

***International
Approaches for
Nuclear Waste Disposal
in Geological
Formations: Report on
Fifth Worldwide Review***

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition Campaign
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ACRONYMS

DOE	Department of Energy
EPA	Environmental Protection Agency
HLW	High-Level Nuclear Waste
IAEA	International Atomic Energy Agency
LBNL	Lawrence Berkeley National Laboratory
LILW	Low- and Intermediate-Level Nuclear Waste
NRC	Nuclear Regulatory Commission
ORE	Oxford Research Encyclopedia
R&D	Research and Development
SNF	Spent nuclear fuel
SNL	Sandia National Laboratories
WIPP	Waste Isolation Pilot Plant
WWR	Worldwide Review
WWR-5	5 th Worldwide Review

PROJECT SUMMARY

An important issue for present and future generations is the final disposal of spent nuclear fuel. Over the past over forty years, the development of technologies to isolate both spent nuclear fuel (SNF) and other high-level nuclear waste (HLW) generated at nuclear power plants and from production of defense materials, and low- and intermediate-level nuclear waste (LILW) in underground rock and sediments has been found to be a challenging undertaking. Finding an appropriate solution for the disposal of nuclear waste is an important issue for protection of the environment and public health, and it is a prerequisite for the future of nuclear power. The purpose of a deep geological repository for nuclear waste is to provide to future generations, protection against any harmful release of radioactive material, even after the memory of the repository may have been lost, and regardless of the technical knowledge of future generations.

The results of a wide variety of investigations on the development of technology for radioactive waste isolation from 19 countries were published in the *First Worldwide Review* in 1991 (Witherspoon, 1991). The results of investigations from 26 countries were published in the *Second Worldwide Review* in 1996 (Witherspoon, 1996). The results from 32 countries were summarized in the *Third Worldwide Review* in 2001 (Witherspoon and Bodvarsson, 2001). The last compilation had results from 24 countries assembled in the *Fourth Worldwide Review* (WWR) on radioactive waste isolation (Witherspoon and Bodvarsson, 2006).

Since publication of the last report in 2006, radioactive waste disposal approaches have continued to evolve, and there have been major developments in a number of national geological disposal programs. Significant experience has been obtained both in preparing and reviewing cases for the operational and long-term safety of proposed and operating repositories. Disposal of radioactive waste is a complex issue, not only because of the nature of the waste, but also because of the detailed regulatory structure for dealing with radioactive waste, the variety of stakeholders involved, and (in some cases) the number of regulatory entities involved.

In the U.S., Federal government agencies involved in radioactive waste management include: the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), and the Department of Transportation. In addition, the states and affected Indian Tribes play a role as stakeholders in siting waste disposal facilities. In the U.S., the Waste Isolation Pilot Plant (WIPP), in Carlsbad, New Mexico, was licensed to permanently dispose of transuranic waste for 10,000 years. Europe, Sweden and Finland have already submitted applications to the public authorities to establish final repositories for spent nuclear fuel, with Finland receiving construction authorization. Although these countries are frontrunners in the area of nuclear waste disposal, many more countries are in the process of similar approaches for disposal.

Lawrence Berkeley National Laboratory (LBNL) and Sandia National Laboratories (SNL) initiated preparation of the 5th Worldwide Review (WWR-5) on these approaches for nuclear waste disposal in geologic formations. The overall objective of the WWR-5 report is to publish reports from many of these countries documenting their approaches and development of technologies to isolate these in deep geologic repositories.

Understanding of pros and cons of this topic has advanced around the globe for the past years. Approaches have continued to evolve over the past ten years, and there have been major developments in a number of national geological disposal programs since the previous publication of the worldwide review in 2006. Substantial experience has been obtained both in preparing and reviewing cases for the operational and long-term safety of proposed and operating repositories. Experience has also been gained in communication with, and outreach to, potential host communities to gain public support for a projected deep geologic repository. It has also become clear that disposal of radioactive waste is a complex issue,

not only because of the complex nature of the waste and complexity of geological media, but also because of the complex regulatory structure for dealing with radioactive waste.

The Workshop on the 5th Worldwide Review was held in Berkeley, California. This workshop included presentations on the experience and lessons learned in more than 20 countries, and served to establish future cooperation/collaboration among the participating countries.

Preparation of the WWR-5 Report is now in the final stage of editing the chapters and formulation of the report summary based on the progress made in many countries. The chapters will cover the progress in advancing approaches to the isolation of radioactive wastes using deep geologic disposal as the final disposition, as well as a number of discussions related to (a) the current status of nuclear waste disposal, and (b) foundational/revolutionary discoveries and advances.

The WWR-5 Report provides scientific and technical experiences on preparing for and developing scientific and technical bases for nuclear waste disposal in deep geologic repositories in terms of requirements, societal expectations and the adequacy of cases for long-term repository safety. The Chapters include potential issues that may arise as repository programs mature, and identify techniques that demonstrate the safety cases and aid in promoting and gaining societal confidence. The report will also be used to exchange experience with other fields of industry and technology, in which concepts similar to the design and safety cases are applied, as well to facilitate the public perception and understanding of the safety of the disposal approaches relative to risks that may increase over long time frames in the absence of a successful implementation of final dispositioning.

1. PROJECT DESCRIPTION

1.1 Description of project phases

The project has been planned and conducted in three phases:

Phase 1– The announcement and request to participate in an on-line survey for the WWR-5 for the representatives of countries working on approaches to establishing the technical bases for nuclear waste disposal in geological formations. This first phase was established to facilitate the identification of key personnel willing to coordinate and contribute a chapter to the 5th WWR detailing their country's program. The questionnaire can be found at https://docs.google.com/a/lbl.gov/forms/d/1-koeo1gpo8hAEWYvizO2dOFSZ2bTM4AX_qCVo6NhSCA/viewform

We are now in the final stage of summarizing the contributions from different countries, and will include the summary in the WWR-5 report.

Phase 2 – Collection of the papers from different countries, editing the contributions, and drafting the publication of the 5th World Wide Review volume.

We developed the formatting guidelines for preparation of Chapters of the WWR-5, following the general style of the previous WWR-4, and also taking into account the formatting style of the Oxford Research Encyclopedia (ORE). Then, we prepared a final template that is being used for final version of the WWR-5 report.

The following 22 countries submitted their Chapters – Brazil, Bulgaria, Canada, China, Czech Republic, Finland, France, Germany, Hungary, India, Japan, Latvia, Lithuania, Mexico, Slovenia, South Africa, Spain, Slovakia, Switzerland, Ukraine, United Kingdom, and United States of America.

Phase 3 – As originally planned, the Workshop on the 5th Worldwide Review was held at Lawrence Berkeley National Laboratory (LBNL), in Berkeley, California on May 25 and 26, 2016. This workshop included presentations on the experience and lessons learned documented in the WWR-5 volume, and helped establish future cooperation/collaboration among the participating countries.

1.2 WWR-5 Report Contents

The following is the table of contents of the WWR-5 report, including the names of contributors, and their affiliations (Draft as of August 2016).

Chapter 1 INTRODUCTION

Boris Faybishenko¹, Jens Birkholzer¹, Peter Persoff¹, David Sassani², and Peter Swift²

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- 1 Introduction and Motivation
- 2 Objectives and Scope
- 3 Scientific and Practical Benefits

Chapter 2 BRAZIL

Radioactive Waste Management in Brazil Including Spent Fuel

Paulo Fernando Lavalle Heilbron Filho¹, Jesus Salvador Pérez Guerrero¹, Monica da Costa Pereira Lavalle Heilbron², Claudio de Morisson Valeriano, and Corbiniano Silva², ¹Waste Management Department, Brazilian Nuclear Energy Commission, ²State University of Rio de Janeiro

- 1 Introduction
- 2 The Brazilian Nuclear Program
- 3 Classification of Radioactive Waste in Brazil
- 4 Radioactive Waste Management Regulations, Laws and Conventions in Brazil
- 5 Main Aspects of the Brazilian Waste Disposal Law 10 308/2001
- 6 Financial Compensation Model for Radioactive Disposal Sites
- 7 Final Waste Disposal Facilities for Environmental Protection
- 8 Management of Spent Fuel
- 9 Waste Management Considerations in Brazil
- 10 Site Selection Regulation for near Surface Repositories for LLW
- 11 Participation of the Scientific Community
- 12 Communication and Involvement of Society
- 13 Conclusions
- 14 References

Chapter 3 BULGARIA

Site Selection Approach to Geological Disposal of High-Level Waste in Bulgaria

Doncho Karastanev, Geological Institute of Bulgarian Academy of Sciences

- 1 Introduction
- 2 Methodology of Preliminary Site Selection Analysis
- 3 Conclusions
- 4 References
- 5 Acronyms

Chapter 4 CANADA

Progress Towards Long-Term Management of Used Nuclear Fuel in Canada

*Mark Jensen, Jo-Ann Facella, Paul Gierszewski, Chris Hatton, Sean Russell
Nuclear Waste Management Organization, Toronto, Ontario, Canada*

- 1 Introduction
- 2 Adaptive Phased Management
- 3 Siting Process
- 4 Optimizing Repository Designs
- 5 Further Increasing Confidence in Safety
- 6 International Collaboration
- 7 Conclusions
- 8 References
- 9 Acronyms

Chapter 5 CHINA

Geological Disposal Program for High-Level Radioactive Waste and the Plan for the Underground Research Laboratory in China

*Ju Wang, Rui Su, Liang Chen, Xingguang Zhao, Yuemiao Liu, Zihua Zong,
Beijing Research Institute of Uranium Geology, China National Nuclear Corporation*

- 1 Introduction
- 2 The Long-Term Plan for High Level Radioactive Waste Disposal
- 3 Plan for China's Underground Research Laboratory
- 4 Progress in Site Selection and Site Characterization
- 5 Progress in Engineered Barrier Studies
- 6 Progress in Rock Mechanics Studies
- 7 Conclusions
- 8 Acknowledgments
- 9 References
- 10 Acronyms

Chapter 6 CZECH REPUBLIC

Progress of the Czech Deep Geological Repository Program

Jiří Slovák, Správa úložišť radioaktivních odpadů

- 1 Introduction
- 2 Design
- 3 Siting
- 4 Underground Research Facilities
- 5 Research
- 6 International Cooperation
- 7 Role of the Public in the Decision-Making Process Regarding Director Geosciences Research (DGR) Siting
- 8 Conclusions
- 9 References
- 10 Acronyms

Chapter 7 FINLAND

Towards Implementation of the Spent Nuclear Fuel Repository in Finland

Mari Lahti, Posiva Oy, Olkiluoto, Finland

- 1 Introduction
- 2 Progress
- 3 Development of Technology and Disposal Concept
- 4 Construction License Application
- 5 Next Steps
- 6 References
- 7 Acronyms

Chapter 8 FRANCE

Progress Towards Geological Disposal of High-Level and Intermediate-Level Long-Lived Radioactive Waste at an Industrial Scale: The Cigéo Project in France

Sebastien Farin, Thibault Labalette, Gerald Ouzounian, Frederic Plas, ANDRA, French National Radioactive Waste Management Agency

- 1 Legal Process and Developments of the Cigéo Project
- 2 Communications and Integration to the Territory
- 3 Acknowledgments
- 4 References
- 5 Acronyms

Chapter 9 GERMANY

Current Status of Nuclear Waste Disposal in Germany

Volkmar Bräuer, Federal Institute for Geosciences and Natural Resources, Hannover, Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)

- 1 Introduction
- 2 Radioactive Waste in Germany
- 3 Political Background and Institutional Framework
- 4 National Disposal Facility Projects
- 5 German R&D Activities
- 6 Conclusions and Outlook
- 7 Acknowledgement
- 8 References
- 9 Acronyms

Chapter 10 HUNGARY

Current Status of Geological Disposal Projects in Hungary

*A. Baksay, K. Benedek, B. Molnár, P. Molnár, B. Nős and Gy. Tungli
Public Limited Company for Radioactive Waste Management (PURAM)*

- 1 Introduction
- 2 National Radioactive Waste Repository
- 3 Siting Program for a Deep Geological Repository
- 4 References
- 5 Acronyms

Chapter 11 INDIA

Host Rock Characterization, In-Situ Experiments, Numerical TMH Simulations and Natural Analogue Studies in Indian Deep Geological Disposal Programme

*R.K. Bajpai, P. Shrivastava, P.K. Narayan, K., Banerjee
Bhabha Atomic Research Center, Mumbai, India*

- 1 Introduction
- 2 Conceptual Design
- 3 Experimental Set Up
- 4 Some Important Indian Host Rocks
- 5 Development of Engineered Barrier System
- 6 Natural Analogues
- 7 Conclusions
- 8 Acknowledgements
- 9 References

Chapter 12 JAPAN

Progress in Geological Disposal Program in Japan

Akira Deguchi¹, Hiroyuki Umeki¹, Hiroyoshi Ueda¹, Yoichi Miyamoto², Masahiro Shibata², Morimasa Naito², Toshihiko Tanaka, ¹Nuclear Waste Management Organization of Japan (NUMO), Tokyo; ²Japan Atomic Energy Agency (JAEA), Tokai; ³Radioactive Waste Management Funding and Research Center (RWMC), Tokyo

- 1 Introduction
- 2 National Nuclear Policy and Legal Framework
- 3 Siting Activities and Public Relations
- 4 Technical R&D Programs
- 5 Concluding Remarks
- 6 References
- 7 Acronyms

Chapter 13 LATVIA

On Interdisciplinary International Approach in Geological Disposal in Latvia

Andrejs Dreimanis, Radiation Safety Centre of the State Environment Service (Latvia)

- 1 Introduction
- 2 The Most Significant Aims of Multilevel Stakeholder Involvement
- 3 An Extended Concept of the Stakeholder Framework
- 4 A Possible Approach to Stakeholder Interaction on International Scale
- 5 Multilevel Confidence Building of Stakeholders in Nuclear Activities
- 6 Conclusions
- 7 References

Chapter 14 LITHUANIA

Approach to Disposal of Radioactive Waste and Spent Nuclear Fuel in Lithuania

Povilas Poskas, Lithuanian Energy Institute, Kaunas

- 1 Introduction
- 2 Low and Intermediate Level Waste
- 3 Spent Nuclear Fuel and Long-Lived Waste
- 4 Conclusions
- 5 References
- 6 Acronyms

Chapter 15 MEXICO

Mexico's Plans for the Disposal of Radioactive Waste in a Deep Geological Repository

*J.R. Mota Aguilar¹, F. Puente-Espel¹, R. Carmona Hernandez², R. A. Suarez Alvarado³,
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³National Commission of Nuclear Safety and Safeguards (CNSNS); ⁴Laguna Verde
Nuclear Power Plant, Federal Electricity Commission (CFE)

- 1 Background
- 2 Present Legal Framework
- 3 The National Policy for the Management of Radioactive Waste
- 4 The Plan for the Definitive Disposal of High-Level and Long-Lived Radioactive Wastes
- 5 Types of Waste Considered for Disposal
- 6 Waste Volume Estimates
- 7 Expected Characteristics of the Geological Formations and Repository
- 8 Repository Design
- 9 Process for Site Selection
- 10 Establishment of an R&D Plan
- 11 Acknowledgments
- 12 References
- 13 Anonyms

Chapter 16 SLOVAKIA

Development of the Slovak Deep Geological Disposal – Status In 2015

Peter Salzer¹, Igor Slaninka², Vaclava Havlova³, Miroslav Pereszlenyi⁴

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Bratislava

- 1 Introduction
- 2 The Preliminary Design Stage (1996-2001)
- 3 The Interim Stage between 2002 and 2012
- 4 Recent Developments
- 5 References

Chapter 17 SOUTH AFRICA

Radioactive Waste Disposal in South Africa in 2015: Status and Research and Development Strategies

M.A.G. Andreoli¹, E. Raubeheimer², A.C. Carolissen², J.F. Beyleveld²

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²South African Nuclear Energy Corporation, Pretoria, South Africa

- 1 Introduction
- 2 Sources of Radioactive Waste in South Africa
- 3 Research and Development at Vaalputs
- 4 Acknowledgments
- 5 References
- 6 Anonyms

Chapter 18 SPAIN

Geological Disposal of Spent-Fuel and High-Level Waste in Spain

Juan Carlos Mayor, Empresa Nacional de Residuos Radiactivos, S.A. (ENRESA), Madrid

- 1 Introduction
- 2 R&D Activities Performed (2006-2014)
- 3 Conclusions
- 4 References
- 5 Acronyms

Chapter 19 SWEDEN

Licensing of the KBS-3 Concept for Spent Nuclear Fuel in Sweden

Berit Lundqvist and Monica Hammarström, Swedish Nuclear Fuel and Waste Management Company (SKB), Sweden

- 1 Background
- 2 Spent Nuclear Fuel
- 3 Short-lived Waste
- 4 Long-lived Waste
- 5 Conclusions
- 6 References
- 7 Acronyms

Chapter 20 SWITZERLAND

Swiss Geological Studies to Support Implementation of Repository Projects: Status 2015 and Outlook

A. Claudel, A. Gautschi, S. Vomvoris, National Technical Competence Centre in the Field of Deep Geological Disposal of Radioactive Waste (NAGRA), National Cooperative for the Disposal of Radioactive Waste

- 1 Background and Historical Evolution of Radioactive Waste disposal in Switzerland
- 2 The Repository Concepts
- 3 The Site Selection Process and a Geological Basis for NAGRA's Proposals
- 4 Geological Studies at the Underground Research Laboratories —the Grimsel Test Site and the Mont Terri Rock Laboratory in Switzerland
- 5 International Collaboration
- 6 References
- 7 Acronyms

Chapter 21 UKRAINE

Geological Disposal of Radioactive Waste In Ukraine: Background, Status, And Future Steps

V.M. Shestopalov¹, Iu.A. Shybetskyi¹, M.I. Proskura², L.I. Zinkevich², R.G. Temny³

¹ National Academy of Sciences; ² State Agency of Ukraine on the Exclusion Zone Management; ³ National operator for radioactive waste disposal (SSE CERWM).

- 1 Introduction
- 2 Legislative and Institutional Framework
- 3 Ukrainian Inventory of RAW Considered for Geological Disposal
- 4 History of Developments
- 5 Current Status of the National Geological Disposal Program
- 6 Main Challenges and Conclusions
- 7 References

Chapter 22 UNITED KINGDOM

The Status of Geological Disposal in the UK

Cherry Tweed, University of Birmingham

- 1 Introduction
- 2 Inventory for Disposal
- 3 Preparations for Siting
- 4 Working with Waste Producers
- 5 Science and Technology
- 6 Working with the Regulators
- 7 Key Challenges
- 8 Next Steps
- 9 Acknowledgments
- 10 References
- 11 Acronyms

Chapter 23 UNITED STATES OF AMERICA

Research and Development Program for the Used Nuclear Fuel and High-Level Radioactive Waste Disposition in the United States

Timothy C. Gunter and Prasad K. Nair, U.S. Department of Energy

- 1 Introduction
- 2 Goals of the UFDC R&D Program
- 3 Disposal Environment Options
- 4 Summary - Used Nuclear Fuel Management
- 5 References
- 6 Acronyms

Chapter 24 MULTINATIONAL GEOLOGICAL DISPOSAL FACILITIES

Charles McCombie and Neil Chapman, Arius Switzerland

- 1 Introduction
- 2 The Bigger Picture
- 3 Strengthening the Documentary Basis
- 4 Progress in Europe
- 5 2016: Australia Takes the International Lead
- 6 Elsewhere in the World
- 7 Arius: Moving the Concept Forward
- 8 The Next Ten Years
- 9 Acknowledgements
- 10 Acronyms

1.3 WWR-5 Workshop

1.3.1 Workshop Goal

The primary goal of the Fifth Worldwide Review (WWR-5) Workshop on the International Approaches for Deep Geologic Disposal of Nuclear Wastes was to re-establish a series of worldwide reviews on this topic, and provide a forum for learning from international, regional and national assessments of perspectives of nuclear waste disposal in geological formations. The Workshop was held at LBNL on May 25-26, 2016. The presenters both in the conference room and through videoconferencing did an outstanding job of sharing their expertise and covered many important topics during the workshop. The overall opinion of the participants was that the workshop was informative and worthwhile.

The Workshop Agenda is given in Attachment 1 to this report. In total 45 participants represented 21 countries; 22 participants were present at LBNL, including 17 presenters from 12 countries, and there were 23 virtual (through videoconferencing) participants, with 10 presenters from 8 countries. A list of the names, countries, and affiliations of participants is given in Attachment 2.

The Workshop included four discussion sessions, and topics of these discussion sessions are summarized below.

1.3.2 Topics of Discussion Sessions at the WRR-5 Workshop

Special Discussion Session #1 “Summary of various disposal geological media and relevant technical issues” Moderator: Jens Birkholzer (LBNL)

There are multiple ways to achieve safe and effective long-term isolation, and many concepts can work well. Different geological media have been proposed and explored for deep geologic disposal of radioactive waste. In many countries and over a long time, considerable efforts have gone into understanding various potential disposal media.

For those countries whose development program for deep disposal has not yet begun in a serious way, a careful discussion of characterization of different geological settings can be of major benefit. Those countries, along with countries already involved in the programs of Nuclear Waste disposal, can use the information to concentrate efforts accordingly, including various attributes, most importantly technical feasibility attributes, social attributes, and economical attributes related to the overall cost and benefits of a disposal program.

The discussion topic was: What is known about various attributes of the common geologic settings being explored for deep geologic mined-repository disposal of radioactive waste, and the linkage between geological media and relevant technologies.

This discussion session also focused on the integration of engineered barriers into the various geologic systems to produce an overall safe repository concept that isolates waste. Comparing and contrasting these aspects would be useful for younger programs and provide a discussion forum on efficient approaches to utilizing the various geologic systems for safe waste isolation.

Special Discussion Session #2 “How long will the dry storage systems last and what are implications for disposal programs?” Moderator: Thomas Isaacs

During the 2000s, dry storage systems were used in the United States, Canada, Germany, Switzerland, Spain, Belgium, Sweden, Russia, the United Kingdom, Japan, Armenia, Argentina, Bulgaria, Czech Republic, Hungary, South Korea, Romania, Slovakia, Ukraine and Lithuania. Spent nuclear-reactor fuel is being moved from the spent-fuel pools where it must spend its first few years to on-site dry-cask storage canisters. This technology is now mature, with several vendors and many years of experience in manufacturing, installation, and monitoring. The dry storage system “design life” is variously reported as being a few decades in duration, and sometimes the regulatory license for such casks is short – in the U.S. NRC has in the past granted these licenses for 20 years; current requirements in 10 CFR 72.42 allow for 40 year licenses with a possible extension for an additional 40 years. But the design or regulatory “life” may be different from the actual duration before these casks will start to lose their integrity. The U.S. NRC has a written position on this, documented in the 2014 “Continued Storage Rule” and supporting Environmental Impact Statement (EIS), which is that “spent fuel canisters and casks would be replaced approximately once every 100 years.” The comprehensive evaluation of technical concerns associated with extended dry storage is a difficult exercise.

From a standpoint of final disposition of these wastes, geologic disposal is needed regardless. However, if the dry storage systems can be relied on for X years, the question is: for how long will the need for a deep geologic repository for disposal of the spent fuel be delayed?

In different countries, there are different drivers on the timing of accomplishing disposal, the reinvigoration of the nuclear industry being one primary one. The discussion topic was: What is known, technically, about how long the dry storage systems will actually last before their contents need to be removed, or the systems need to be refurbished or replaced? What are implications for disposal programs?

Special Discussion Session #3 “Deep Boreholes” Moderator: David Sassani (SNL)

For many years, the idea of using very deep boreholes to dispose of radioactive waste has been discussed, and several specific design ideas have been developed on paper in a number of countries including the United States, Sweden, the United Kingdom, and Russia (during the previous Soviet Union).

Recently, the idea has received increased attention, and a few new research projects have been undertaken. In the US, a new DOE initiative has begun to the process to site and implement a Deep Borehole Field Test (involving no nuclear waste) to evaluate the feasibility of the method for disposal purposes.

The topic has received attention recently because borehole-disposal proponents often claim that this method of disposal may offer unique flexibility for disposing of small waste forms and may be more rapidly deployed than would be feasible for a deep mined repository. Those who have less enthusiasm commonly state that deep-borehole disposal appears less feasible for some important radioactive waste streams, such as direct disposal of spent reactor fuel.

Key points for the discussion included:

- What is known, technically, about the feasibility of deep borehole technology?
- For which types of radioactive waste is it most suitable, and for which other types might it be generally unsuitable?
- What is known about the potential cost?

Special Discussion Session #4 “Duration of the period of regulatory concern – technical issues and regulatory policy.” Moderators : Peter Swift, Mark Jensen

For a mined repository for deep geologic disposal of radioactive waste, various countries have adopted (or proposed) a variety of different durations for the period of regulatory concern. This is defined as the period over which the repository’s performance must be demonstrated in order to obtain a regulatory approval to proceed with the repository.

As an example, in the U.S. the duration of regulatory concern for the Yucca Mountain repository has two parts, one part corresponding to evaluations out to 10,000 years, with additional consideration using the same modeling approaches out to 1,000,000 years.

The topic for discussion here is not “*What should the period of regulatory concern be?*” That is an inherently political decision that is beyond the scope of discussion at this Workshop. The discussion topic here is: How difficult is it to demonstrate regulatory compliance for various periods of regulatory concern, as a function of the disposal scheme – meaning not only the geologic setting but also the engineering technology used for the repository? What is known technically about the issues, and why? What research is appropriate to help provide greater insight into this set of questions?

1.4 Potential Publications

Following several conversations with the Editor of the ORE, we achieved the following agreement about publication of the WWR-5 volume.

The ORE, Environmental Science, will feature a live link to the digital version of the report (e-book in the PDF format) as open access. The link will be complimented by, and cross-referenced to, the overview article on nuclear waste geological repositories, which the ORE will publish. This will be a peer-reviewed publication.

The ORE will have a link to a blog post that we can provide on the WWR-5 in a written and/or video interview form.

This approach is anticipated to be efficient for preparation of the WWR-5 volume in terms of updates from the different countries on their radioactive waste programs, and to facilitate distribution of the report to all interested parties in all countries.

The Concept paper entitled “International Approaches for Nuclear Waste Disposal in Deep Geological Formations” has been submitted to the ORE. The Editorial Board of the ORE accepted the concept paper for publication upon presentation of the full paper. We plan to submit a full version of the paper upon the release of the final WWR-5 report.

We consider several other publications, including submitting an invited chapter about the WWR-5 to the book on Underground Research Laboratories in the Society for Rock Mechanics Book series, to be published by CRC Press, LLD.

2. SUMMARY AND SCIENTIFIC AND PRACTICAL BENEFITS

The goal of the Fifth Worldwide Review is to document evolution in the state-of-the-art of approaches for nuclear waste disposal in geological formations since the Fourth Worldwide Review that was released in 2006. The last ten years since the previous Worldwide Review has seen major developments in a number of nations throughout the world pursuing geological disposal programs, both in preparing and reviewing safety cases for the operational and long-term safety of proposed and operating repositories. The countries that are approaching implementation of geological disposal will increasingly focus on the feasibility of safely constructing and operating their repositories in short- and long terms on the basis existing regulations. The WWR-5 will also address a number of specific technical issues in safety case development along with the interplay among stakeholder concerns, technical feasibility, engineering design issues, and operational and post-closure safety.

Preparation and publication of the Fifth Worldwide Review on nuclear waste disposal facilitates assessing the lessons learned and developing future cooperation between the countries. The Report provides scientific and technical experiences on preparing for and developing scientific and technical bases for nuclear waste disposal in deep geologic repositories in terms of requirements, societal expectations and the adequacy of cases for long-term repository safety. The Chapters include potential issues that may arise as repository programs mature, and identify techniques that demonstrate the safety cases and aid in promoting and gaining societal confidence. The report will also be used to exchange experience with other fields of industry and technology, in which concepts similar to the design and safety cases are applied, as well to facilitate the public perception and understanding of the safety of the disposal approaches relative to risks that may increase over long times frames in the absence of a successful implementation of final dispositioning.

The primary goal of the Fifth Worldwide Review (WWR-5) Workshop on the International Approaches for Deep Geologic Disposal of Nuclear Wastes was to re-establish a series of worldwide reviews on this topic, and provide a forum for learning from international, regional and national assessments of perspectives of nuclear waste disposal in geological formations. The Workshop was held at LBNL on May 25-26, 2016. The presenters both in the conference room and through videoconferencing did an outstanding job of sharing their expertise, and covered many important topics during the workshop. The overall opinion of the participants was that the workshop was informative and worthwhile. There were 45 participants from 21 countries. At LBNL, 22 participants were present in the room, including 17 presenters from 12 countries, and there were 23 virtual (through videoconferencing) participants, with 10 presenters from 8 countries. The Workshop included 4 discussion sessions, and topics of these discussion sessions are summarized below.

Phases 1 and 2 of the project have been completed, and the third phase is ongoing to publish the WWR-5 report.

The report is being published in the format in which it has been previously published, but now as a digital version (in the universal PDF format), and it will have an International Standard Serial Number (ISSN) number to identify the publication. The information about the ISSN is given at <http://www.issn.org/understanding-the-issn/what-is-an-issn/> and <http://nsl.nisair.res.in/issn.jsp> (We may consider also publication of a limited number of hard copies of the report, depending on the price of publication.)

3. ACKNOWLEDGEMENTS

Funding for this work was provided by the Used Fuel Disposition Campaign, Office of Nuclear Energy, of the U.S. Department of Energy under Contract Number DE-AC02-05CH11231 with Lawrence Berkeley National Laboratory.

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Robert Budnitz provided descriptions of discussion sessions and many other useful suggestions. Maryann Villavert and Sherry Seybold developed a website and provided other support. Cindy Tilton assisted in the development of the workshop logistics and performed report formatting and prepared a final version of the current milestone report. Marilyn Saarni developed the report template and edited report chapters. Krys Aviña edited report chapters, and Helen Prieto assembled the first version of PDF files of the report.

4. REFERENCES

- Witherspoon, P.A., ed., (1991) Geological Problems in Radioactive Waste Isolation: A World Wide Review, Report LBL-29703
- Witherspoon, P.A., ed., (1996) Geological Problems in Radioactive Waste Isolation: Second Worldwide Review, Report LBL-38915
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ATTACHMENT 1. WWR-5 WORKSHOP AGENDA



WORKSHOP ON THE FIFTH WORLDWIDE REVIEW “CHALLENGING ISSUES IN DEEP GEOLOGIC DISPOSAL OF NUCLEAR WASTES”

Supported by U.S. Department of Energy

May 25-26, 2016

Location - Perseverance Hall, Building 54 at LBNL

<http://esd.lbl.gov/wwr5/>

Wednesday, May 25

Note: * Presentations given through Videoconferencing

7:30	8:00	Arrive and Check-in
Moderator: Peter Swift		
8:00	8:20	Welcome and Overview of Geosciences at LBNL (Jens Birkholzer, Director, Energy Geosciences Division, Head, Nuclear Energy and Waste Program, LBNL)
8:20	8:40	Welcome from the DOE Used Fuel Disposition R&D Campaign (Peter Swift, National Technical Director, DOE-NE Used Nuclear Fuel Disposition Campaign)
8:40	9:00	LBNL Welcome and Overview (Horst Simon, Berkeley Lab Deputy Director)
9:00	9:15	WWR-5 status and timeline of the report preparation (Boris Faybishenko, LBNL)
9:15	10:15	Presentations – Session 1 International Atomic Energy Agency (IAEA): Progress towards

		<p>implementing HLW/SNF disposal – Meeting challenges through international cooperation (Stefan Mayer)*</p> <p>UK: “The Status of Geological Disposal in the UK” (Cherry Tweed)*</p> <p>Hungary: “Current Status of Geological Disposal Projects in Hungary” (Péter Molnár)*</p>
10:15	10:30	Break
10:30	11:15	<p>Special Discussion Topic #1: <u>“Summary of various disposal geological media and relevant technical issues.” (Moderator: Jens Birkholzer)</u></p>
11:15	12:15	<p>Presentations – Session 2</p> <p>Canada: “Progress Towards Long-Term Management of Used Nuclear Fuel in Canada” (Mark Jensen)</p> <p>France: “Progress Towards Geological Disposal of High-Level and Intermediate-Level Long-Lived Radioactive Waste at an Industrial Scale: The CIGEO Project in France” (Patrick Landais)</p> <p>Czech Republic: “Progress of the Czech Deep Geological Repository Program” (Jiri Slovak)</p>
12:15	1:15	Lunch
Moderators: Jens Birkholzer & Prasad Nair		
1:15	2:40	<p>Presentations – Session 3</p> <p>USA: “Research & Development Program for the Used Nuclear Fuel and High-Level Radioactive Waste Disposition in the United States” (Prasad Nair)</p> <p>Germany: “Current Status Of Nuclear Waste Disposal In Germany” (Gerhard Enste)</p> <p>Mexico: “Mexico’s Plans for the Disposal of Radioactive Waste in a Deep Geological Repository” (Juan Ramon Mota-Aguilar)</p> <p>Finland: “Towards implementation of the spent nuclear fuel repository in Finland” (Tiina Jalonen)*</p>
2:40	3:00	Break
3:00	3:50	<p>Special Discussion Topic #2: <u>How long will the dry storage systems last and what are implications for</u></p>

		<u>disposal programs? Moderator – Tom Isaacs</u>
4:00	5:00	Tour to Advanced Light Source of LBNL (Peter Nico), and a group photo
7:00	9:30	Dinner, Location: Revival Bar + Kitchen

Thursday, May 26

7:30	8:00	Arrive and Check-in
Moderator: David Sassani		
8:00	9:40	<p>Presentations – Session 4</p> <p>Ukraine: “Geological Disposal of Radioactive Waste in Ukraine: Background, Status, and Future Steps” (Iurii Shubetsky & Vyacheslav Shestopalov)*</p> <p>Latvia: “On Interdisciplinary International Approach in Geological Disposal in Latvia” (Andrejs Dreimanis) *</p> <p>Slovenia: “Slovenian approach to strategy and planning for high level waste and spent fuel deep geological disposal” (Tomaz Zagar)*</p> <p>Slovakia: “Development of the Slovak Deep Geological Disposal – Status In 2015” (Peter Salzer)*</p>
9:40	10:00	Break
10:00	11:00	Special Discussion Topic #3: <u>Deep Boreholes (Moderator David Sassani)</u>
11:00	12:00	<p>Presentations – Session 5</p> <p>Bulgaria: “Site Selection Approach to Geological Disposal of High-Level Waste in Bulgaria” (Doncho Karastanev)</p> <p>US NRC: “Potential Uses of Robotic Technologies and Sensors to Address Borehole Characterization, Monitoring and Sealing” (Tom Nicholson)*</p>
12:00	1:00	Lunch
Moderator: Jens Birkholzer		
1:00	2:20	<p>Presentations – Session 6</p> <p>Japan: “Progress in Geological Disposal Program in Japan” (Morimasa Naito)</p> <p>ARIUS: “Multinational Solutions to Geological Disposal” (Charles McCombie)</p>

		<p>India: "Host Rock Characterization, In-Situ Experiments, Numerical TMH Simulations and Natural Analogue Studies in Indian Deep Geological Disposal Programme" (R.K. Bajpai)*</p> <p>China: "Geological Disposal Program for High Level Radioactive Waste and the Plan for Underground Research Laboratory in China" (Like Ma)</p>
2:20	2:40	Break
2:40	3:25	<p>Special Discussion Topic #4: <u>"Duration of the period of regulatory concern – technical issues and regulatory policy."</u> Panel Discussion: Peter Swift, Mark Jensen</p>
3:25	4:00	<p>Information about publication of the WWR-5 Report (Boris Faybishenko) Closing statements (Jens Birkholzer and Peter Swift).</p>
4:00		Close Meeting

ATTACHMENT 2.
LIST OF PARTICIPANTS OF THE WWR-5 WORKSHOP

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	Name	Organization/country	Country	e-mail	Workshop participants and presenters
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