Japanese Concepts on the Repository of Nuclear Wastes and Possible Deep Borehole Disposal

DBD Working Group Meeting

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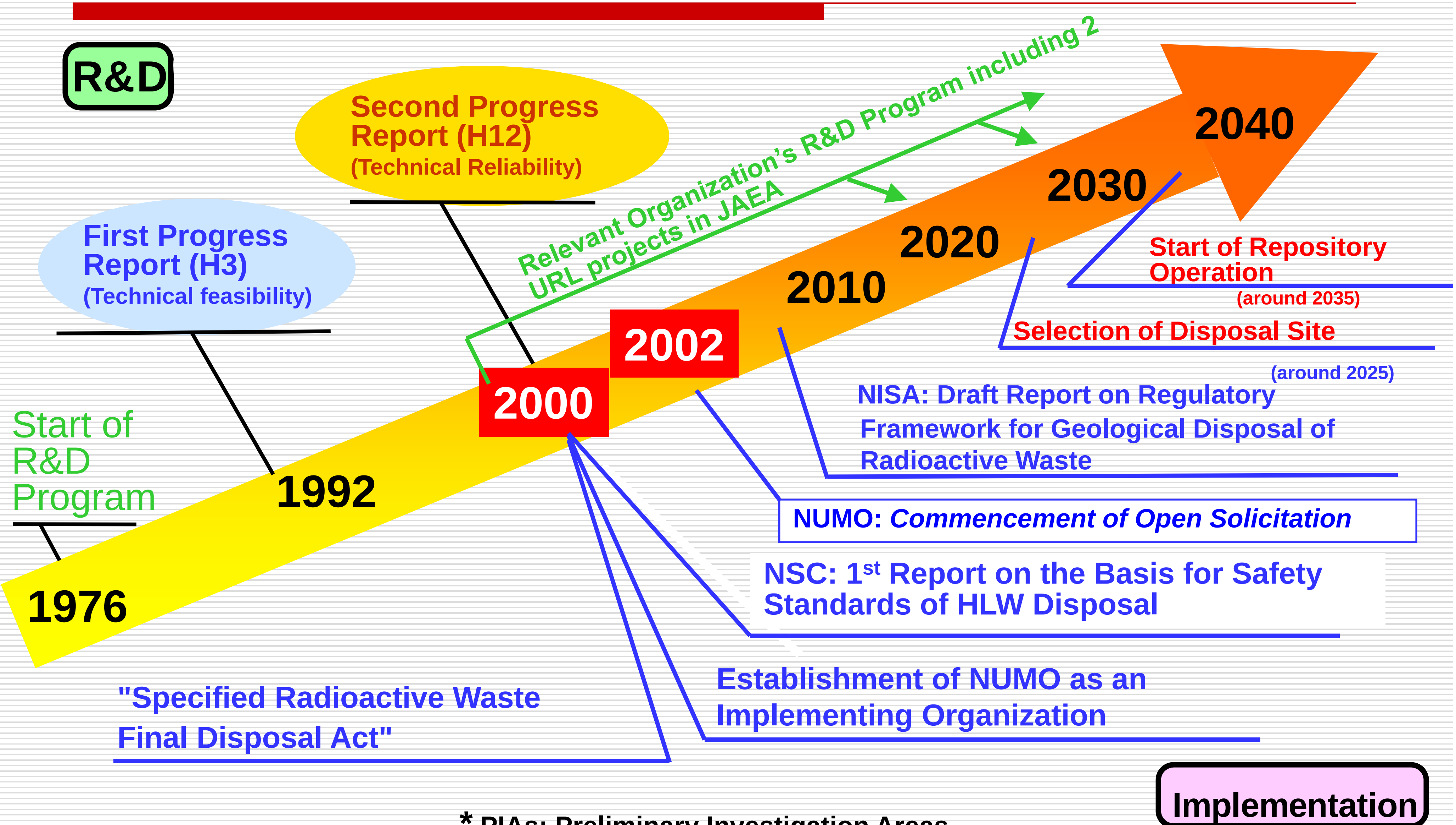
Contents of this presentation

- R&D history of high-level radioactive wastes (HLW) disposal in Japan
- Present status on the siting activities and challenges faced
- Information related to deep drilling disposal
  - Japanese experience on deep drilling
  - Geological characteristic necessary to be considered, i.e., deep fluid circulation, in-situ stress condition
  - Pros-and-Cons/challenges for DBD
- Concluding remarks

Development of HLW Disposal Program



* PIAs: Preliminary Investigation Areas

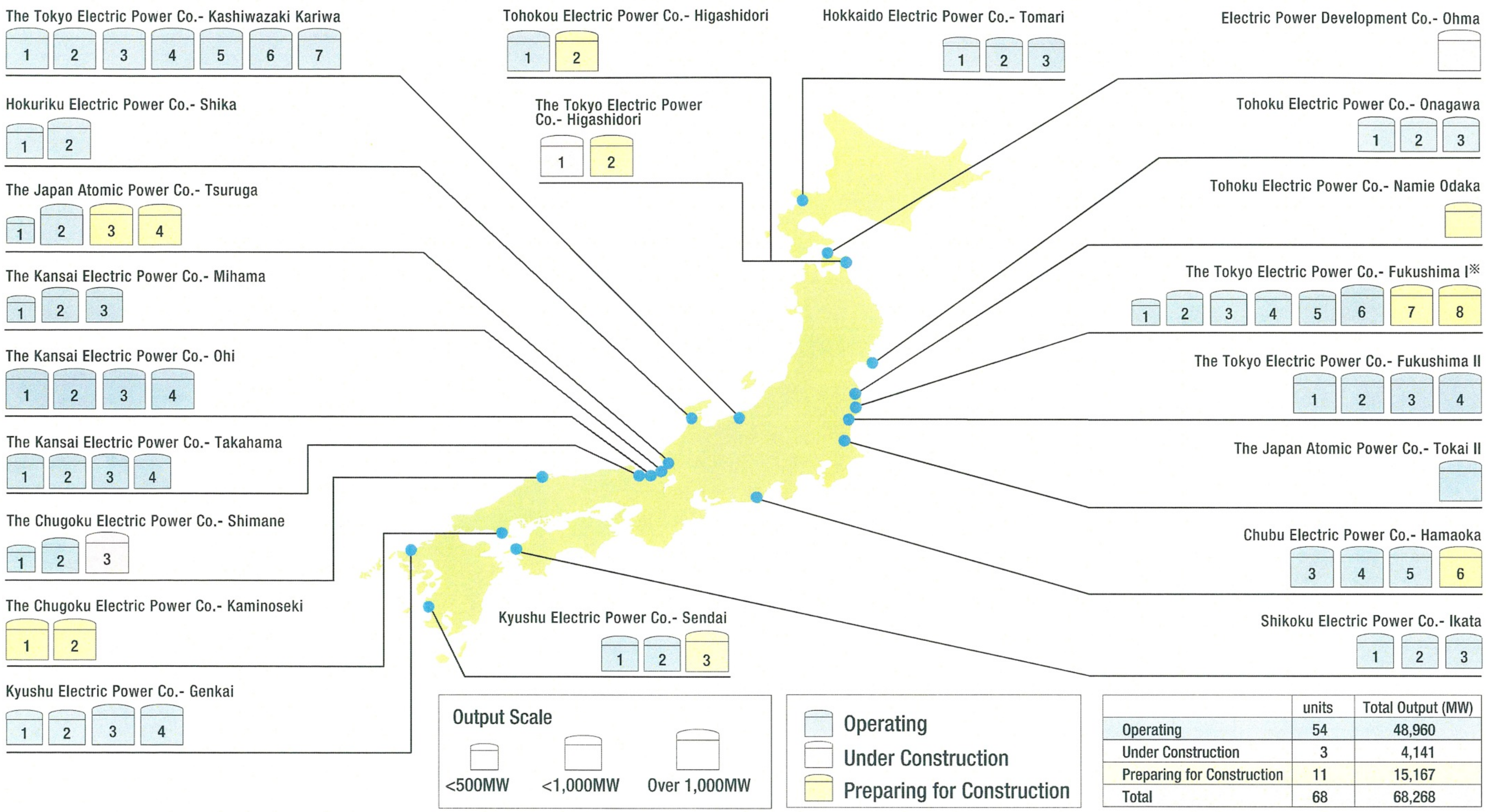
** HLW: High-level Radioactive Waste

Background of HLWM program in Japan

- Extensive Nuclear power program with nuclear fuel recycle option
- Challenge due to complex geology/active tectonic setting
- Intensive development of HLWM program for generic studies for more than 3 decades

Nuclear Power Plants in Japan

(Commercial Plants, as of the end of March 2011)



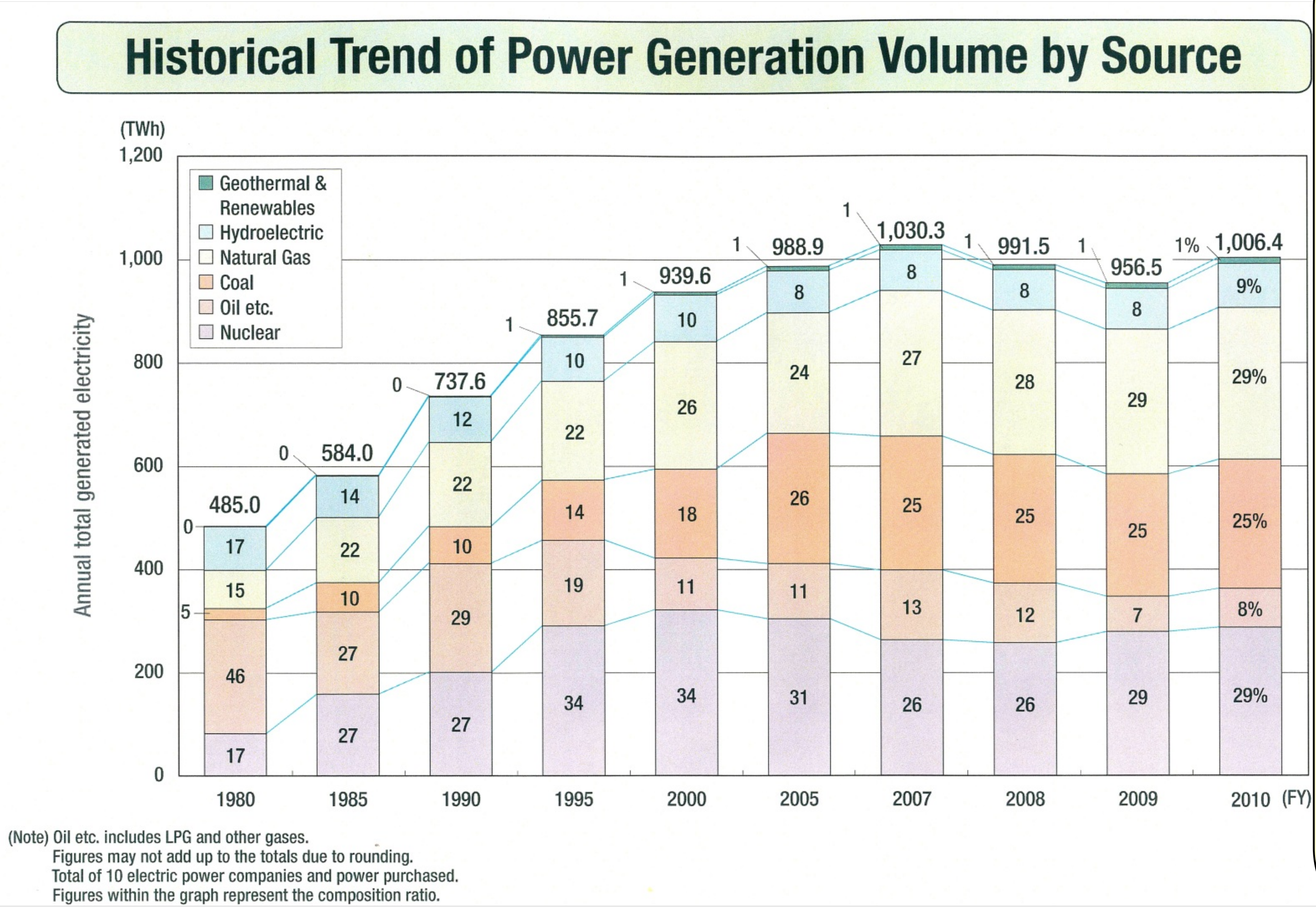
	units	Total Output (MW)
Operating	54	48,960
Under Construction	3	4,141
Preparing for Construction	11	15,167
Total	68	68,268

End of Operation: The Japan Atomic Power Co.- Tokai (March 31, 1998) / Chubu Electric Power Co.- Hamaoka reactors 1 and 2 (January 30, 2009)

※ In May, 2011, Tokyo Electric Power Company decided to decommission Units 1 to 4 and to abolish plans to build Unit 7 and 8 at Fukushima Daiichi Nuclear Power Station which were severely damaged due to the Tohoku-Pacific Ocean Earthquake and the tsunami that followed after on March 11, 2011.

(http://www.fepc.or.jp/english/library/graphical_flip-chart/__icsFiles/afieldfile/2012/04/02/all_english.pdf)

Vitrified HLW with Large Inventory



In storage: ~1,700 vitrified HLW

Total volume: corresponding to ~23,100 vitrified HLW
(as of Mar 2010)

Estimated total volume: ~40,000 vitrified HLW
(by 2020)

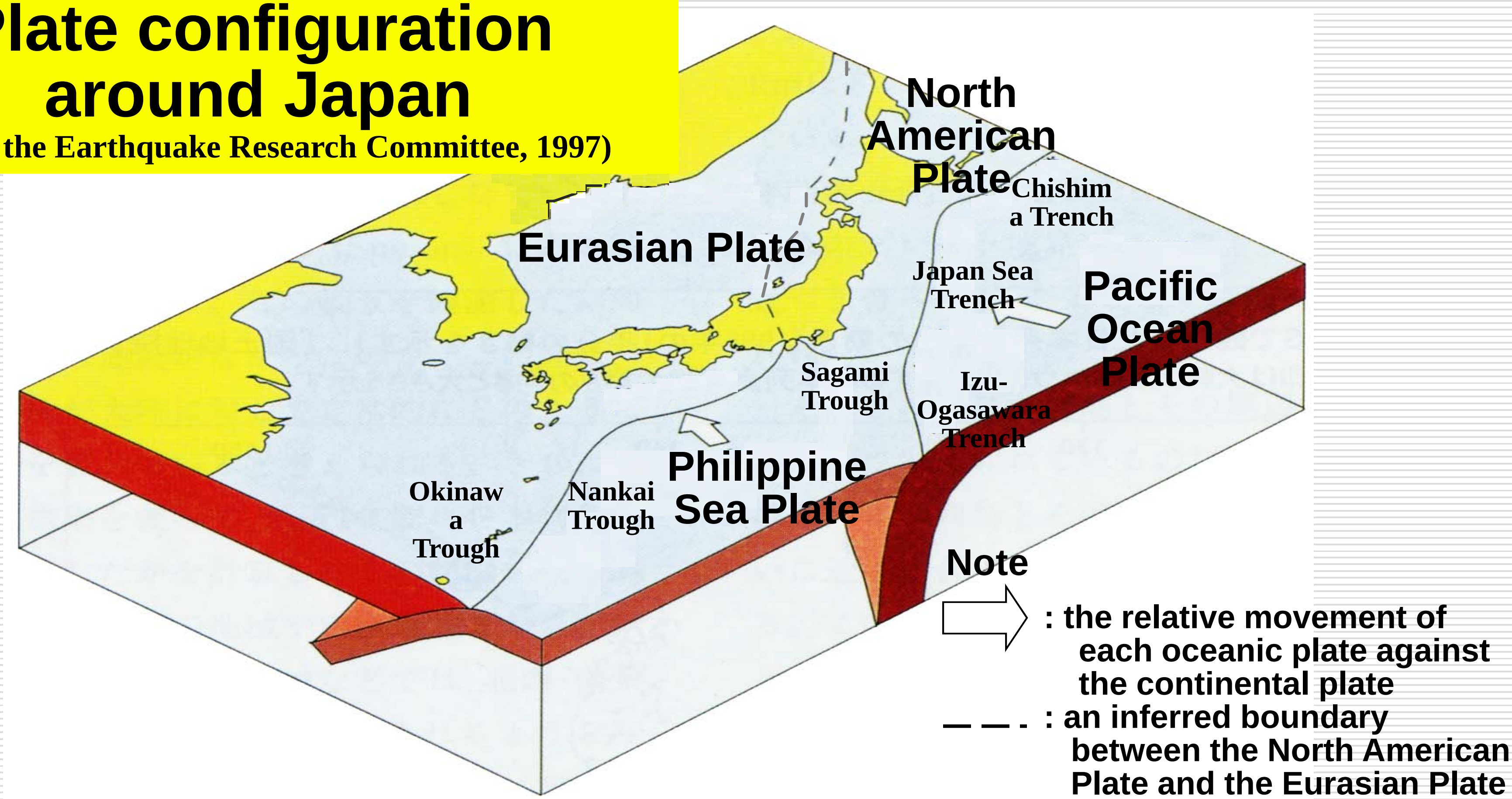
Repository operation
(around 2030s)

(http://www.fepc.or.jp/english/library/graphical_flip-chart/__icsFiles/afieldfile/2012/04/02/all_english.pdf)

Geological Environment

- Fairly active tectonic setting
- Complexity of geology

Plate configuration around Japan
(after the Earthquake Research Committee, 1997)



Conditions for the Second Progress Report issued in 2000

- Disposal capacity of 40,000 canisters of high-level vitrified waste (HLW) based on an extensive nuclear power program with nuclear fuel recycle option
- 3 types of HLWs from overseas reprocessing (COGEMA and BNFL) , and PNC Tokai Vitrification Facility
- Interim storage for cooling for 30 – 50 years before disposal
- Multiple-barrier concept
- A wide range of geological environments – challenges due to complex geology / active tectonics
- No regulatory guidelines/requirements for specifying the design or subsystem performance

First report

- HLWs from commercial reprocessing (JNFL)
- Extensive improvement of R&D facilities
  - ENTRY, QUALITY, Kamaishi-mine, Tono-mine
- Advancement in computing science
- Expansion of international collaboration
  - Exchange of research outcomes, experiences
  - Use of Internationally available Data-bases
- Fallen Trust in nuclear industry due to repeated accidents
  - Consideration for disclosure, accountability, transparency etc.
  - SPR documentation should be carried out in a transparent manner

Repository Design and Engineering Technology

Design to avoid over conservatism

- More detailed, realistic and comprehensive design methodology
- More realistic database of properties on the engineered barrier system (EBS) materials and the host rocks
  - Laboratory experiments on long-term corrosion behavior of carbon steel under the simulated deep underground condition
  - Laboratory experiments on properties for a mixture of bentonite and quartz sand (70:30)
  - Literature surveys and measurements in Tono area and Kamaishi mine

Technical Demonstration

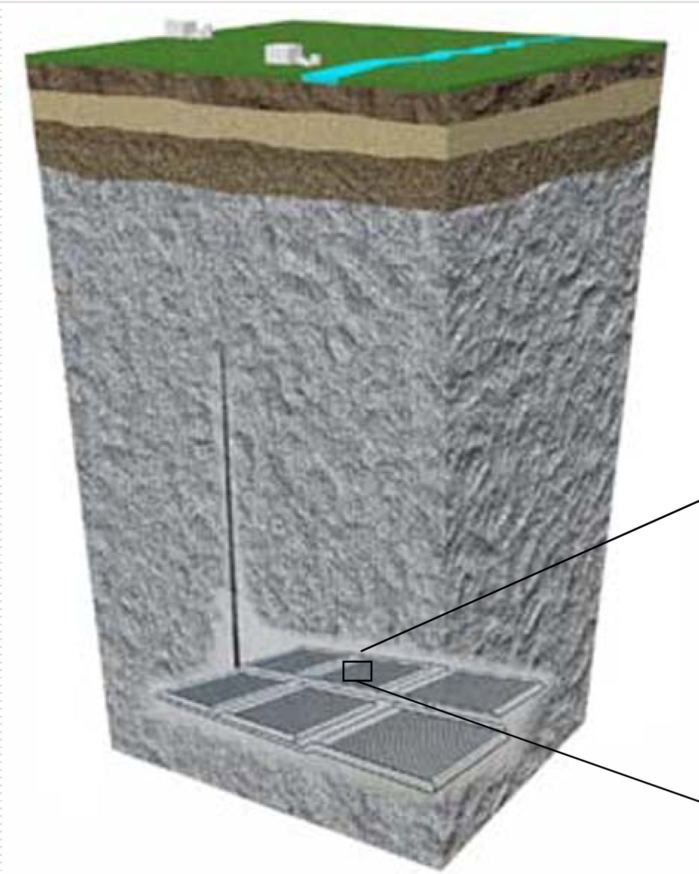
Engineering-scale laboratory experiments and field test

- Kamaishi in-situ test for buffer emplacement
- Sealing tests at URL in Canada
- Full-scale manufacturing test of overpack

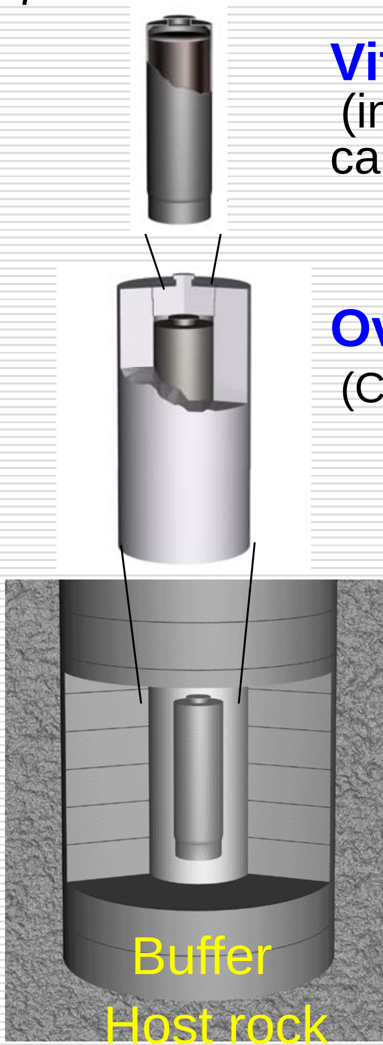
Development of Disposal Concept: Multi-barrier System

Geological environment

- Long-term stability
- Favorable geological conditions
- Function as a natural barrier system



Engineered Barrier System (EBS)



Vitrified waste
(in stainless steel canister)

Overpack
(Carbon steel)

Buffer
(Mixture of bentonite and sand)

Repository Design

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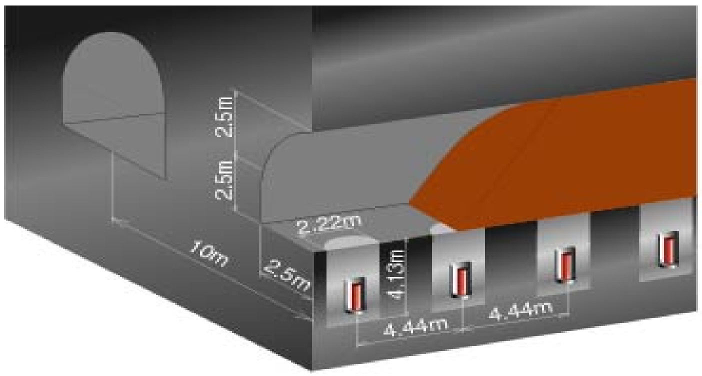
<tr><th></th><th>Pit disposal</th><th>Tunnel disposal</th></tr>
<tr><td>Hard rock</td><td>


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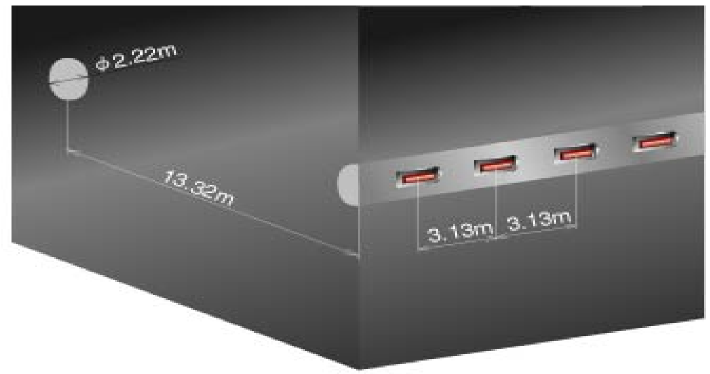

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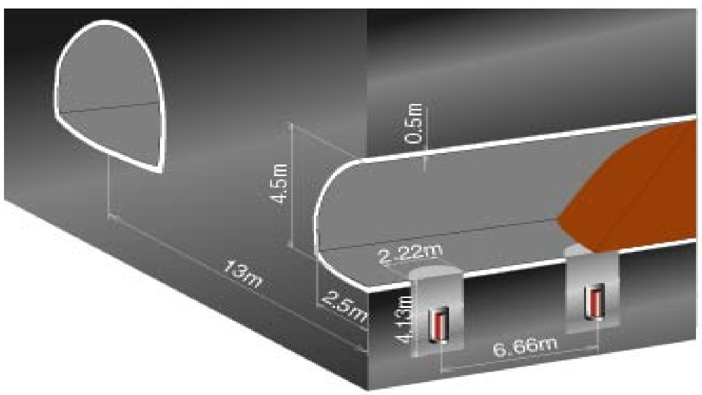
<tr><td>Soft rock</td><td>


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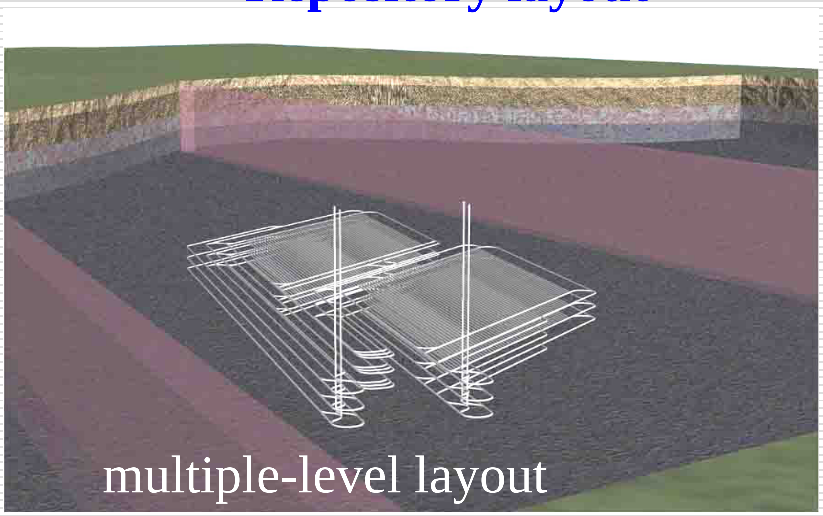
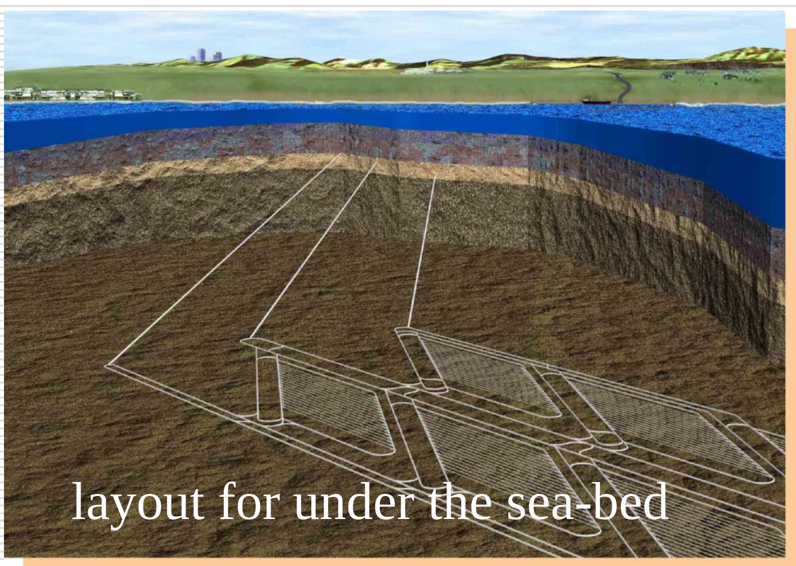
Design criteria: **mechanical stability, maximum temperature of the buffer below 100˚C**

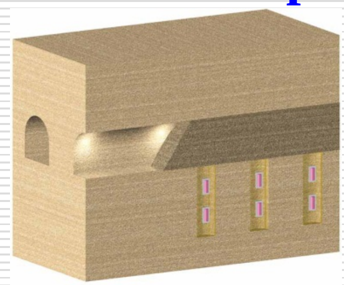
Design Variants

Repository layout



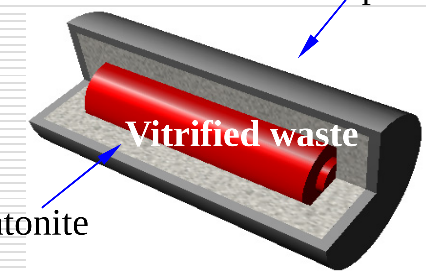


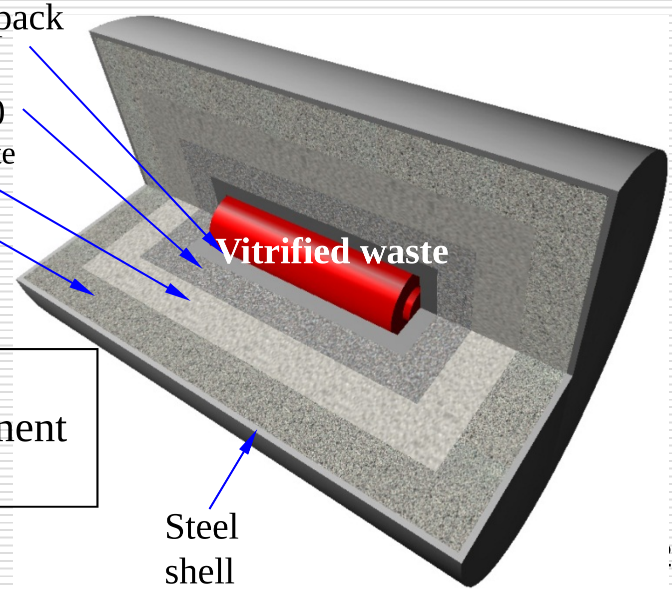
Emplacement of waste package



IWP
(Integrated Waste Package)

Vertical multiple emplacement





MCM
(Multi-Component Module)

Conclusions of the Second Progress Report

- Although Japan lies in a tectonically active setting with fairly complex geology, stable geological environments for potentially suitable sites are widely distributed.
- By applying conventional engineering technology, an appropriate repository can be designed for any suitable host rock.
- Safety concept is robust, offering large safety margins and having low sensitivity to model and database uncertainties.

➡ These results provide a technical and scientific basis for proceeding with both the site selection process and development of a regulatory framework.

Roles and Outputs of SPR

To provide information to stakeholders for decision making on putting the Japan's Program into the implementing phase

➡ Demonstration of the technical feasibility of the disposal concept in a higher degree of confidence

- "Specified Radioactive Waste Final Disposal Act" (June, 2000)
- Establishment of NUMO (October, 2000)

To input for implementing organization

To input for regulatory authority

➡ Clarification of scientific and technical basis for siting and regulatory processes

- NUMO Information Package for Volunteer site (Dec.,2002)

Legal background for HLW disposal

The "Specified Radioactive Waste Final Disposal Act" (Jun. 2000)

- Formulation of basic policy and final disposal plan
- Establishment of implementing organization
- Cost estimation and fund management
- Step-wise approach
  - Preliminary Investigation Areas (PIA)
  - Detailed Investigation Areas (DIA)
  - Final Disposal Site (FDS)
- Regulation for safety of geological disposal of radioactive waste
  - Separate legislation

Safety Regulation

1.Policy (NSC)

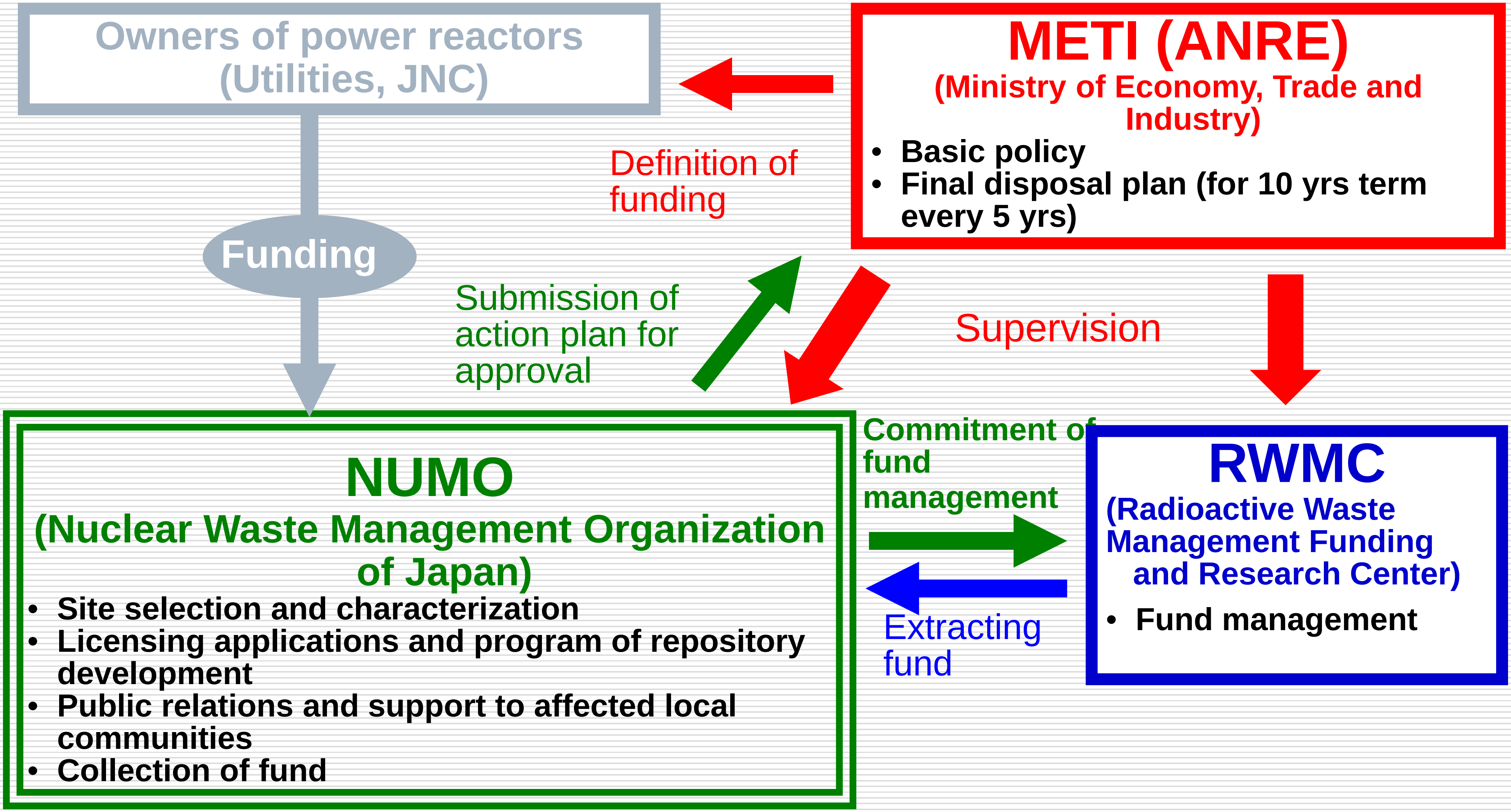
"First Report on the Basis for Safety Standards for HLW Disposal" (Nov. 2000)
"Requirements of Geological Environment to Select PIAs of HLW Disposal"（Sep. 2002）

2.Regulatory Framework (NISA)

"Report on Regulatory Framework for Geological Disposal of Radioactive Waste" (Sept.,2006)

Framework of implementation

Specified radioactive waste final disposal act (7 Jun., 2000)



NUMO's Siting Activities

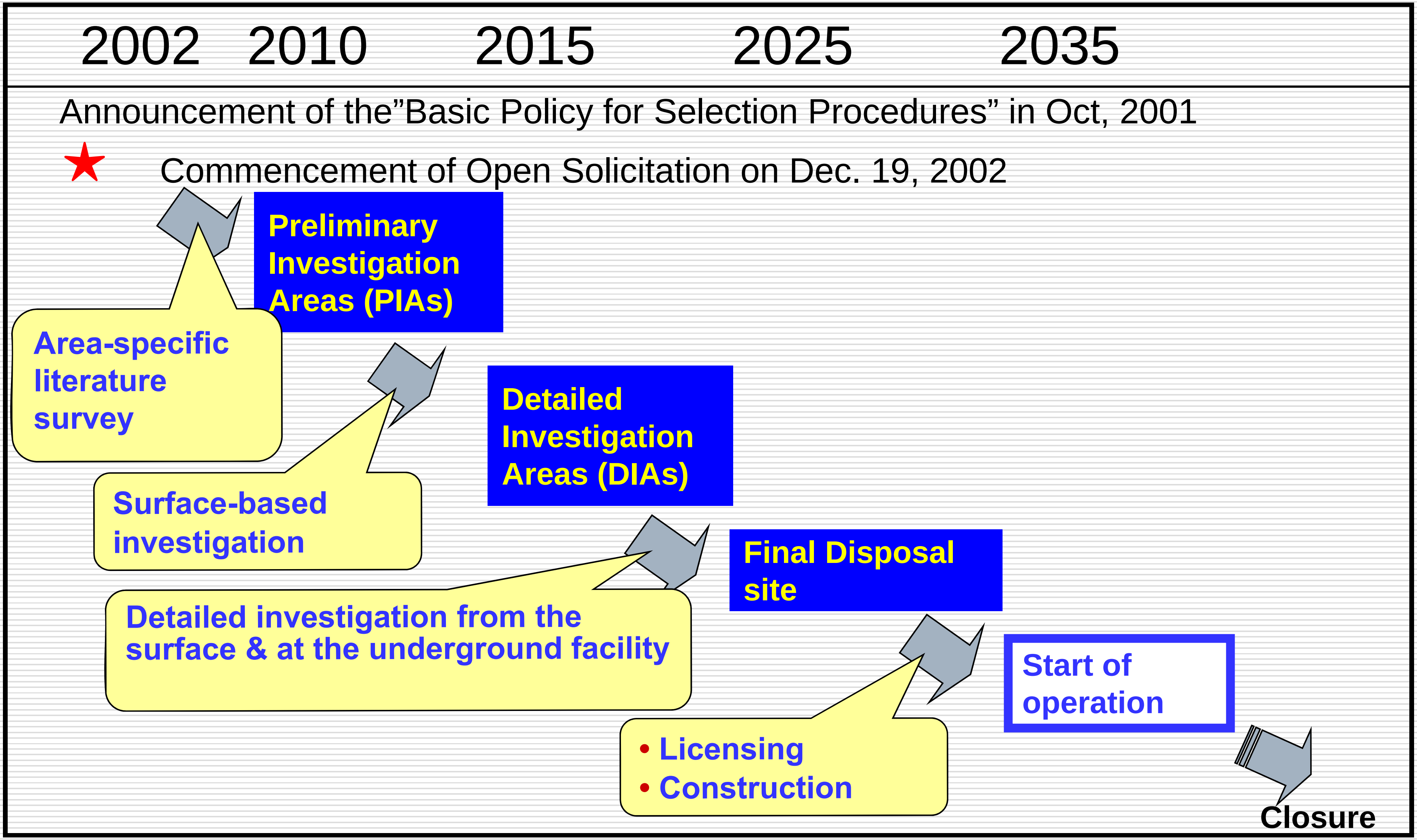
Basic Policy

- Stepwise project development
- Engaging communities
- Focusing on transparency

Approach

- Three-step incremental siting process: PIAs, DIAs, FDS
- *Open solicitation of volunteer municipalities* for selection of PIAs
- Building a long-term working relationship with local communities and *providing them schemes for compensation*
- *Public involvement in decision-making in the process* of selecting sites

Stepwise approach for site selection



Open solicitation

- **19 Dec. 2002**
  - **Commencement of Open Solicitation**
  - **Sending an "Information Package" to all 3,239 municipalities and other relevant organizations in Japan**
- **All of municipalities have a right to apply for the Open Solicitation**
- **Deadline of the Open Solicitation is not set at present stage.**

Information Package

(http://www.numo.or.jp/english/publications/main.html)

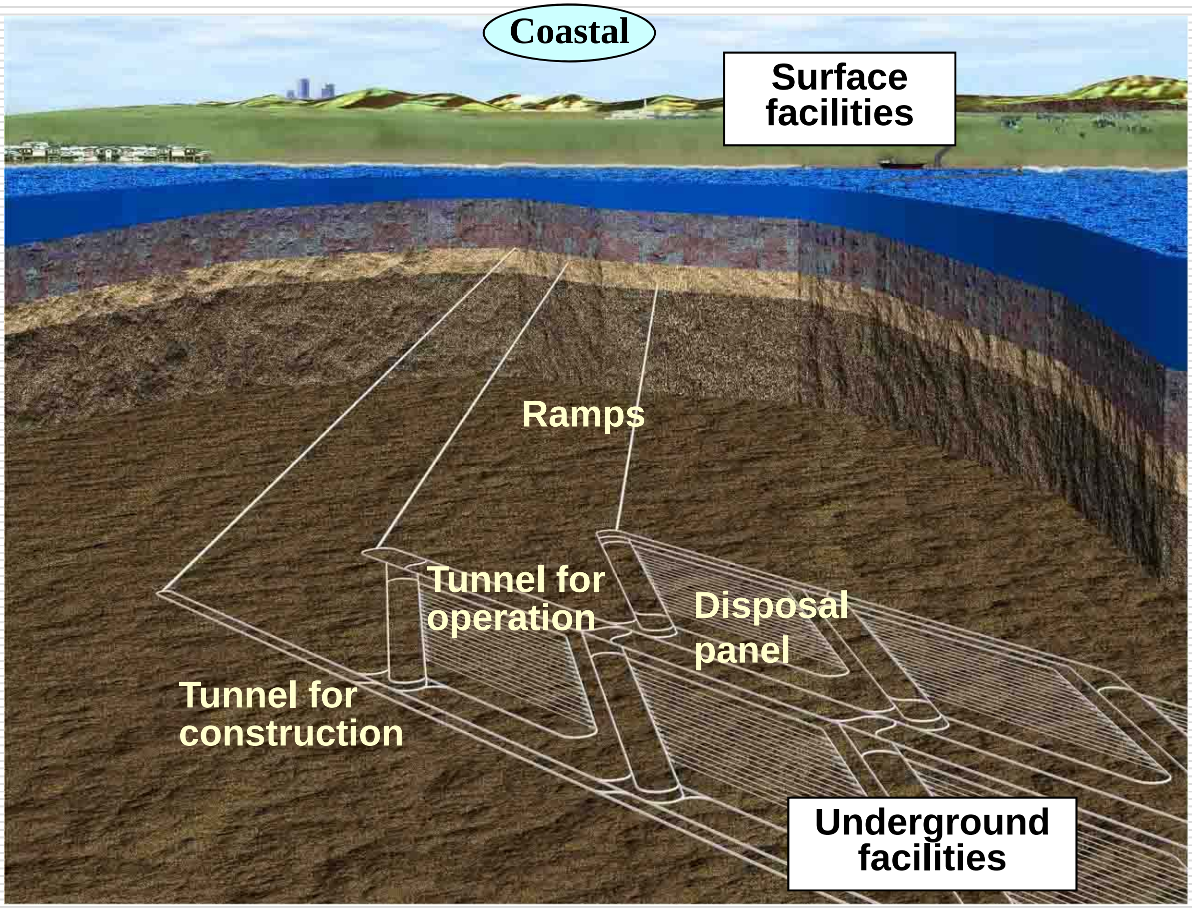
Information Package

"Repository Concepts"

A set of repository concepts developed for the siting environments expected in potential candidate site

Aim:

To provide information on what the planned repository is and how it will be developed for siting environments at candidate sites



Information Package

“Siting Factors for the Selection of PIAs”

Evaluation Factors for Qualification:

→exclusion of areas where

- -Clearly-identified active faults,
- -Within a 15km radius of center of Quaternary volcanoes,
- -Uplift more than 300m during the last 100,000 years,
- -Quaternary unconsolidated deposits,
- -Economically valuable mineral resources.

Favorable Factors:

Favorable factors used to assess characteristics of PIAs comprehensively and comparatively if necessary.

Information Package

“Site Investigation Community Outreach Scheme”

Economical benefits on local community arising from the repository

Local order placements in the prefecture with the siting municipality	~ 740 billion yen (2025-84) (~ 12.3 billion yen / year)
Production inducement effect	~ 1.65 trillion yen (2025-84) (~ 27.5 billion yen / year)
Employment creation effect	~ 130 thousand people (2025-84) (~ 2200 people / year)

“Incentive for Regional Acceptance” provided by the Japanese Government to volunteer municipalities

- ~ 1 billion yen/y (for a period of PIA selection stage)
- ~ 2 billion yen/y (for a period of DIA selection stage)

An Example of Publicity Activities

Information campaign (Newspapers, magazine, etc.)

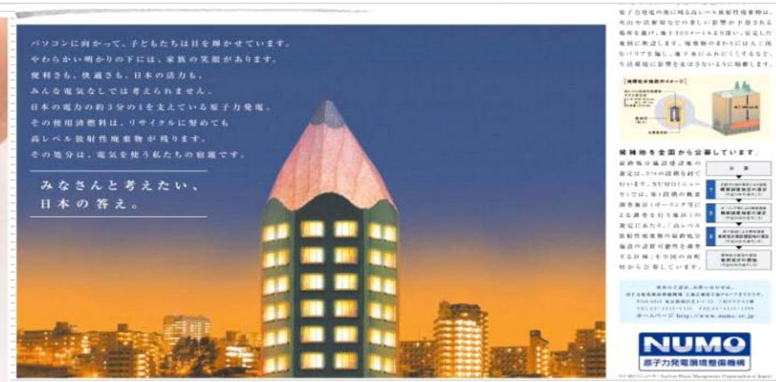
□Core massages

- Existing HLW is urgent issue and needs solution
- Inter-generational equity

□Promotion words

We will not simply pass on the waste from our electricity production to future generation.

We will carry out our responsibility to ensure safety of future generations.



Homework for an electricity country

Progress in Siting Process

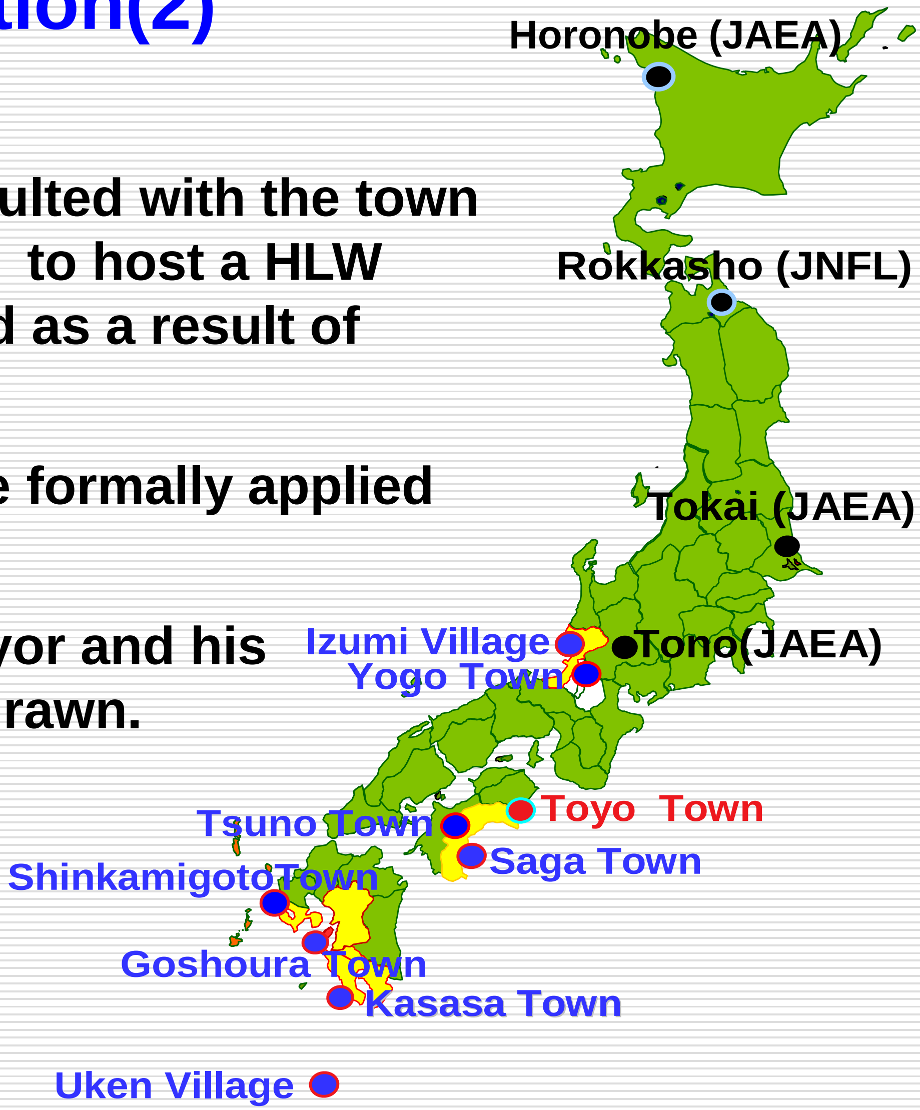
Reaction to open solicitation(1)

1. 9 municipalities expressed their interest to be a volunteer site since the first voice from Izumi village on April 2003.
2. 6 municipalities decided to call off further consideration as soon as the local paper exposed the plan to host a HLW repository. Mayors of these municipalities made as same comments as " I am not confident to answer the growing public concern over safety of repository in the local communities".
3. Most governors of the prefecture persuaded mayors of local municipality to give up hosting a repository.

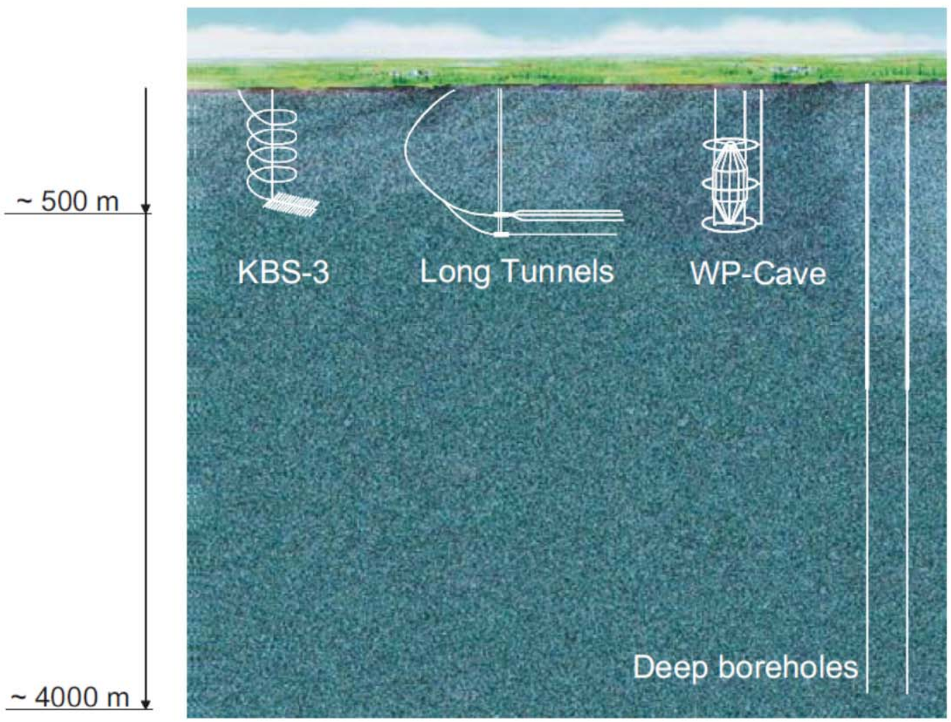
Progress in Siting Process

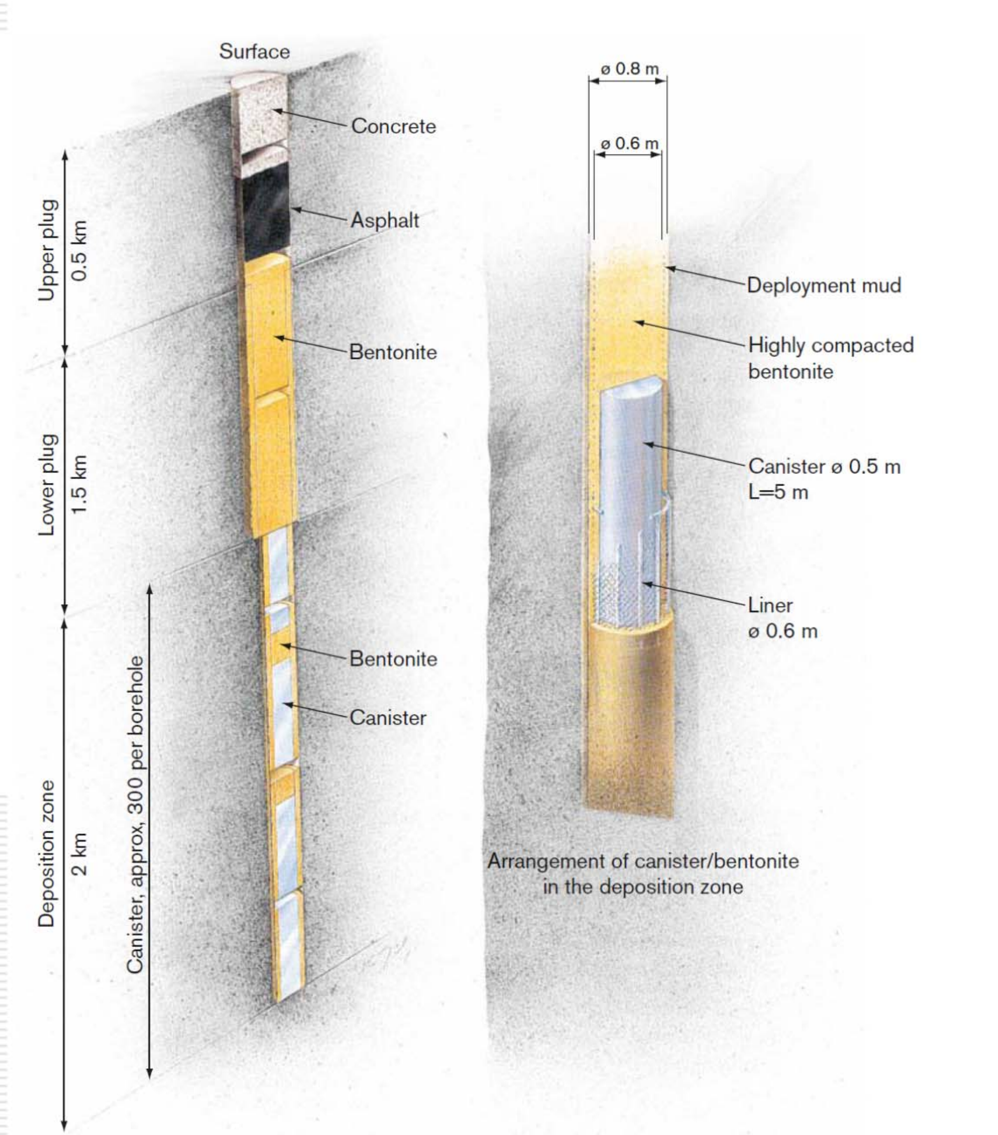
Reaction to open solicitation(2)

4. In 2 municipalities, the mayor consulted with the town council about a petition requesting to host a HLW repository, but they were dismissed as a result of deliberation.
5. Only Toyo town in Kochi-prefecture formally applied to NUMO for literature survey.
6. Because of the election of new mayor and his decision, the application was withdrawn.



Deep Borehole Disposal Concept





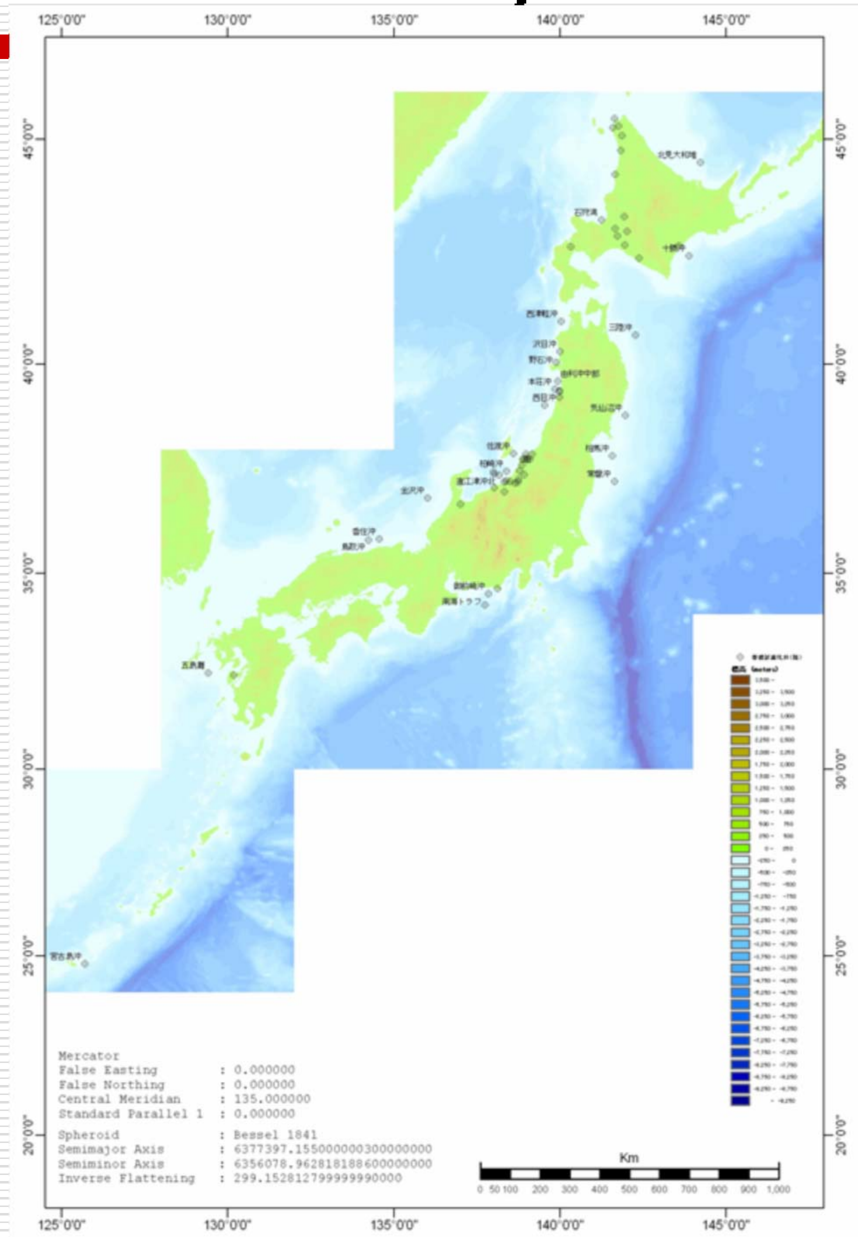
Deposition of spent nuclear fuels at a depth of several thousand meters

(SKB, 2010)

Deep Drilling Experience in Japan

- Oil and gas exploration (up to 6 km)
  - 85 exploration wells by METI/JOGMEC (as of Oct. 2009)
  - Oil/gas exploration companies wells in petroliferous area (mainly sedimentary rocks)
- Monitoring of seismic activities (NIED)
  - 2 boreholes deeper than 3 km
  - 11 boreholes deeper than 2 km
- Geothermal exploration/hot springs

METI/JOGMEC Exploration wells



Example of the deep drilling in Japan

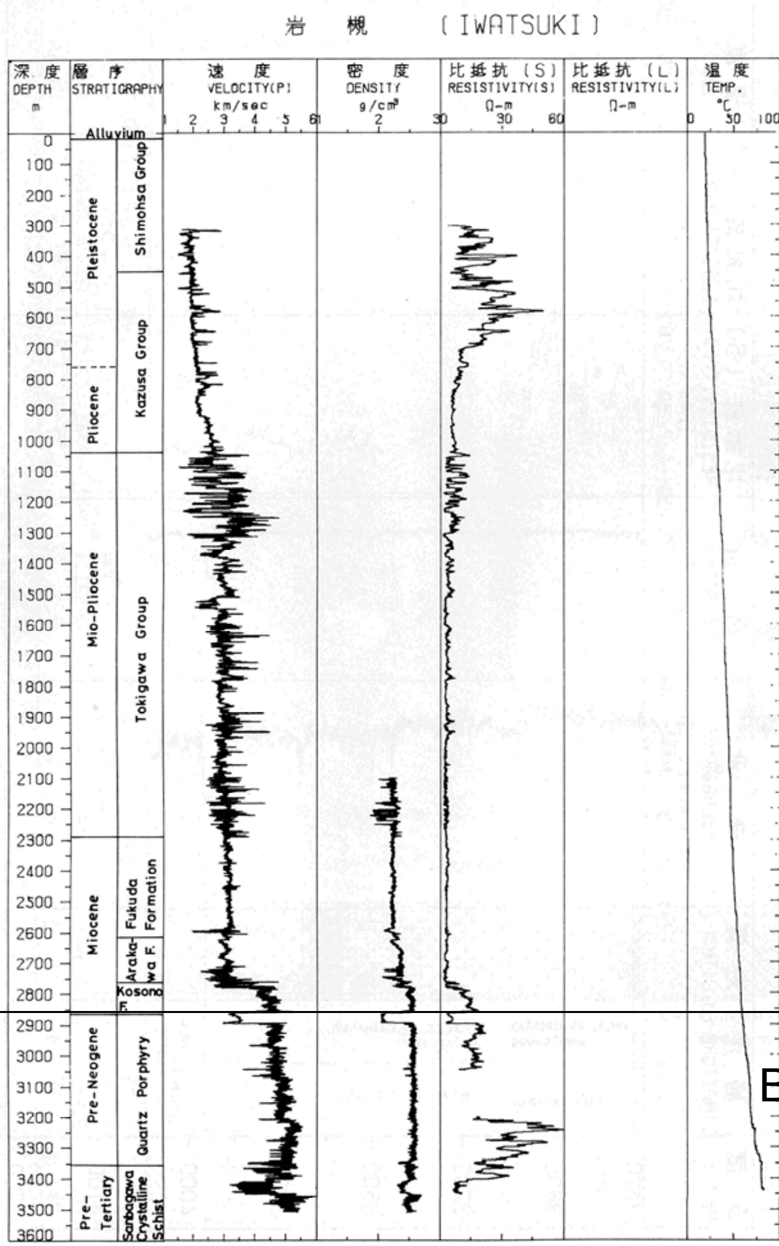


図3−1−B 岩槻孔井検層図 Fig. 3−1−B Well log (Iwatsuki).

Basement rocks

TD: 3510 m

Borehole diamaters:

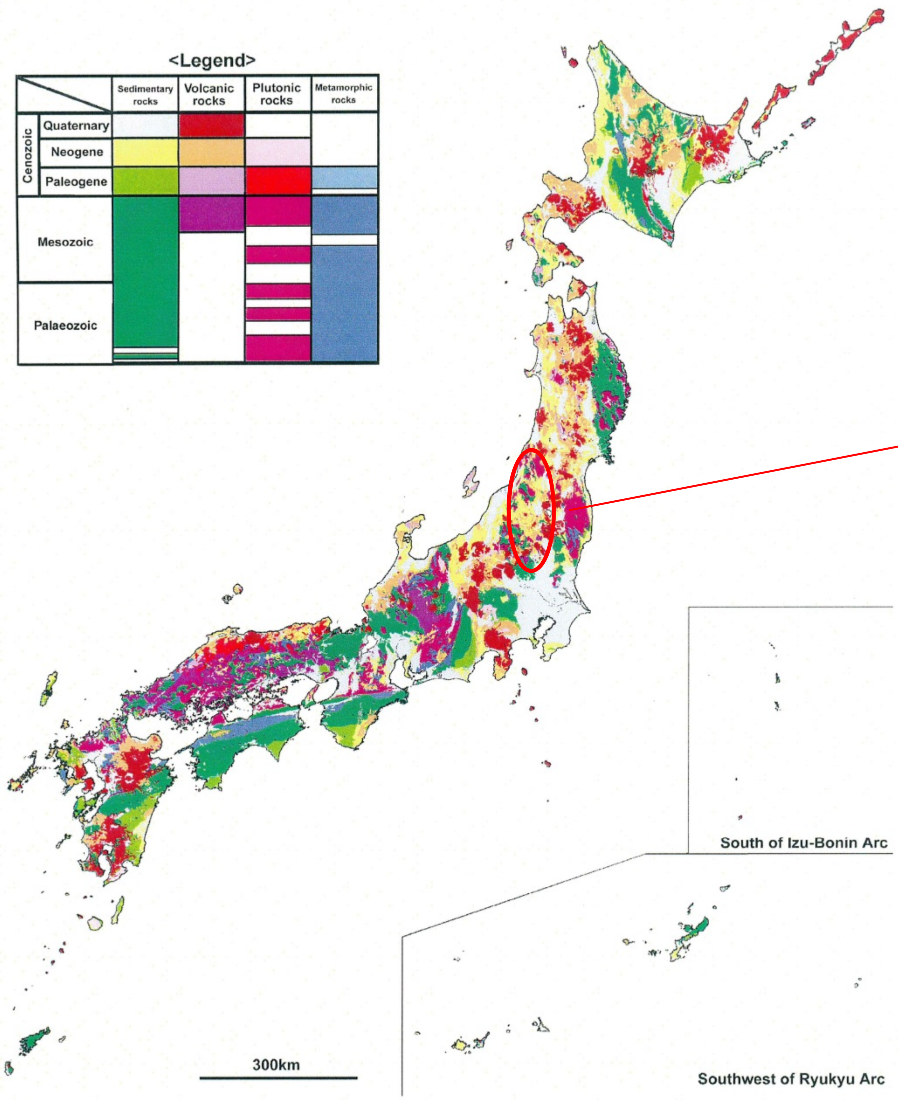
0 to 2599 m 12 1/4’’

2599 to TD 8 5/8’’

cf: 17 ½’’ in Sandia report

(Suzuki et al., 1981)

Geology of Japan (well understood?)



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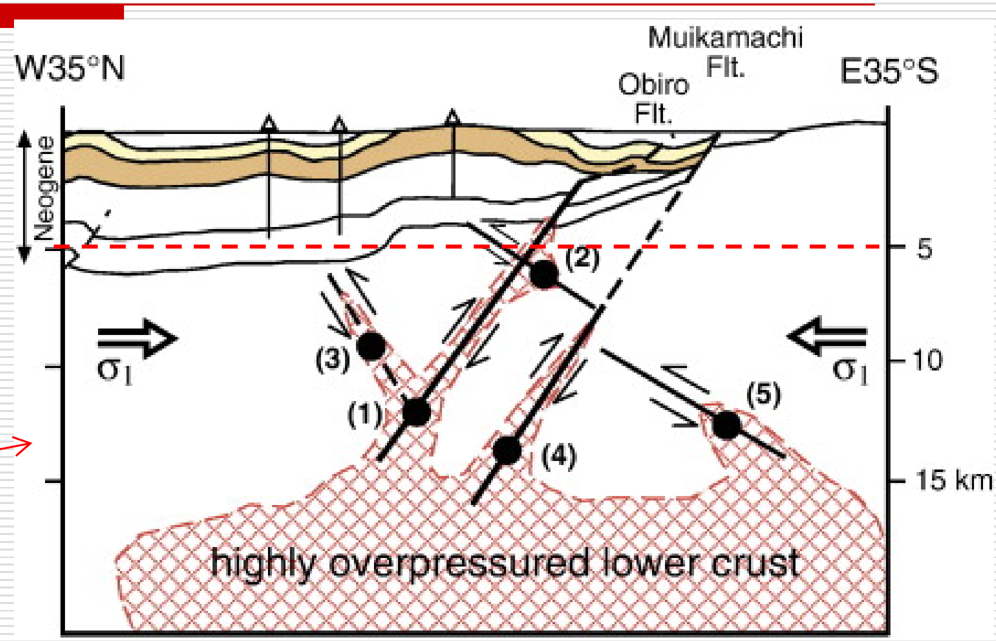
(NUMO, 2004)

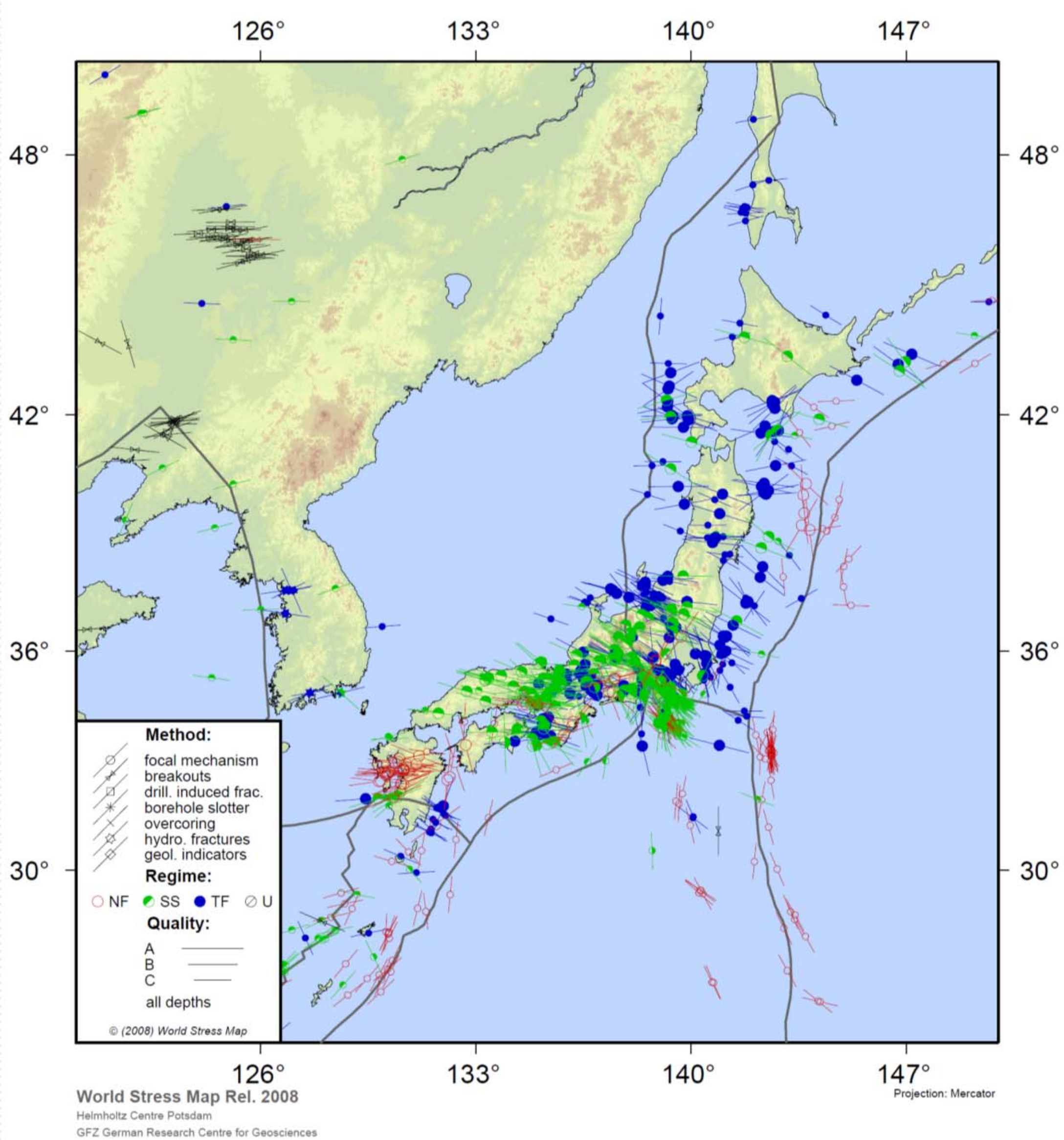


(Sibson, 2007)

Possible upwelling of the deep-seated "overpressured fluid"??
Deep fluid processes have been discussed, i.e., Matsushiro earthquake swarms, mud volcanoes, hot springs with mantle signature

Need to find the locations with "stagnant" groundwater flow condition at depth Not very many information in our hand at present

Strongly anisotropic stress field



Stress condition in Japan is highly anisotropic due to complex subduction system of plates.

Evaluation of DBD by SKB (2010)

- Possible advantages
  - Better protection against intrusion and illicit trafficking of nuclear material
  - Groundwater movement are expected to be slow Stagnant groundwater as main safety feature

- Challenges
  - Very little is known about the geological, hydrogeological and geochemical conditions at depth.
  - Possible aggressive environment makes it uncertain the long-term behavior of engineered barrier.
  - Site investigation will be difficult.

Possible advantages of DBD

- Better protection against intrusion and illicit trafficking of nuclear material
- Drilling technologies used in oil industries can be used.
- Could be less expensive.
  - Number of necessary holes =40,000/400=100
  - Cost for borehole construction = \5B x 100=\0.5 T
  - Long-term management of the facility may not be necessary
  - Almost all the activities can be done at surface.
  - Technologies in oil/nuclear industries can be used.

Challenges for implementing DBD

- Need to develop the scenario for safety analysis
  - Engineered barriers may not be effective.
  - Behavior of iodine-129 and radioactive noble gas may be the issue.
- Develop a proven technology for deployment of wastes, possible retrieval, and radiation shielding at borehole mouth.
  - Stacking during installation could be one of the issues.
- Improve the understandings on the ultra-deep geological situation.
  - It IS an important issue in Japan considering the tectonic setting and active fluid-related processes.

Concluding Remarks

- The largest part of the past 30 years Japanese HLW disposal program was spent for generic R&D studies without discussion of siting and institutional frameworks.
- This approach was motivated by the need to consider the geological features specific to Japan and the need for answering key technical questions relevant to these features. We can, however, also recognize the important role of generic R&D in the early stages of the repository program, which provides a foundation for subsequent phases of the program.
- As HLW repository projects move closer to implementation and possible change of the boundary conditions, designs with more flexibility are needed. This is critical for an organization like NUMO with a volunteering approach to siting; a wide range of options allow tailoring designs to both the given geological environment and the desires of the host community.
- Deep Borehole Disposal (DBD) could be an alternative option even though there is little discussion in Japan. Extensive efforts are needed to accumulate the knowledge of the ultra-deep geological environments, to develop proven technology for drilling and installing the waste, and to analyze the long-term safety of the DBD.