from current technology must be disposed of as usual.)



Ministry of Education, Culture, Sports, Science and Technology, Working Group on Evaluation of Partitioning and Transmutation Technology, "Evaluation of Partitioning and Nuclear Transmutation Technology (Summary of Interim Issues)," 2013

①b. P&T may also reduce disposal area (French study)

A study conducted by ANDRA in 2012

- Waste produced between 2040 and 2150 is covered.
- ANDRA considered the merits and demerits of transmutation from the viewpoint of 120-year storage, further densification of high-level waste disposal area and long-lived intermediate-level waste disposal area including unification of modules.
- For example, regarding the high-level waste disposal area, extend the cell length from 40m to 80m, optimize the module layout, and review the long-life intermediate-level waste disposal area.
- Although the high-level waste area is reduced to 1/10, the total area including the long-lived intermediate-level waste area is only 1/3.

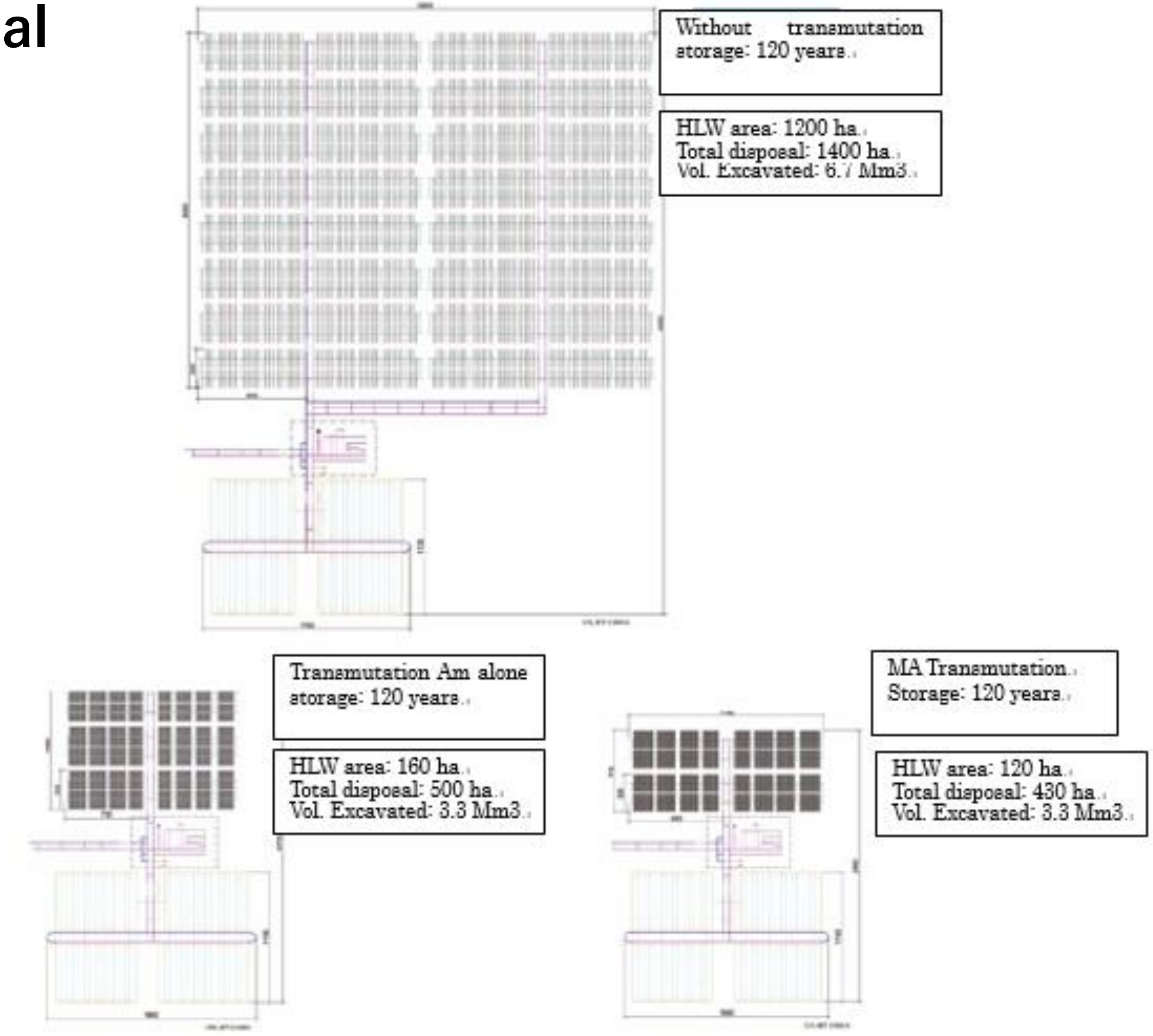


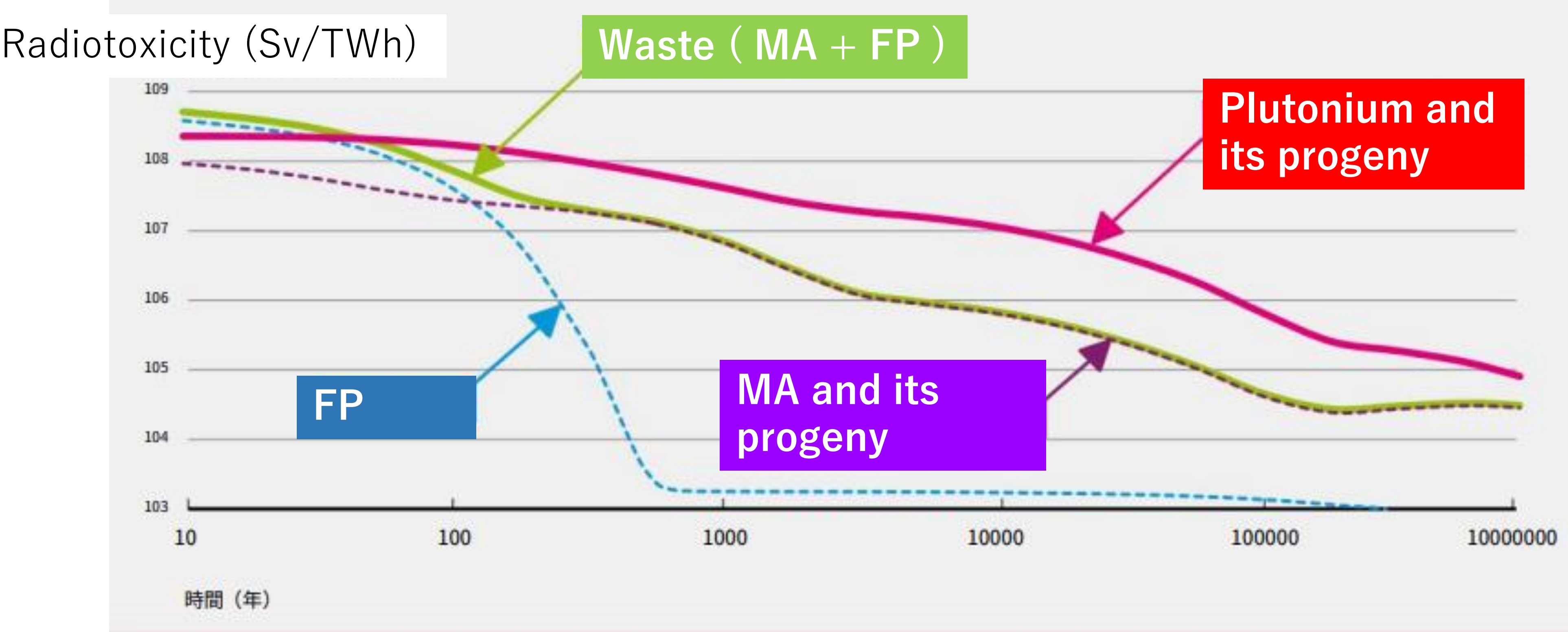
Figure 42: Comparison of underground disposal architectures for different scenarios of the 2012 study (single disposal for all the waste produced over the duration of the scenarios - 110 years of production)

①c. Selection of target nuclides for research on P&T (France)

MA was selected from the perspective of potential radiotoxicity.

Ref; CEA Nuclear Energy Division, Séparation transmutation des éléments radioactifs à vie longue, Dec. 2012.

Radiotoxicity of spent fuel with or without transmutation of the minor actinides (UOx 45GWd/t)

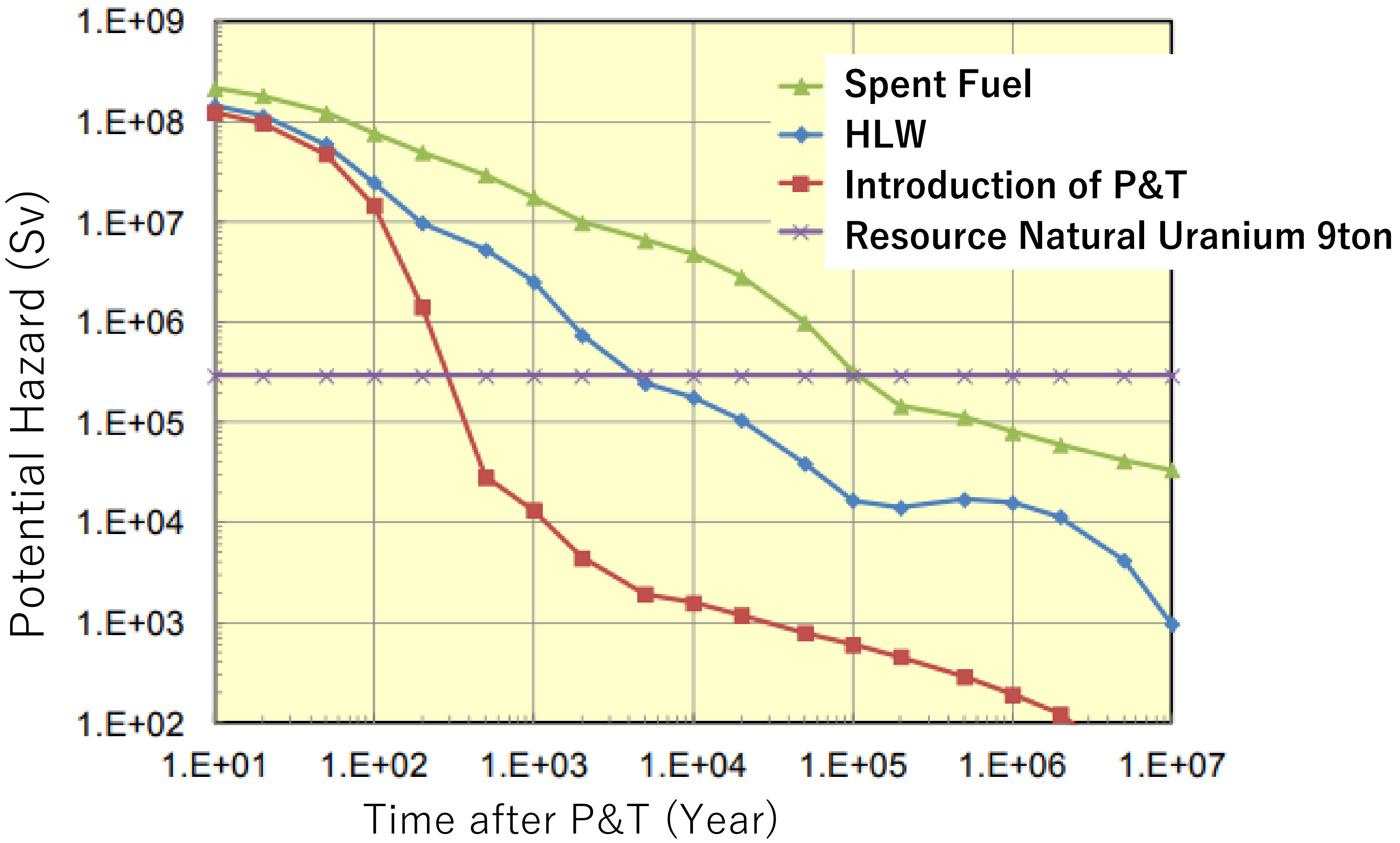


From the perspective of radiation exposure risk , iodine, technetium, and cesium were selected as the dominant nuclides based on the results of safety assessments in EURATOM joint studies (PAGIS (1985) and subsequently EVEREST (1997) and SPA (2000)).

①c. Reduction of potential radiotoxicity through P&T

Attenuation of potential hazards of spent fuel and the effect of transmutation

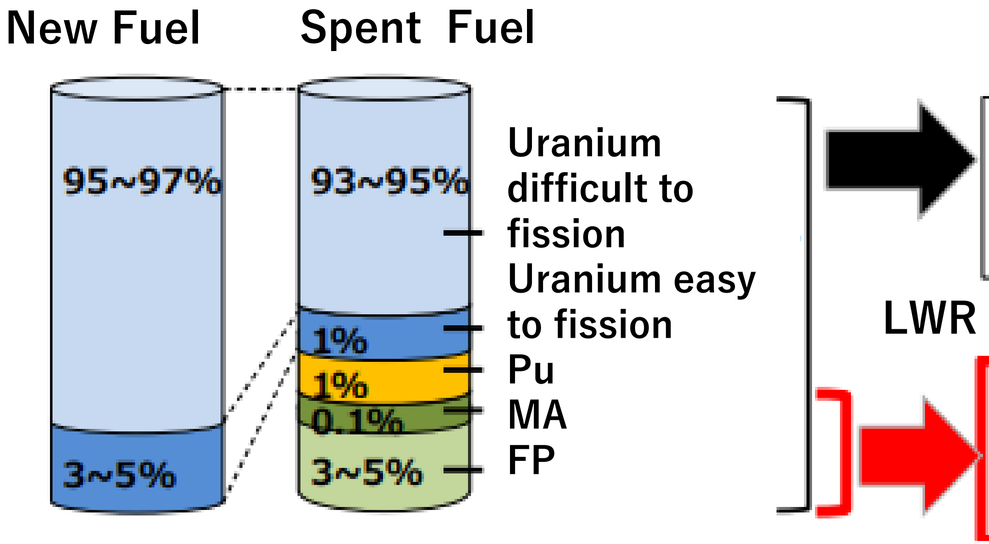
Potential Hazard: An index weighted by the effect of each radionuclide on the human body (dose conversion coefficient)



Source: Hiroyuki Oigawa, Current Status and Outlook of P&T Technology, Energy Square, Dec 2012.

①c. Mechanism for reducing the toxicity of high-level radioactive waste

When reprocessing, uranium, plutonium, and other elements with long half-lives are recovered and used, which is more effective in reducing harmfulness than direct disposal.



Direct Disposal

主な物質の半減期（例）
プルトニウム239：約２万４千年

- Direct disposal involves disposing of the spent fuel itself, including uranium and plutonium, which have long half-lives.
- It will take 100,000 years for the harmful effects to decrease.

LWR Cycle (Reprocessing)

主な物質の半減期（例）
アメリシウム243：約７千４百年

- Uranium and plutonium are recovered through reprocessing, and only minor actinides and fission products are disposed of.
- It will take 8,000 years for the harmfulness to decrease.

FNR Cycle (Reprocessing)

主な物質の半減期（例）
セシウム137：約３０年

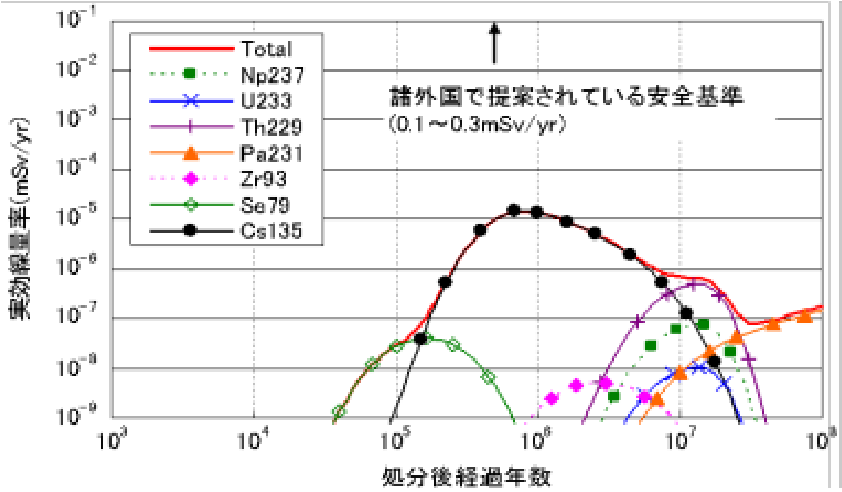
- In fast reactors, minor actinides are also transmutated, and only fission products are disposed of.
- It will take 300 years for the harmful effects to decrease.

*The reduction in potential hazard is an estimate of the period required for the radiation dose (Sv) of high-level waste per unit of electricity generated to fall to a level equivalent to that of the natural uranium needed to generate that electricity.

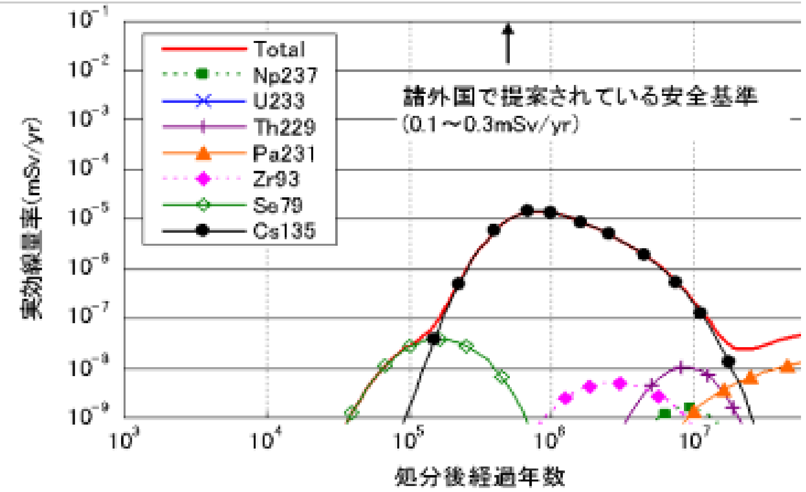
Source: Agency for Natural Resources and Energy, Efforts to Establish a Nuclear Fuel Cycle and Future Considerations, June 25, 2024

①c. Reduction of radiation risks through P&T

Effect of application of P&T technology on radiation exposure dose assessment (groundwater scenario)



Effective dose rates from repository, groundwater scenarios
Without P&T of MA



Effective dose rates from repository, groundwater scenarios
With P&T of MA

（FBRを40 GWe 40年間運転した場合に発生する29,000本のガラス固化体に規格化）

- Although it depends on the rock type and groundwater environment, in Japan, groundwater scenarios are basically dominated by FPs such as Cs-135, and the effect of MA transmutation is small.
- However, in exposure scenarios involving disturbances such as human intrusion, the effect of MA transmutation is heavily influenced by MA.
- Reducing the source term MA, to the extent reasonably possible for the current generation is considered to be effective in reducing the impact of uncertainties associated with setting long-term scenarios exceeding 100,000 years.

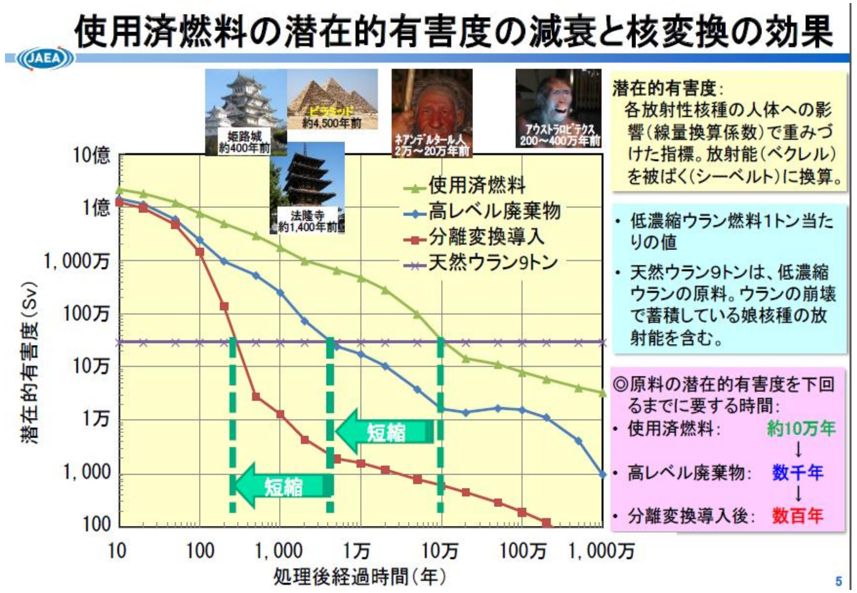
Source: Hiroyuki Oigawa, Current Status and Outlook of P&T Technology, Energy Square, Dec 2012.

①c. Which indicators are appropriate for evaluating HLW disposal?

a.Potential radiotoxity (Sv)

An index weighted by the effect of each radioactive substance in radioactive waste on the human body (dose conversion coefficient). Radioactivity (becquerels) is converted into exposure (sieverts) and expressed.

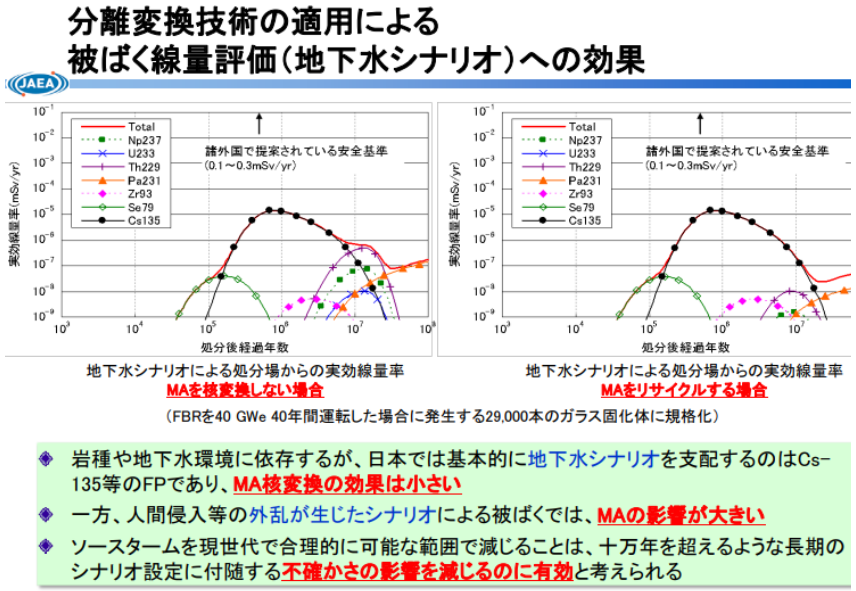
a.



b.Radiological exposure (radiation risk)

Evaluate the migration of radioactive materials into the biosphere when radioactive waste is disposed of, and evaluate the effects on the human body via various routes in terms of radiation exposure dose (Sieverts / year).

b.

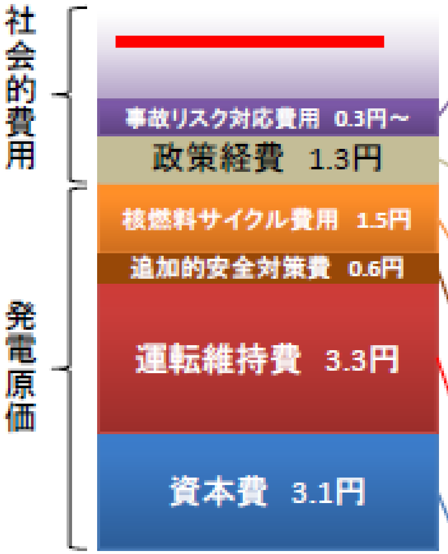


①d. Calculation method and specifications for nuclear power generation costs in Japan

原子力発電コストの算定方法と諸元

➢ 発電に直接関係するコストだけでなく、廃炉費用、核燃料サイクル費用（放射性廃棄物最終処分含む）など将来発生するコスト、事故対応費用（損害賠償、除染含む）、電源立地交付金・もんじゅなどの研究開発等の政策経費といった社会的費用も織り込んで試算。

原子力発電コスト（2014年）
10.1円～/kWh



※設備容量120万kw、設備利用率70%、割引率3%、稼働年数40年のプラントを想定。

※設備利用率は60%・70%・80%、割引率は、0・1・3・5%、稼働年数は40年・60年の複数ケースで試算

事故リスク対応費用(0.3円～/kWh)
・福島原発事故による事故対応費用を、約12.2兆円と想定し,出力規模等により約9.1兆円に補正。
・前回の共済方式を踏襲しつつ、追加安全対策の効果を反映し、4,000炉・年に設定。（ただし今後、全ての追加的安全対策を実施した場合の効果を勘案する必要あり。）
・損害費用は増える可能性があるため、下限を提示。事故廃炉・賠償費用等が1兆円増えると0.04円/kWh増加。

政策経費(1.3円/kWh)
・立地交付金（約1,300億円/年）、もんじゅ等の研究開発費（約1,300億円/年）を含めた約3,450億円を反映。※2014年度予算ベース

核燃料サイクル費用(1.5円/kWh)
・使用済燃料の半分を20年貯蔵後に再処理し、残りの半分を45年貯蔵後に再処理するモデル。
・フロントエンド0.9円、バックエンド0.6円（再処理：0.5円、高レベル廃棄物：0.04円）を含む。

追加的安全対策費(0.6円/kWh)
・新規制基準に基づく、追加的安全対策費を追加。モデルプラントとして計上すべき費用を精査し601億円を計上。（追加的安全対策の実施状況により増減の可能性あり。）

運転維持費(3.3円/kWh)
・人件費20.5億円/年、修繕費2.2%（建設費比例）、諸費84.4億円/年、業務分担費。

資本費(3.1円/kWh)
・建設費37万円/kW（4,400億円/1基）、固定資産税1.4%、廃止措置費用716億円を反映。51

The cost of HLW disposal is estimated as 0.04 yen among around 10.1 yen/kWh. Is disposal cost reduction by P&T comparable to cost of introducing P&T into fuel cycle?

Source: "Report on the Verification of Power Generation Costs, etc. to the Long-Term Energy Supply and Demand Outlook Subcommittee of the Basic Policy Subcommittee of the Advisory Committee for Natural Resources and Energy" (May 2015)

① d. Effect of P&T on cost of Reactor and fuel cycle (French study)

The economic assessment based on the average electricity generation cost showed no difference between the transmutation models, except for the scenario where an accelerator-driven subcritical reactor (ADS) was used for the actinide burner.

For all scenarios using FR, the additional costs due to transmutation ranged from 4 to 9%, while for the scenario using ADS, the additional costs were about 25%.

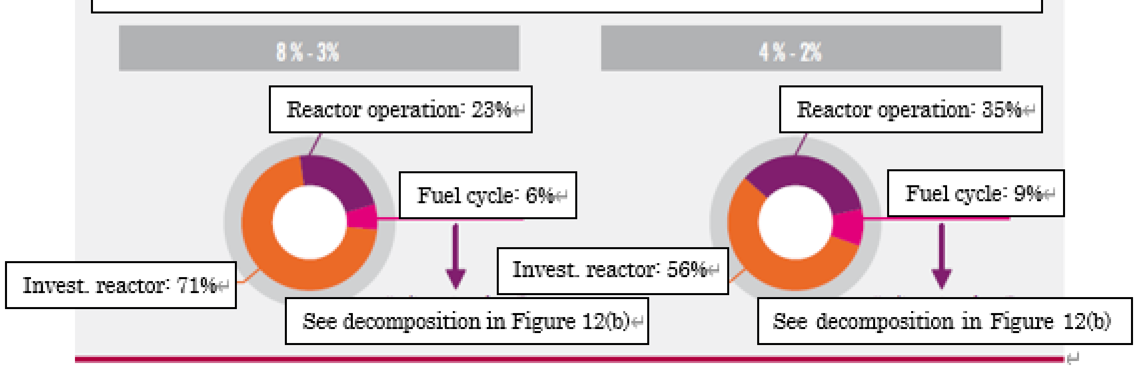


Fig.46 Dividend composition of the FR cost of production after 2120 according to the discount rate

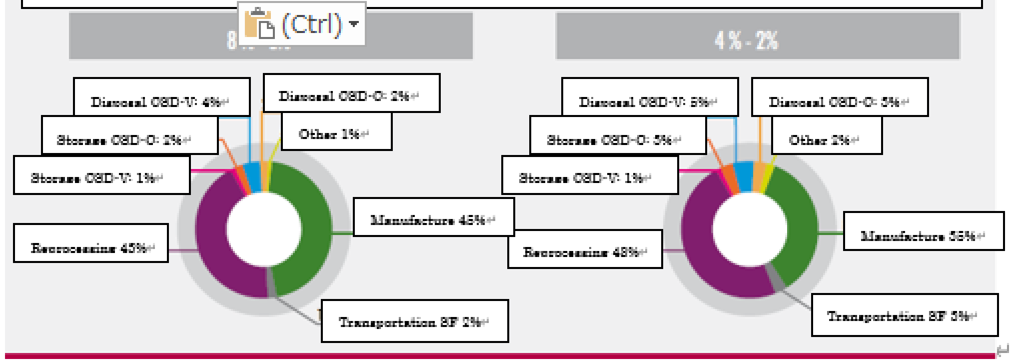


Fig.47 Dividend composition of the FR cost of production after 2120 according to the discount rate

Scenario	Discount rate 8% → 3%			Discount rate 4% → 2%		
	Total	Reactor	Cycle	Total	Reactor	Cycle
Without PT	100	94	6	100	91	9
Heterogenius (MA)	106	96	10	107	92	14
Heterogenius (Am)	104	95	9	105	92	13
Homogenius (MA)	108	95	12	109	92	17
Homogenius (MA)	105	95	10	106	92	13
ADS (MA)	126	116	10	124	110	14

Ref. CEA, Séparation-transmutation des éléments radioactifs à vie longue, December 2012.

①e. Public acceptance

Will P&T improve the public acceptance of nuclear fuel cycle, especially GD?

Effect of P&T on fuel cycle, especially GD (geological disposal) are introduced from the following point of view.

a. Efficient use of resources (U, Pu)

b. Volume of HLW (GD)

c. Reducing the toxicity of high-level radioactive waste (GD)

d. Cost (Fuel cycle)

Now, please consider the effect of P&T on the public acceptance of GD.

Ref; CEA Nuclear Energy Division, Report on Sustainabel Radioactive Waste Management, Dec. 2012.

①e. What do ordinary people think?

- **From NUMO's "Frequently Asked Questions"**

Q: How will you respond when new technology is established?

A: Research and development is being continuously conducted on geological disposal with the aim of ensuring safety, etc., and if a more appropriate technology emerges, it will be incorporated into the disposal project. In parallel with this, research and development is being conducted on P&T of radioactive nuclides to reduce the amount of radioactive waste, etc. NUMO does not allow the current generation to make all the decisions at this point in time, but rather prepares the information necessary for future generations to make appropriate decisions under the various conditions of their generation, and ensures that waste placed underground can be retrieved until the underground facility is backfilled, assuming safety is ensured.

- **Questions and answers at the interactive nationwide briefing on the scientific characteristics map (held at 22 locations from May 10 to August 1, 2018)**

Q: Kochi location: Is there a way to eliminate or reduce radioactive waste?

A: Research on nuclide transmutation is being conducted, but it is not yet practical. Even if it were to be put into practical use, radioactive waste would not be completely eliminated, so geological disposal would be necessary in any case.

Q: Chiba location: Is there any option other than geological disposal?

A: Nuclide P&T technology is being researched, but it is difficult to transmute all long-lived nuclides.

Q: Fukui location: Methods other than geological disposal should also be considered.

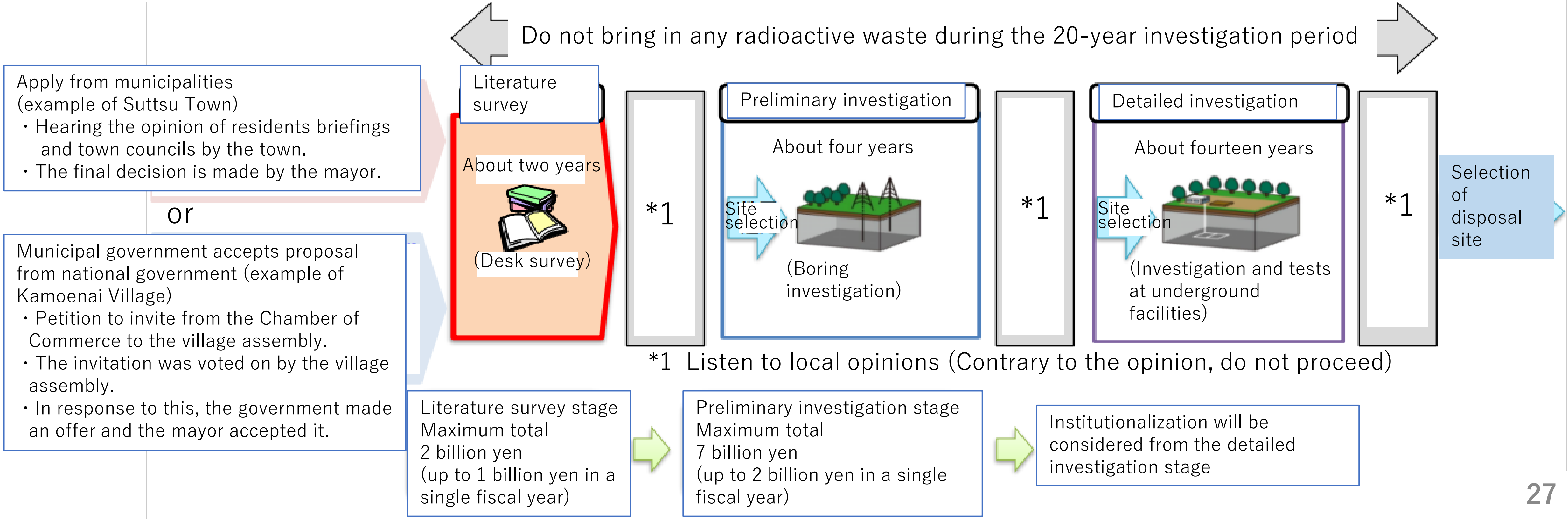
A: JAEA and the Cabinet Office are conducting research on nuclide transmutation, which converts long-lived nuclides into short-lived nuclides. However, it is difficult to transmute all radioactive materials, and geological disposal remains necessary.

② Site selection

- From technical point of views, site investigation to select a site will be done by 3 steps, i.e. consists of an initial literature survey phase and three subsequent stages: selection of Preliminary Investigation Areas (PIAs), selection of Detailed Investigation Areas (DIAs) and selection of the repository site.
- Adopting consent-based processes is common in most countries and needs community engagement.
- Each country determine site selection systems, methods, decision-making processes, etc., reflecting differences in national character, socio-politics, and historical circumstances.

Site selection process of Japan

Ref. Radioactive waste WG (April, 2022) Document 3



③ Multiple safety functions by combining engineered barriers and geological formation

-Although the safety principles and strategies for disposal are the same, the existence of geological formation differs from country to country, the types and characteristics of geological formation to be disposed of differ, and development has been based on the development policies of each country. Because of these reasons, the disposal concepts that have been developed are partly different.

-However, the understanding of the functions that natural and engineered barriers contribute to safety (safety functions) is basically the same, and radionuclides are confined and attenuated by the combination of those barriers and at the point of reaching the biosphere. To date, it has been shown that radiological effect on human may fall below protection targets.

③ Summary of disposal concepts and safety assessment cases in other countries

Country	Waste	Natural barrier	Primary role of engineered barrier system (EBS)＊	Features of safety assessment
France	HLW	Clay layer Saturation layer Reducing environment	Waste packages ensure safety during storage, transport and repository operation, and limit gas release during this period. The overpack and buffer control THM conditions within the repository and protect the host rock from mechanical damage. The seals alleviate radionuclide transport through the excavation-disturbed zone (EDZ) and prevent a “short circuit” pathway through the geosphere.	Deterministic evaluation Analyze for each scenario and compare with protection standards
Finland	SF	Granite Saturation layer Reducing environment	Providing isolation and confinement of the waste, and minimizing radionuclide releases.	Deterministic evaluation Analyze for each scenario and compare with protection standards

＊OECD/NEA, Engineered Barrier Systems and the Safety of Deep Geological Repositories State-of-the-art Report, ISBN 92-64-18498-8, In co-operation with the EUROPEAN COMMISSION, EUR 19964 EN, 2003.

③ Summary of disposal concepts and safety assessment cases in other countries

Country	Waste	Natural barrier	Primary role of engineered barrier system (EBS) ∗	Features of safety assessment
Sweden	SF	Granite Saturation layer Reducing environment	The KBS-3 concept emphasizes the role of the long-lived waste container in isolating the waste from potential receptors. If the isolation fails, the disposal system still provides adequate performance because the waste form is stable and the bentonite buffer and geosphere provide further barriers to radionuclide migration.	Complement probabilistic evaluation with deterministic evaluation Evaluate events probabilistically Analyze for each scenario and compare with protection standards
USA	SF, HLW	Tuff Unsaturated layer Atmosphere	Complementing the natural barriers in providing waste isolation by using long-lived drip shields and waste packages and limiting release of radionuclides by retention, retardation and diffusion barriers	Evaluate events probabilistically Comprehensive performance evaluation (TSPA) results compared to protection standards

∗ OECD/NEA, Engineered Barrier Systems and the Safety of Deep Geological Repositories State-of-the-art Report, ISBN 92-64-18498-8, In co-operation with the EUROPEAN COMMISSION, EUR 19964 EN, 2003.

References for ③

International organizations

-INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, Specific Safety Requirements, IAEA Safety Standards Series No. SF-1, IAEA, Vienna, 2006.

-INTERNATIONAL ATOMIC ENERGY AGENCY, Disposal of Radioactive Waste, Specific Safety Requirements, IAEA Safety Standards Series No. SSR-5, IAEA, Vienna, 2011.

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-OECD/NEA, Engineered Barrier Systems and the Safety of Deep Geological Repositories State-of-the-art Report, ISBN 92-64-18498-8, In co-operation with the EUROPEAN COMMISSION, EUR 19964 EN, 2003.

France

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Sweden

-SKB, Fact sheet - Spent Fuel Repository, 2018.

-SKB, Long-term safety for the final repository for spent nuclear fuel at Forsmark Main report of the SR-Site project Volume I, SKB TR-11-01, 2011.

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-SKB, Radionuclide transport report for the safety assessment SR-Site, SKB TR-10-50, ISSN 1404-0344, 2010.

Finland

-POSIVA, SAFETY CASE FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AT OLKILUOTO –SYNTHESIS 2012, POSIVA2012-12, 2012.

-POSIVA, Safety Case for the Disposal of Spent Nuclear Fuel at Olkiluoto -Assessment of Radionuclide Release Scenarios for the Repository System 2012, POSIVA2012-09, 2012.

USA

-DOE, DOE/RW-0573, Update No. 1, Yucca Mountain Repository License Application, SAFETY ANALYSIS REPORT, Chapter 2: Repository Safety After Permanent Closure, 2008.

④ Institutional control after closure of repository

- Memory keeping
- Marker
- Monitoring (before and after closure)
- Prohibition of unauthorized excavation at disposal site, etc.

- Issues common to all countries that have been discussed by experts from various countries at international organizations such as the IAEA, OECD/NEA, and the EU.
- For example, OECD/NEA, Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Final Report of the RK&M Initiative, 2019.
- Some of these issues have been discussed or incorporated into Acts in Japan, but further consideration is necessary.

IAEA SSR-5; 5.12. Geological disposal facilities have not to be dependent on long term institutional control after closure as a safety measure (see Requirement 5).
Nevertheless, institutional controls may contribute to safety by preventing or reducing the likelihood of human actions that could inadvertently interfere with the waste or degrade the safety features of the geological disposal system. Institutional controls may also contribute to increasing public acceptance of geological disposal.

⑤ Reversibility and retrievability (R&R)

- What is reversibility and retrievability?

- Reason for incorporating reversibility and retrievability

- In Japan, the basic policy for final disposal of HLW revised in 2015 guarantees reversibility from the perspective of securing a wide range of options in the future.

Ref. OECD/NEA, Reversibility and Retrievability (R&R) for the Deep Disposal of High-level Radioactive Waste and Spent Fuel　Final Report of the NEA R&R Project (2007-2011) , December 2011.

Journal of AESJ, Vol.55, No.9 (2013). Vol.55, No.11 (2013). Vol.56, No.1 (2014). Vol.56, No.2 (2014).

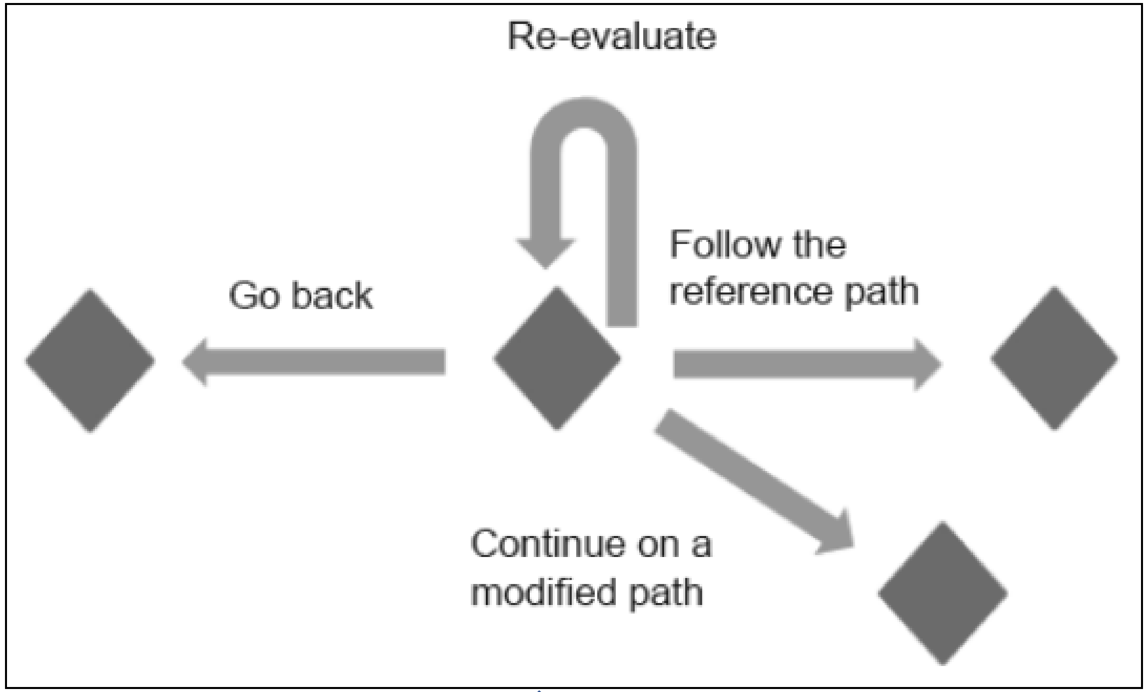
⑤ Definition of R&R

Terminology matters a great deal when discussing R&R and geological repository concepts. For the sake of clarity, the project produced its own definitions of key terms:

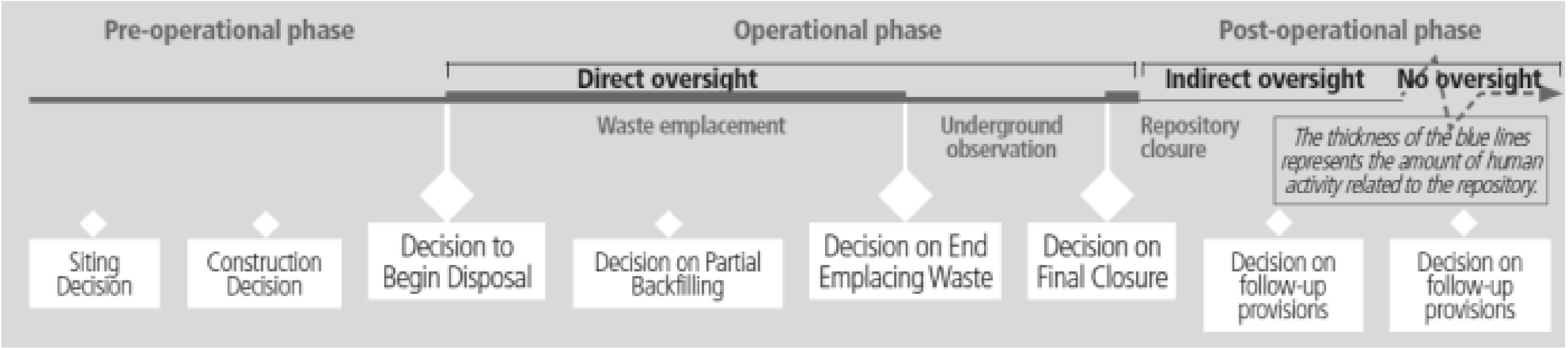
Reversibility describes the ability in principle to reverse or reconsider decisions taken during the progressive implementation of a disposal system; reversal is the concrete action of overturning a decision and moving back to a previous situation.

Retrievability is the ability in principle to recover waste or entire waste packages once they have been emplaced in a repository; retrieval is the concrete action of removal of the waste. Retrievability implies making provisions in order to allow retrieval should it be required.

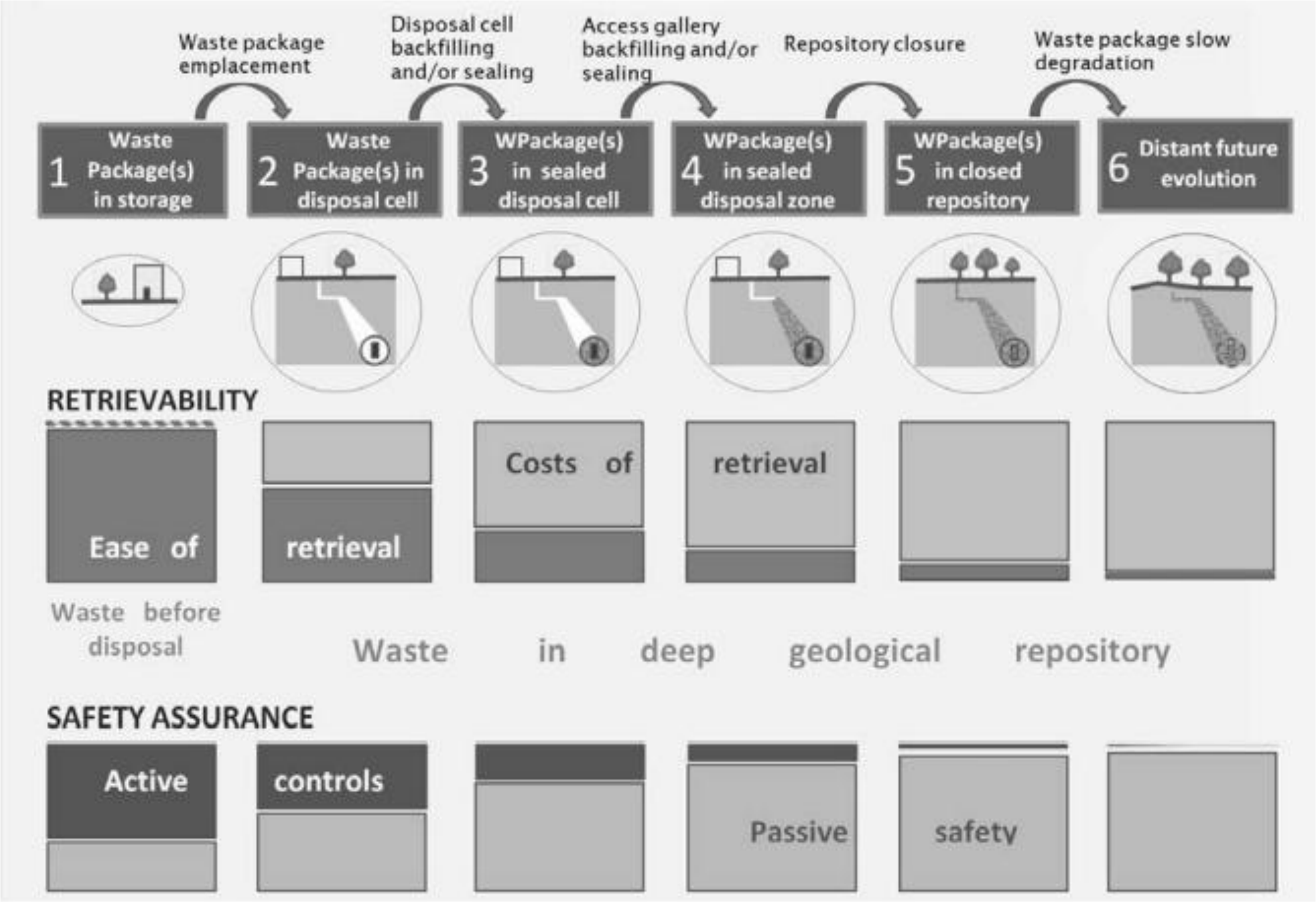
⑤ Reversibility of decisions - potential outcomes of options assessment, including reversal



Repository life phases and examples of associated decisions



⑤ Retrievability



“R-scale” - Lifecycle stages of the waste, illustrating changing degree of retrievability, passive vs. active controls and costs of retrieval in a deep geological repository. During the operational phase, not all waste packages present in the facility will be at the same lifecycle stage.
Note: exact proportions of illustrated rectangles may vary depending on the repository design.

⑤ Observations of R&R project

- There are various approaches to R&R in the policies and laws of each country (some countries require reversibility and retrievability by law, while others do not formally state them).
- It is recognized that even in countries where R&R is not formally enshrined in law or policy, these can be important issues.
- There are technical differences between countries, such as differences in host rocks and differences in the design of reference disposal sites (for example, it is possible to keep tunnels open for a long time after emplacement in some countries).
- Importantly, each country has its own distinct history of repository development, as well as its unique social, cultural and legal environment.
- Given the existence of these fundamental differences, it is to be expected that there will be diversity in R&R efforts.

⑥ Socio-economic issues and countermeasures (how to respond to literature surveys, etc.)

History of Final Disposal and Nationwide Dialogue Activities

-Confidence and trust building

-Information dissemination, dialogue activities (government, NUMO)

a. Transmission of information

-Dissemination to various social strata - cross-media public relations, information dissemination via websites, SNS, and information dissemination via e-mail magazines

-Efforts for the mass media and media, support for geological disposal model exhibition vehicles, workshops and debate classes for educators, etc.

b. Dialogue

-Interactive nationwide information meeting (145 times in total)

-Nationwide expansion of interest groups that want to know more deeply through dialogue activities (approximately 110 interest groups)

-Activities to promote understanding of geological disposal by next-generations

-Dialogue activities in the community

-Regional development

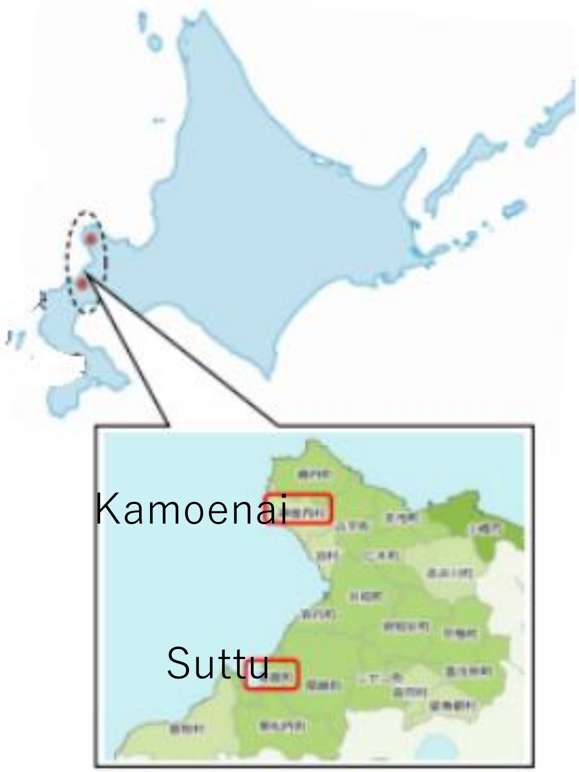
-Countermeasures against reputational damage caused by harmful rumors

Ref. Radioactive waste WG (April, 2022) Document 3

⑥ History of Japanese site selection process from 2000 to 2024

The basic policy was revised in 2015, the "Nationwide Map of Scientific features for Geological Disposal" was published in 2017, and as a result of the accumulation of steady understanding activities since then, a literature survey was started in three municipalities in Hokkaido (Suttsu Town, Kamoenai Village) in 2020, and in Kyushu (Saga Town) in 2024.

2000: Enactment of the Final Disposal Act
⇒ Established NUMO (Nuclear Waste Management Organization of Japan) as the implementer of GD
⇒ Nationwide call for public application of local governments accepting disposal site selection surveys (since 2002)
2007: Toyo Town, Kochi Prefecture (Applied → Withdrawn) ⇒ No host municipality appeared
2013: Establishment of final disposal-related ministerial conference ⇒ Start of drastic review of initiatives
2015: Cabinet decision on new basic policy
• Promote initiatives for geological disposal as a responsibility of the current generation
• Share respect and appreciation for the host community with the people
• Secure reversibility from the perspective of securing a wide range of options in the future
• The national government takes the initiative, such as presenting areas that are scientifically considered to be more suitable.
2017: Published the Scientific Characteristics Map
• Started dialogue activities nationwide
2018: Commencement of detailed dialogue activities centered on dark green areas on the map
2019: Strengthening information provision based on the needs of interested groups who want to know more, etc.
Formulation of the "immediate action policy toward the start of literature surveys in multiple regions"
2020: Literature survey started in two municipalities in Hokkaido (Suttsu Town, Kamoenai Village)



Ref. Radioactive waste WG (April, 2022) Document 3

⑥ Recent movement of literature survey at three municipalities

(1) Suttsu Town and (2) Kamoenai Village, Hokkaido

- In February 2024, NUMO reported and published a draft report on the literature survey for Suttsu Town and Kamoenai Village to the METI’s Council.
- After that, the Council deliberated and evaluated the report, and NUMO made preparations such as preparing a revised report based on the evaluation.
- As a result, on November 22,, as a statutory process based on the Final Disposal Act, the Chairman of the NUMO Board delivered the report and summary of the literature survey to the Mayor of Suttsu Town, the Mayor of Kamoenai Village, and the Governor of Hokkaido, and published notices in the Official Gazette, Hokkaido Prefectural Gazette, and daily newspapers regarding "Place, period, and time for public viewing of reports, etc.", "Date and time and place for holding explanatory meetings," and "Submission of opinions on reports, etc."

(3) Genkai Town, Kyushu

- In April 2024, a petition was submitted to the town council in Genkai Town, Saga Prefecture, requesting the acceptance of a literature survey. On April 26 of the same year, the Genkai Town Council adopted a petition requesting the acceptance of the literature survey at its general meeting.
- On May 1 of the same year, the national government made a request to conduct a literature survey, and on May 7 of the same year, the Genkai Town Mayor met with the Minister of Economy, Trade and Industry, and on May 10 of the same year, the Genkai Town Mayor expressed his intention to accept the national government's request for a literature survey.
- On June 10 of the same year, NUMO received approval from the national government to change its business plan and began the literature survey.

(4) Tsusima City, Kyushu

- In June 2023, a total of eight petitions regarding the attraction (promotion/opposition) of a disposal site were submitted to the city council in Tsushima City, Nagasaki Prefecture.
- On September 27 of the same year, the intention not to accept the literature survey was expressed.

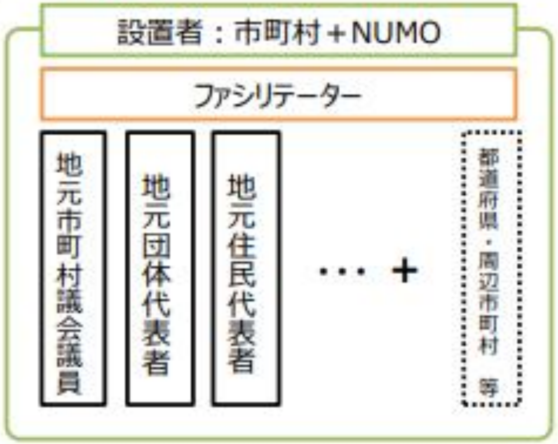
⑥ Dialogue activities

Role of community dialogue forums in Suttu and Kamoenai

- It is important to have continuous dialogue and deepen discussions among residents based on the provision of appropriate information.
- For this reason, a “forum for dialogue” was established when conducting a literature survey. In response to the opinions of the committee members at the "forum for dialogue," various initiatives are implemented to support the region.

<Image of operation of “Forum for Dialogue”>

- 第三者のファシリテーターを配置し、賛否に偏らない議論を行う。
- 立場を超えた自由な議論と透明性の確保を両立。
- 委員以外の一般住民が様々な形で参加できる機会を積極的に設ける。



<諸外国における対話活動の例>

スウェーデン　【写真提供】エストハンマル自治体

カナダ　【出典】イグナス地域連絡委員会HP引用

<Image of study theme>

Disposal business related

- 処分事業の概要
- 安全確保の考え方
- 文献調査の経過報告
- 関連施設への視察　　等

＋

Regional development vision

- 将来のまちづくりに関する議論
- 経済社会影響調査の実施
- プラス影響促進策の提案
- マイナス影響への懸念への対応方針の議論　　等

※海外事例や国内類似例等を参考としつつ、有識者からの意見も踏まえながら議論。

Re. Atomic Energy Sub-committee（May 10, 2022）Document 6.

⑥

Main discussion of dialogue forums in Suttu and Kamoenai

Concerns about geological disposal	✓ No matter what I say, I'm very worried that it will go according to NUMO's policy! ✓ What does NUMO do? Is geological disposal really safe? ✓ How will the literature survey proceed? ✓ (Anxiety) Division of townspeople ✓ Underlying this is a feeling of distrust, saying that “the council and the village chief made the decision on their own” and “it was reported after the reception started,” and recently it has become difficult to talk about literature research. ✓ Isn't the nationwide briefing session ineffective? We should work more nationally. Since it is a national energy policy, I would like the government to be firmly involved and the Energy Agency to join the discussion. Instead of discussing only locally, discuss roads and countries together. The governor and the mayor of the village must discuss together.
Opinions positive about efforts to promote understanding	✓ Through this literature survey, many townspeople have come to think about the future of Suttsu. Create lots of opportunities for discussion. A once-in-a-lifetime chance! ! ✓ Wouldn't it be nice to have a place for the younger generation to discuss things other than a place for dialogue? ! ✓ Regarding the geological disposal project, isn't it necessary to visit what it is actually like in order to promote understanding? Whether you agree or disagree, the first thing is to understand. ✓ I want the pro- and anti-professional groups to discuss. ✓ Too little information on regional development. I would like NUMO to provide information about the potential for regional development in this village. ✓ There are many people of the Showa generation who carry the burden of “because they invited the nuclear power plant”. It would be nice if there was a place for those people to interact with the next generation.

Re. Atomic Energy Sub-committee（May 10, 2022）Document 6.

⑥ Regional development

Subsidies for measures for power source location areas associated with the implementation of literature surveys

- The grant accompanying the literature survey can be used for regional development, public facility development, medical and welfare services, etc., and can be granted up to 2 billion yen during the survey period (maximum of 1 billion yen per year).
- If the grant amount of the survey implementation municipality is 50% or more, the rest can be distributed to the surrounding municipalities according to the actual situation of the region.

Business overview of Suttsu Town (2021)

上期申請分

- 各種行政サービス実施事業【3.7億円】
  - ・消防関連事業（消防士人件費　等）
  - ・環境衛生関連事業（ごみ処理施設運営費　等）
  - ・福祉サービス関連事業（保育所運営費　等）
  - ・人材育成関連事業（食育センター運営　等）など

下期申請分

- 基金計上【5.6億円】
  - ・上期申請と同様の事業を実施するための基金
- 近隣への配分【0.75億円】
  - ・岩内町

※端数を四捨五入している関係で、合計が10億円と一致しない。

Business overview of Kmoenai Village (2021)

上期申請分

- 各種行政サービス実施事業【0.4億円】
  - ・防災関連事業（消防用設備整備　等）
  - ・環境衛生関連事業（塵芥収集車整備　等）
  - ・医療関連事業（診療所機器整備　等）

下期申請分

- 基金計上【7.4億円】
  - ・水産業関連事業（漁協設備整備　等）
  - ・交通インフラ関連事業（村道維持管理費　等）
  - ・観光関連事業（商工会職員人件費　等）　など
- 近隣への配分【2.25億円（0.75億円×３）】
  - ・古平町、泊村、共和町

13

Re. Atomic Energy Sub-committee（May 10, 2022）Document 6.

⑥ Regional development

Image of regional development vision

While utilizing "forums for dialogue" such as the improvement of medical care and the development of transportation infrastructure, we will grasp the issues facing the region, and propose and materialize initiatives that will contribute to these issues. (Utilizing subsidies and various support systems)

Medical care, disaster prevention, education

【医療】
- 元々は眼科診療を実施できる医療機関がなかった地域において、中心となる医療センターに**眼科医療用機器及び眼科診療システム一式を整備**することで、同地域でも眼科診療が実施できるようになった。

【防災】
- 定期バス路線でもあり、地域防災計画でも主要道路にも位置付けられている重要な生活道路において、防護柵が塩害等で老朽化。地域の方々からの不安の声も踏まえて、**防護柵の修繕工事を実施**。

【教育】
- 地域の産業活性化につなげる人材育成のため、**首都圏の大学と連携して社会人向けに講義を開講**。
- 修了生が**地場産品を活用した新たな商品を開発**。起業や新規事業を創出。

Infrastructure development /Invitation of companies

【交通インフラ】
- 入り組んだ地形により交通が不便な地域において、**新たに道路を開通**。救急車等の緊急車両の運転がスムーズになる、学生の通学が便利になる等で、地域の方々の利便性が大きく向上。

【企業誘致】
- **高速ブロードバンド環境の整備**、**オフィス開設のための古民家改修等を支援**。
- **サテライトオフィスを整備**することで、ICTベンチャー系企業の拠点が進出。当該地域への移住者や来訪者も増加。

（古民家を改装したサテライトオフィス）

写真出典：地方創生事例集（内閣官房まち・ひと・しごと創世本部事務局 内閣府地方創生推進事務局）

Tourism promotion and community development

- 廃校を道の駅として再生し、**地場産品の直売**、**教室を使った宿泊施設**、**まちの観光や食の情報発信**等、**交流活性化の拠点として活用**。新規事業者・雇用・交流客を創出。
- **多様な地域関係者が議論をする場**を設けながら、地域の農業を活かして、**農業体験や農家民泊等のプログラムを実施**。当該地域に訪れる人口の増加、農家の収入や雇用の増加に貢献。
- ごみ処理や下水処理等の**バイオマス活用施設の視察**と併せて、観光施設や特産品を提供する飲食店等を案内する**バイオマスツアーを実施**。地域消費額の向上に貢献。

23

Re. About the immediate policy for conducting literature surveys in multiple regions（2019 Local government briefing materials）

⑥ Countermeasures against reputational damage caused by harmful rumors

Example of ALPS treated water release (1)

What are the measures for disposal of ALPS treated water?

・Since the basic policy was decided in April 2021, while starting to promote understanding and public relations, Government has confirmed the real voices of local governments, farmers, foresters and fishermen. Based on these, "immediate measures" were compiled in August.

・Implement monitoring of radioactive substances in fishery products and publish them as needed. With the cooperation of the International Atomic Energy Agency (IAEA) and others, we will thoroughly disclose information overseas.

・In order to further accelerate efforts, in December, an “action plan” was formulated to organize the actions for the next year and the medium- to long-term direction for each measure.

(From Atomic Energy Commission regular meeting (March 22, 2022) Document 3

⑥ Countermeasures against reputational damage caused by harmful rumors

Example of ALPS treated water release (2)

・Established a fund to temporarily purchase marine products whose demand has fallen. (30 billion yen scale)

・Strengthen information dissemination to prevent harmful rumors.

・In the future, the government will collect opinions from the parties concerned and compile an action plan that includes specific measures by the end of the year.

・The government hopes to gain the understanding of the parties involved in the release of treated water by establishing a mechanism in advance to deal with harmful rumors about treated water.

・On August 30th, the government decided to consider establishing a new fund in addition to countermeasures against harmful rumors in order to support the business continuity of fishermen at the relevant ministerial meeting.

⑦ Regulatory system

Regulatory system

-The Designated* Radioactive Waste Final Disposal Act (Final Disposal Act): Business Regulations

Basic Policy Concerning Final Disposal of Specified Radioactive Waste, Plan Concerning Final Disposal of Specified Radioactive Waste, Site selection steps, etc.

-The Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (Reactor Regulation Act): Safety Regulations

Matters to be considered at least for ensuring safety when selecting Preliminary Investigation Areas (PIAs), Detailed Investigation Areas (DIAs), and selection of the repository site. Active fault, volcano, erosion and mineral resources.

Prohibition of excavation: Article 51-29 Without permission from the Nuclear Regulation Authority, no excavation shall be allowed within the designated waste disposal area.

(Reference) NRA Technical Note, NTEN-2022-0001 Background and Evidence of the Regulatory Requirements for Intermediate-depth Disposal.

Note; * Both “designated” and “specified” are used in Japan.

⑧ Uncertainty - Long-term stability of geological formation

US YMP safety protection goals Compliance period:
Geologically stable period (1 million years) discussion (1/2)

1. The NRC rule is based on the discussions and conclusions made when the Environmental Protection Agency (EPA) rule for Yucca Mountain was developed.
2. Request from Congress: EPA rules should reflect the consideration of the National Academy of Sciences (NAS).

<u>EPA's conclusion</u>

1. What is geological stability?

   A state in which the physical and geological processes that may affect the disposal system are relatively stable and can be bounded

2. Differences within and outside the geological stability period (scientific and policy decisions)

   a. Within the period: Radionuclide migration from the disposal system and dose assessment of human exposure can be evaluated as meaningful.

   b. Out-of-Period: Risk may be greatest beyond the period of geological stability, but performance assessments conducted for that period are less reliable and may not be a rational basis for regulatory decisions.

⑧

US YMP safety protection goals Compliance period: Geologically stable period (1 million years) discussion (2/2)

1 Million Years of Compliance Debate NAS vs EPA

1. The NAS has undergone changes in a steady manner during the Quaternary period (last 2 million years) and beyond, not only in the active processes of the site, but also in the site itself, which is consistent with its current behavior, and further concluded that it would continue for the next million years.
2. Meanwhile, EPA requires DOE to consider at least the past 2 million years (the equivalent of the Quaternary period) in characterizing Yucca Mountain's FEP. This is the same content as the above NAS.
3. It is indicated that a million years is a timeframe long enough to assess the potential impact of both slow processes (e.g. fault displacement) and destructive events (e.g. igneous activity and seismic ground motion) on the performance of the disposal system, considering thousands of years of groundwater migration time from repository to RMEI (Individuals reasonably expected to receive maximum exposure) location.

Conducting surveys of geological events over the past two million years

Conclusion that similar geological conditions will continue for the next million years

After 1 million years, unknown geological conditions for rational regulatory assessment

Two million years before | One million years before | **Present time** | **One million years after**

⑧

Differences in Views on NAS Reports and EPA (and NRC) Standards

How far into the future is it reasonable to predict the performance of the disposal system?

1. **NAS**: Recommendation that the **compliance period should be "at the point of greatest risk within the limits imposed on the long-term stability of the geological environment**"
   - ➢ There is **no scientific basis for limiting the individual risk threshold to 10,000 years** or any other value
2. **EPA**: Noting that both **technical and policy considerations** are involved in choosing a compliance period, **adopt a fixed period (10,000 years)** during which the repository must meet the disposal criteria.
3. **Reliability of data, models, etc.** – **Rational basis for regulatory decision-making**
   - ➢ There is still considerable uncertainty about whether current modeling capabilities will allow the development of computer models that give sufficiently meaningful and reliable estimates over timeframes of tens of thousands to hundreds of thousands of years. There is the mere fact that such **models are capable of forecasting over such time periods does not mean that the forecast results are meaningful and reliable enough** to establish a rational basis for regulatory decision-making.

⑨ Principle of waste minimization

-Waste minimization is a requirement of the IAEA. Both radioactivity and volume shall be reduced.

(Reference) IAEA Safety Document "Predisposal Management of Radioactive Waste, Safety Standard Series No. GSR Part5, (2009): Requirement 8 Radioactive waste generation and control

All radioactive waste shall be identified and controlled. Radioactive waste arisings shall be kept to the minimum practicable.

-Japan Atomic Energy Commission, Policy on Processing and Disposal of Low Level Radioactive Waste (Views) (December 28, 2021)

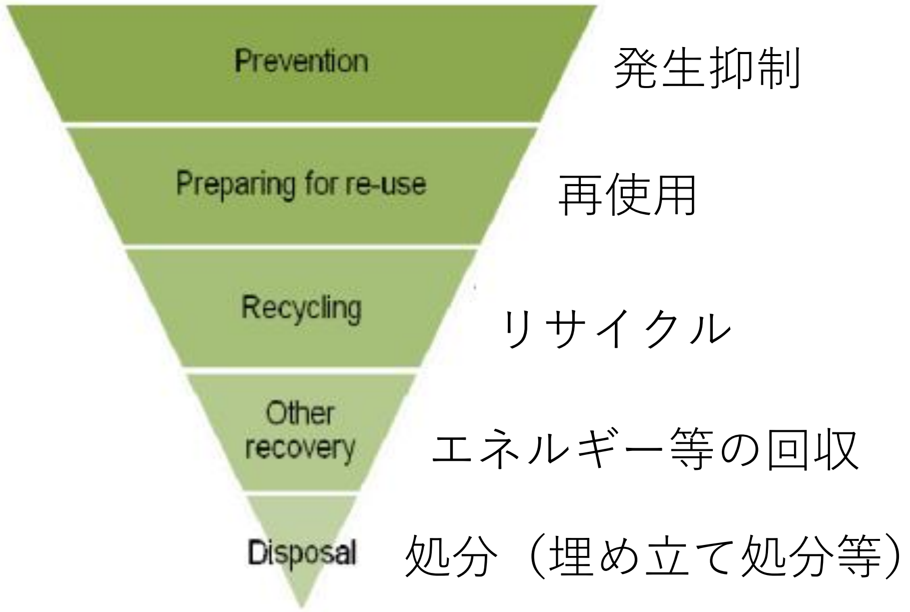
Principle of waste minimization

In the management, treatment, and disposal of waste, it is important to give top priority to ensuring safety. In order to control the environmental impact, the first step is to prevent the generation of waste during decommissioning, etc. as much as possible. , it is necessary to minimize the amount of radioactive materials generated in terms of both quantity and volume. In doing so, we will measure and evaluate the radioactivity of waste such as metals and classify it appropriately based on the results, thereby promoting the reuse of materials that are not contaminated with radioactive substances. It is desirable to promote the reuse of waste that falls below safety standards and does not need to be treated as radioactive waste legally by utilizing the clearance system, as has already been done in Europe. It is appropriate to minimize waste through these efforts and to dispose of the remaining radioactive waste at a landfill site.

The principle of waste minimization is also consistent with the direction of aiming for a sustainable recycling-oriented society.

⑨
Radioactive waste is sorted, processed and then disposed of underground.

- Waste generated from the use of nuclear power and radiation can be classified into the following three types.
  - Waste that is not radioactive waste ⇒ Treated as general industrial waste.
  - Things that do not need to be treated as radioactive materials (clearance) ⇒ Can be reused or disposed of as general industrial waste.
  - Radioactive waste ⇒ Items to be disposed of that are contaminated with radioactive substances.
- Radioactive waste contains radioactive materials, and it is necessary to protect people from the radiation emitted by the radioactive materials. This kind of management is also learned from general industrial waste. An example from the UK is shown below.



Conventional waste management hierarchy

(DEFRA, Guidance on applying the Waste Hierarchy, 2011.)

Solid low level waste management hierarchy

(DECC, et al, UK Strategy for the Management of Solid Low Level Waste from the Nuclear Industry, 2016.)

⑩ Securing fund for HLW disposal

- Estimation of HLW disposal costs
- Final disposal costs for specified radioactive waste and revisions to the unit price of contributions
- HLW producers' Contribution (Ordinance of the Ministry of Economy, Trade and Industry)

Calculation formula for the unit price contributions required for final disposal work per unit amount of specified radioactive waste

$$\text{Unit price of contributions} = \frac{\text{The present value of the total amount of costs necessary to carry out the final disposal work in the future} - \text{Reserve balance of final disposal contribution (including investment profit)}}{\left(\text{Total amount of specified radioactive waste for final disposal} - \text{Amount of specified radioactive waste for which contributions have already been made}\right)\ \text{present value}}$$

⑪ Situation in other countries

-Finland, Sweden, and France are leading the way.

-It is important to learn from other countries' experience.

-Even if a successful example is introduced as it is, it does not necessarily lead to success.

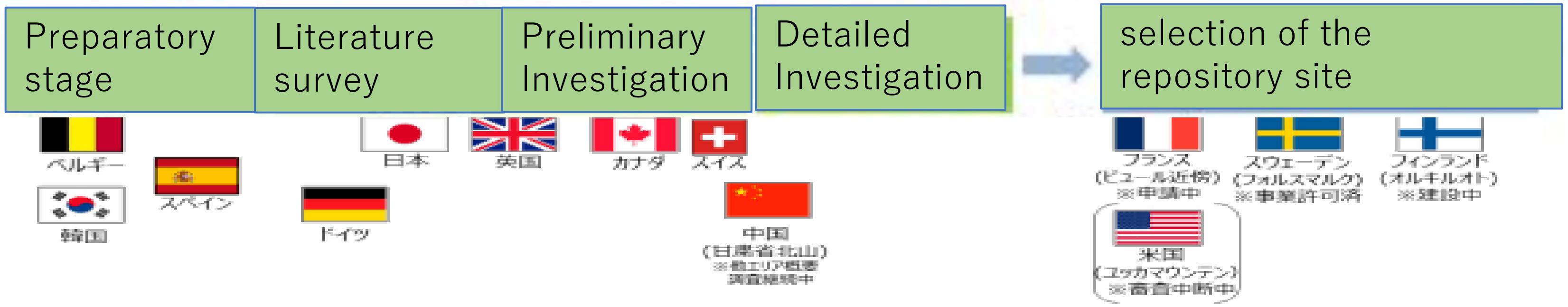
-In EU member countries, conditions for adding nuclear power plants to the EU green taxonomy;

- -Compliance with EU laws, radioactive waste management fund, decommissioning fund
- -Operation of very-low/low/intermediate level radioactive waste repository
- -Plan to operate a geological repository for high-level radioactive waste by 2050

⑪

Situation of Nuclear Powered Countries toward Realization of Final Disposal

- Realizing the final disposal of high-level radioactive waste is a common issue for all countries that use nuclear power.
- Even in Finland, the only geological site for SF in the world that has started construction, it has spent more than 30 years since deciding to implement geological disposal, and has made untiring efforts to gain public and regional understanding.



Finland (Eurajoki)

- Population: about 9400 people
- Olkiluoto Nuclear Power Plant is located
- Nuclear power generation is the main industry

France (near Bure URL)

- Scheduled to be located on the border of Meuse and Haute-Marne departments
- There are about 600 people in the 6 main municipalities (approximately 90km2) where the disposal site will be constructed, and agriculture is the main industry.

Sweden (Östhammar)

- Population: about 22,000
- Forsmark nuclear power plant is located
- There are many archipelagos off the coast, and it is also famous as a summer resort and tourist destination.

Source: Nuclear Energy Subcommittee (May 10 , 2022) Document 6 , Revised based on “Frequently Asked Questions Q&A, as of February 2024”,

⑪ Screening criteria set out in EU taxonomy supplementary delegated rules

4.28. Electricity generation from nuclear energy in existing installations
Description of the activity
Modification of existing nuclear installations for the purposes of extension, authorised by Member States' competent authorities by 2040 in accordance with applicable national law, of the service time of safe operation of nuclear installations that produce electricity or heat from nuclear energy ('nuclear power plants').
The activity is classified under NACE codes D35.11 and F42.22 in accordance with the statistical classification of economic activities established by Regulation (EC) No 1893/2006.
An economic activity in this category is an activity as referred to in Article 10(2) of Regulation (EU) 2020/852 where it complies with all the technical screening criteria set out in this Section.
Technical screening criteria (extract)
1. The project related to the economic activity ('the project') is located in a Member State which complies with all of the following:
(a) Council Directive 2009/71/Euratom and **Council Directive 2011/70/Euratom**;
(b) Euratom Treaty and with legislation adopted on its basis,;
(c) approval date of the project, a radioactive waste management fund and a nuclear decommissioning fund which can be combined;
(d) resources available at the end of the estimated useful life of the nuclear power plant corresponding to the **estimated cost of radioactive waste management and decommissioning**;
(e) **operational final disposal facilities for all very low-, low- and intermediate-level radioactive waste**;
(f) documented plan with detailed steps to have in **operation, by 2050, a disposal facility for high-level radioactive waste** describing all of the following: concepts from generation to disposal, concepts for the post-closure period of a disposal facility's lifetime, the responsibilities for the plan implementation and the key performance indicators to monitor its progress, cost assessments and financing schemes.
For the purposes of point (f), Member States may use the plans drawn up as part of the **national programme** required by Articles 11 and 12 of Directive 2011/70/Euratom

Ref. REGULATIONS COMMISSION DELEGATED REGULATION (EU) 2022/1214 of 9 March 2022 amending Delegated Regulation (EU) 2021/2139 as regards economic activities in certain energy sectors and Delegated Regulation (EU) 2021/2178 as regards specific public disclosures for those economic activities

⑪ Screening criteria set out in EU taxonomy supplementary delegated rules

天然ガス発電施設の建設・稼働（抜粋）	原子力発電施設の建設・稼働（抜粋）
次の1または2のいずれかの基準を満たす 1.ライフサイクル全体での温室効果ガス排出量がCO_2換算量（1kWh当たり、以下同）で100g未満 2.新設（2030年末までに建設認可を受ける）の場合、以下の全ての基準を満たすこと ・直接排出量が270g未満、あるいは20年間にわたって年間直接排出量が設備容量1kW当たり平均550kg未満 ・代替される電力を再生可能エネルギーで賄うことができない ・固体・液体化石燃料を用いた既存の排出量の多い施設を代替する ・代替による出力増加は15%以内 ・代替により排出量を1kWh当たり55%以上削減する、など	2045年までに建設認可を受けている、あるいは2040年までに運転期間延長のための修繕の認可を受けていることが前提 ・ライフサイクル全体の温室効果ガス排出量がCO_2換算量で1kWh当たり100g未満 ・EU関連法令を順守 ・放射性廃棄物管理基金、廃止措置基金を創設 ・放射性廃棄物管理と廃止措置に必要な資金を運転終了時に確保できる見込みを示す ・極低・低・中レベル放射性廃棄物の操業可能な最終処分場を有する ・2050年までに高レベル放射性廃棄物の最終処分場を操業する詳細な計画を有する ・2025年から事故耐性燃料（ATF）を利用（新設、既設改修とも） など

出所：日本エネルギー経済研究所資料

Conclusion

In the keynote speech, technical and social issues of final disposal were introduced.

A major issue for final disposal is safety. Based on this premise, various issues have been also discussed. If the goal of these issues is to get people to understand and accept final disposal and final disposal sites can be managed and closed, I think most of the issues have not yet been answered.

Are there any students who are interested in the subject I introduced today? If anyone is interested in them, I hope that you will be able to think and express your own opinion about them.

These issues have been discussed for many years in international organizations or through international projects from the 1990s to today. Relevant information can be collected through the Internet.

I hope that you will first gather relevant information, read and understand the contents, exchange opinions with your colleagues if possible, and be able to make and express your own opinions. By doing so, I think the information becomes your own living knowledge.

As final disposal is a project that spans more than 100 years, I hope that you and succeeded next generations will continue to do so.