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LINKÖPING UNIVERSITY,
SWEDEN

HOW TO COMMUNICATE OVER 100 MILLENIA?

ON NUCLEAR MEMORY AND THE MANAGEMENT OF UNCERTAIN FUTURES

FOCUS

I. Project Context: Writing the Key Information File for a Swedish Repository for Highly Radioactive Spent Nuclear Fuel

II. Problem of ‘nuclear memory’: How to communicate over 100,000 Years?

III. Pathways for managing deep nuclear waste futures: The Key Information File

KEY INFORMATION FILE PROJECT

PROJECT AIMS

Three year research project (April 2021- September 2024) with Prof Anna Storm (Linköping University)

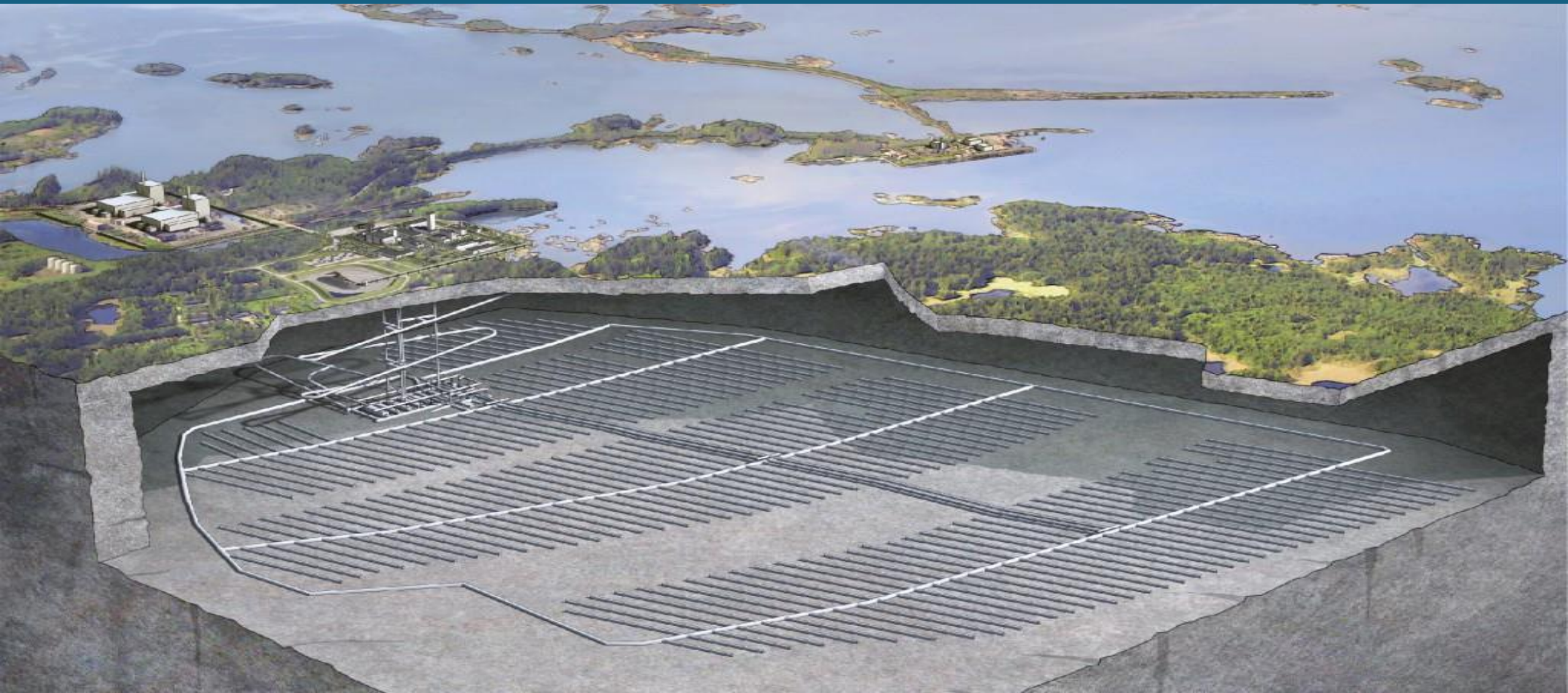
Commissioned by the Swedish Nuclear Fuel & Waste Management Company (SKB) aiming to:

I. Develop *methods* and *writing* for a Key Information File (KIF) that contributes to memory communication of Sweden's permanent geological repositories for nuclear waste

II. Carry out *independent research* laying a meta-perspective on societal processes that characterize the work of permanent nuclear waste repositories, including relations between technical and *existential questions*, power hierarchies and their changes over time, and how actors articulate different future scenarios and their consequences


This map depicts the expected location of the Spent Fuel Repository in Forsmark.As the land is slowly rising in relation to the sea level (approximately 6 mm per year), this map may no longer be correct in the future.
Forsmark village
Forsmark Spent Fuel Repository
1:50 000

FINAL REPOSITORY FOR SPENT NUCLEAR FUEL: FORSMARK, SWEDEN FOR 100,000 YEARS



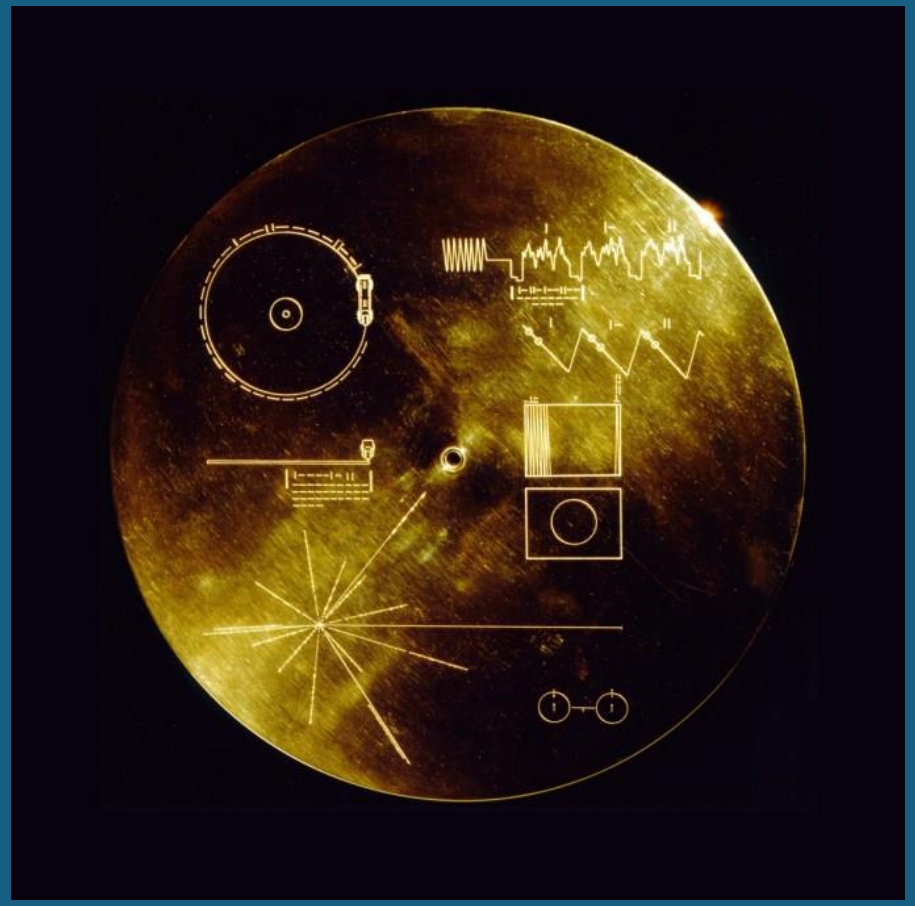
FINAL REPOSITORY FOR SPENT NUCLEAR FUEL: FORSMARK, SWEDEN FOR 100,000 YEARS

- Approved for development by the Swedish government January 2022
- Spent nuclear fuel (nuclear waste) filling and sealing of the repository expected to be completed after the turn C22
- Sweden and Finland are the only nations to have adopted ‘final repositories’ for nuclear waste
  - Premised on KBS-3 technology
  - Non-retrievable waste storage
  - Principle of “passive safety” – hence no human monitoring

PROBLEM OF FUTURE MEMORY COMMUNICATION

- One implication of the development of ‘final’ repository is that it brings into focus the problem of how to communicate over 100, 000 years that the buried nuclear waste will remain harmful to organic life

- Whilst the technical challenges of spent nuclear fuel storage have engaged the sciences for many decades, the *social challenges* of communicating the existence of buried waste to future generations has been treated as of marginal importance by nuclear waste industries and governments internationally

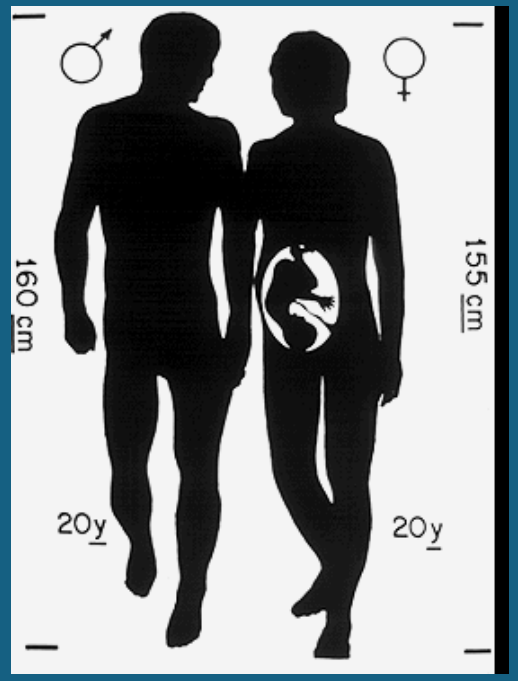


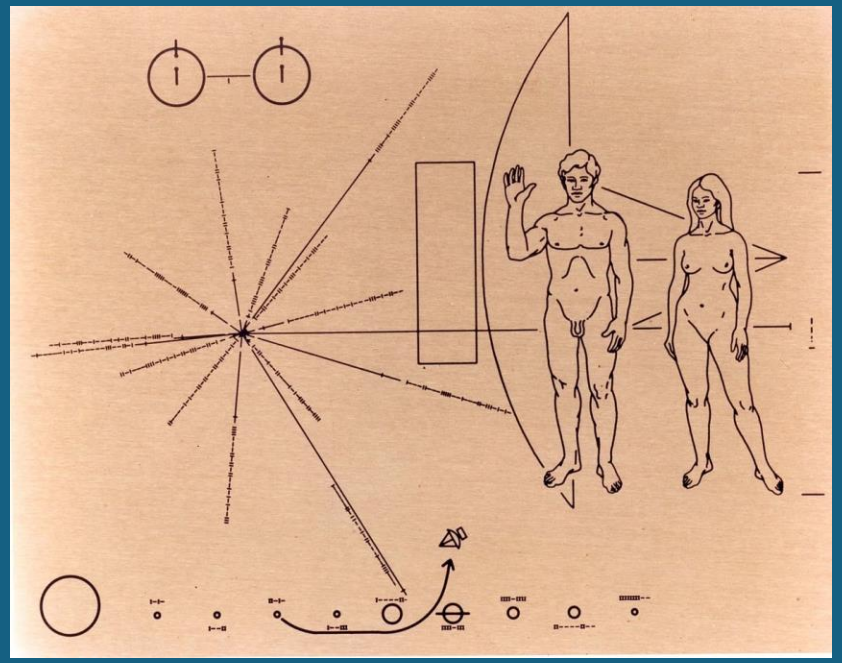
Cover of Carl Sagan Voyager Golden Record launched into space in 1977

HOW TO COMMUNICATE OVER 100 000 YEARS?

- Carl Sagan's 'forever archive' archive in the Voyager 1 spacecraft 1977

Selection of images onboard Voyager 1





MANAGING NUCLEAR WASTE FUTURES: 100,000 YEARS

Original Research Article

Progress in Environmental Geography
2023, Vol. 2(1-2) 97–117

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Nuclear memory: Archival, aesthetic, speculative

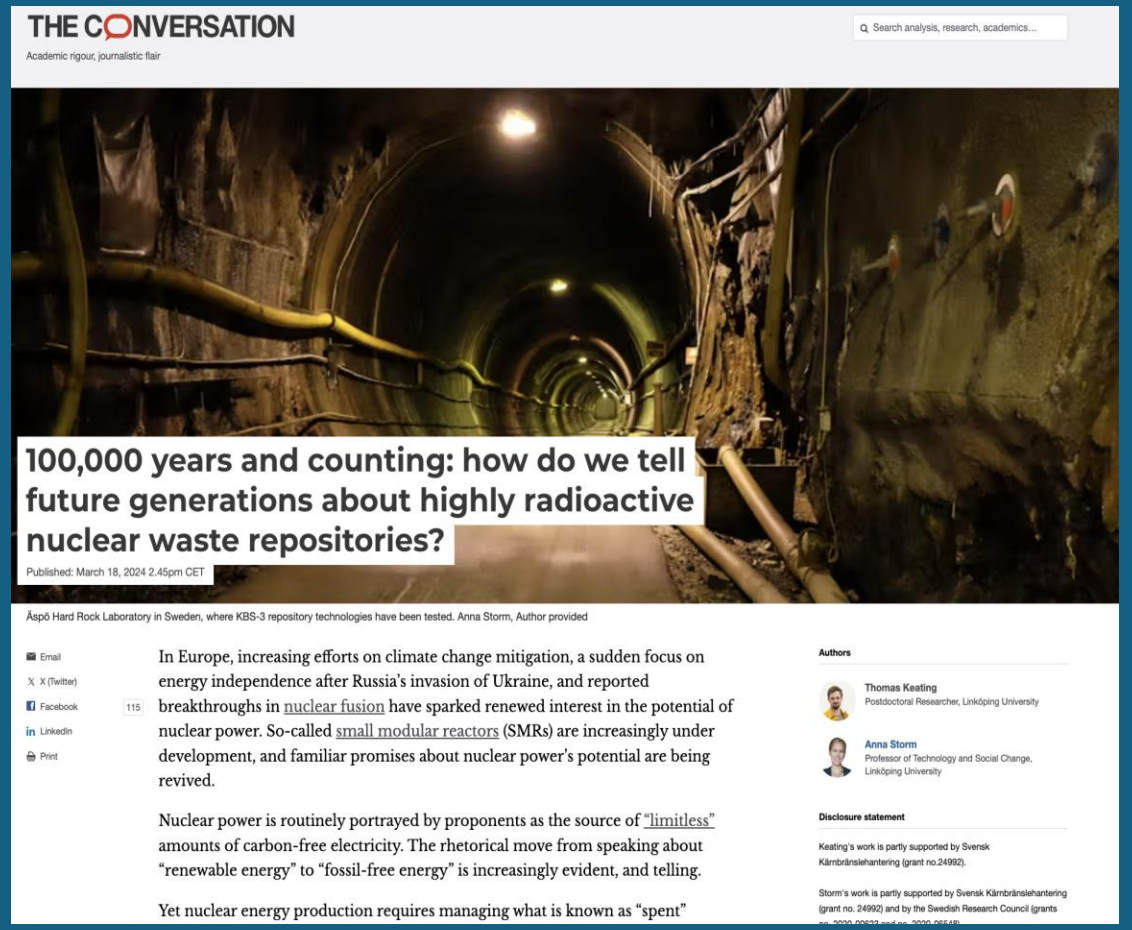
Thomas P. Keating and Anna Storm
Linköping University, Sweden

Abstract
This article assays geographical research into nuclear cultures, and cognate conversations in atomic heritage, toxic waste studies, and memory and landscape studies, as one way to develop the notion of nuclear memory. In doing so, we survey how geographers and social scientists have sought to think and communicate memory of nuclear things through three specific modes: the archival, the aesthetic, and the speculative. Our central argument is that nuclear memory provides a theoretical orientation for geographers to engage with alternative possibilities for thinking nuclear waste futures besides anthropocentric notions of common sense.

Keywords
Atomic heritage, nuclear waste futures, living archives, temporality, non-human, speculation

"A place we must remember to forget." (Madsen 2010)

(Hecht 2014) directly and indirectly approach the problem of how to think the enduring materialities of nuclear things into the future



THE CONVERSATION
Academic rigour, journalistic flair

Search analysis, research, academics...

100,000 years and counting: how do we tell future generations about highly radioactive nuclear waste repositories?

Published: March 18, 2024 2.45pm CET

Äspö Hard Rock Laboratory in Sweden, where KBS-3 repository technologies have been tested. Anna Storm, Author provided

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In Europe, increasing efforts on climate change mitigation, a sudden focus on energy independence after Russia's invasion of Ukraine, and reported breakthroughs in nuclear fusion have sparked renewed interest in the potential of nuclear power. So-called small modular reactors (SMRs) are increasingly under development, and familiar promises about nuclear power's potential are being revived.

Nuclear power is routinely portrayed by proponents as the source of "limitless" amounts of carbon-free electricity. The rhetorical move from speaking about "renewable energy" to "fossil-free energy" is increasingly evident, and telling.

Yet nuclear energy production requires managing what is known as "spent"

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Disclosure statement

Keating's work is partly supported by Svensk Kärnbränslehantering (grant no.24992).

Storm's work is partly supported by Svensk Kärnbränslehantering (grant no. 24992) and by the Swedish Research Council (grants

NUCLEAR MEMORY PROBLEM: HOW TO COMMUNICATE OVER 100 000 YEARS?

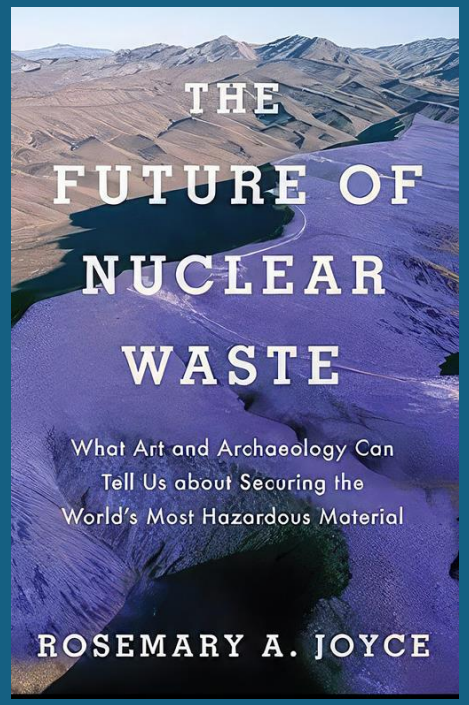
- There are examples of messages communicated over a few thousands of years
  - Tsunami stones (approximately 600 years)
  - Burial sites with human remains such as the Sarcophagus of Eshmunazar II (2455 years)
  - Mythologies and stories such as the Epic of Gilgamesh (approximately 4000 years)
  - Art and drawings such as cave paintings found in the Cave of La Pasiega (approximately 64 000 years)

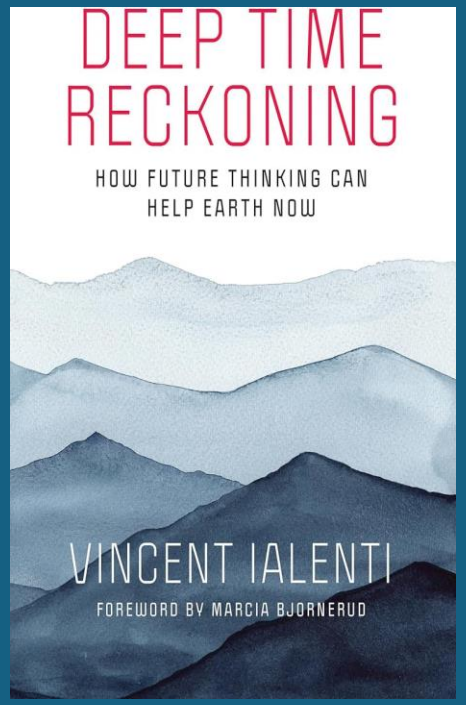
- Yet in most cases the message is often no longer understandable, no longer deemed relevant, or deliberately or accidentally ignored or misinterpreted.

Red scalariform sign - Cave of La Pasiega: 64, 800 years old
Source: Hoffman et al., 2018

https://www.science.org/doi/10.1126/science.aap7778#core-collateral-fulltext-options

NUCLEAR MEMORY COMMUNICATION



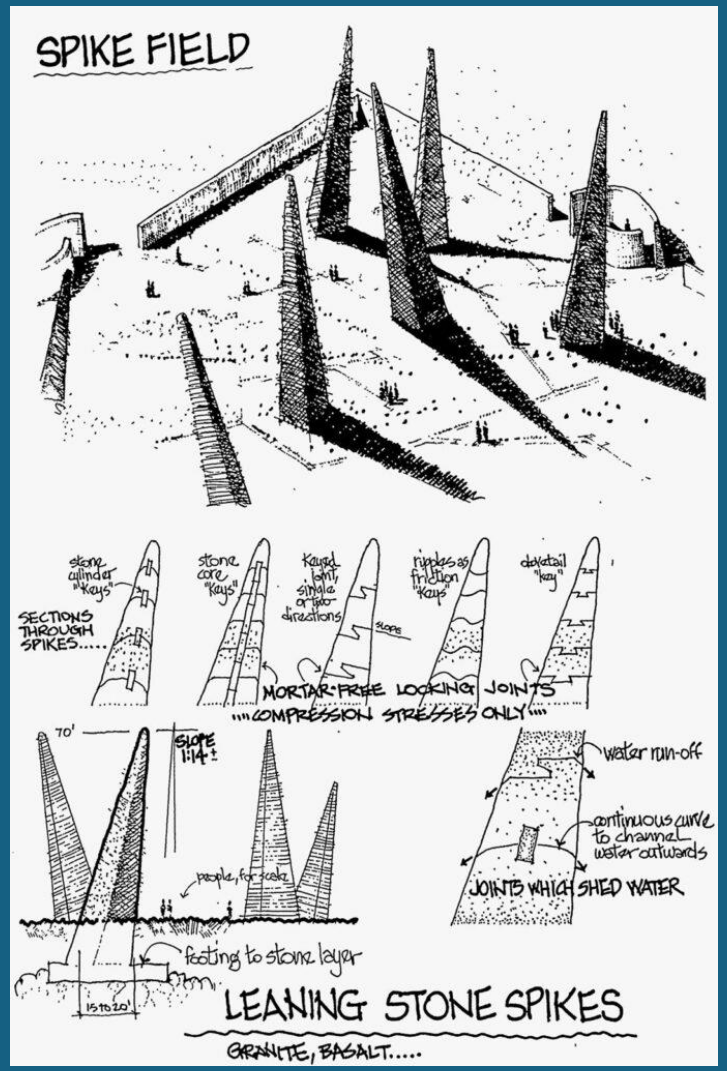


Multiple challenges:

- Risk modelling and calculation (Ialenti, 2021)
- Expert groups in fashioning certain cultures of knowledge and common sense thinking about the future (Joyce, 2021)
- Non-human material things are to be understood as active collaborators in waste management processes (Schürkmann, 2022)
- Nuclear markers and warning signs might act as tools for communicating information into the future (van Wyck, 2005)

PROPOSALS FOR FUTURE MEMORY COMMUNICATION

Warning signs and markers



The “Landscape of Thorns” by Michael Brill and Safdar Abidi. Source: Sandia National Laboratories)

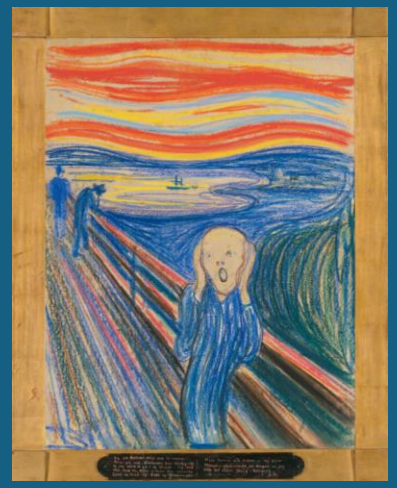
PROPOSALS FOR FUTURE MEMORY COMMUNICATION

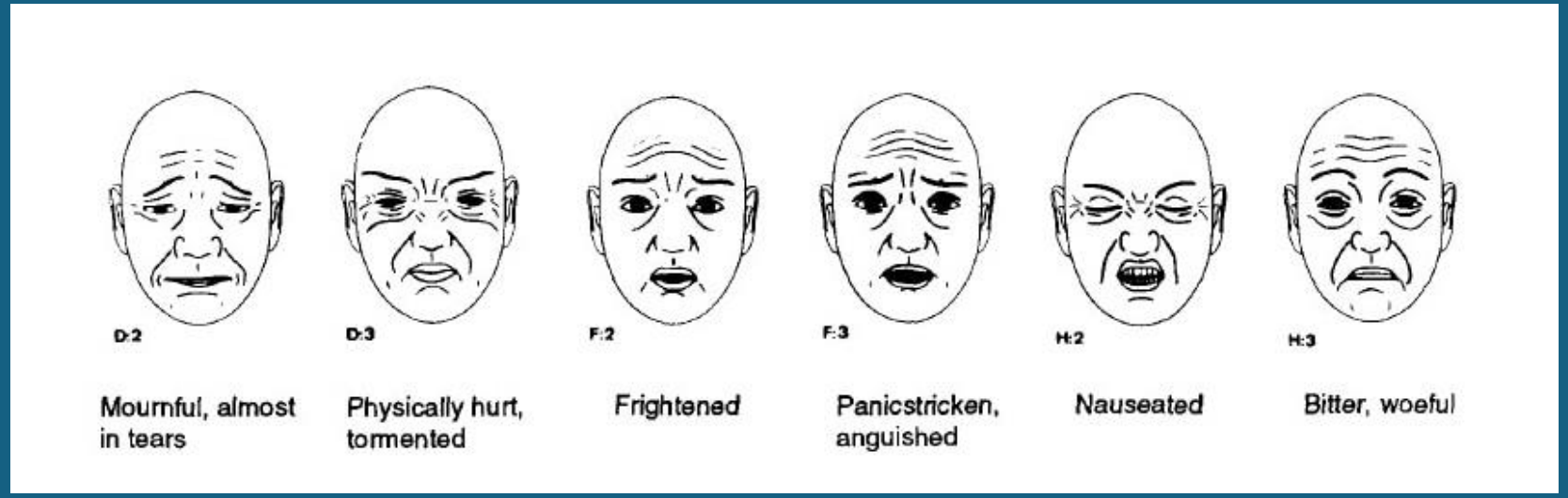
Warning signs and markers

Ast, D.G., Brill, M., Goodenough, W., Kaplan, M., Newmeyer, F., Sullivan, W. (1992) Appendix F: Team A Report: Marking The Waste Isolation Pilot Plant For 10,000 Years. Report by US Department of Energy. https://wipp.energy.gov/library/cca/CCA_1996_References/Chapter%207/CREL3328.PDF accessed on 1 March 2023).

PROPOSALS FOR FUTURE MEMORY COMMUNICATION

Warning signs and markers





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PROPOSALS FOR FUTURE MEMORY COMMUNICATION

Landscape Art

The Blue Zone by Stéfane Perraud and Aram Kebabdijan (2015).

Nuclear Semiotics by Joris Wegner


Nuclear Semiotics by Joris Wegner

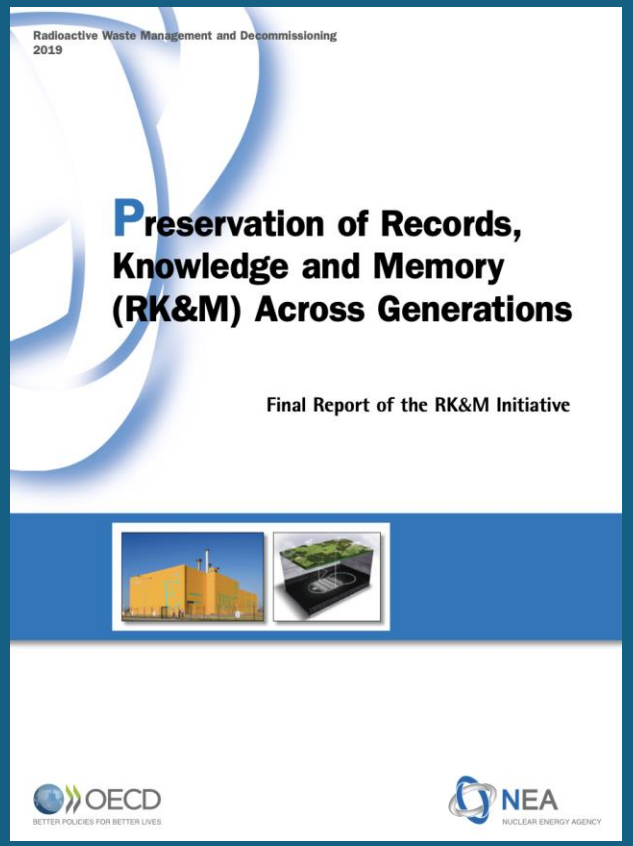
PROPOSALS FOR FUTURE MEMORY COMMUNICATION

Cults and religious groups

Atomic Priesthood project by Bryan McGovern Wilson & Robert Williams (2012–2018).

Illustration by Akuosa

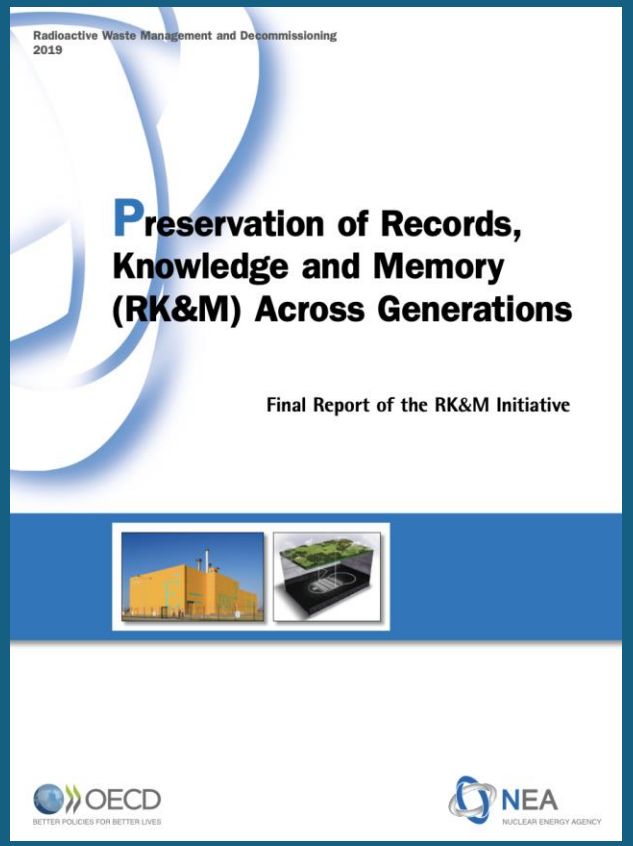
KEY INFORMATION FILE (KIF)



- "…to tell the story of the waste facility in a widely understandable manner (i.e. for an educated but non-specialist readership). It is designed to provide a summary of the existence, location and content of an engineered facility for the permanent disposal of radioactive wastes. It should be a separate, short document, produced to a standard format across national programmes. On this basis, the KIF can contribute to safety, by providing information that should reduce the likelihood of unnecessary human intrusion. Apart from telling the story of the waste facility, it should also point to detailed national records and to the location of other repositories across the globe."

p.19

8 PRINCIPLES
KEY INFORMATION FILE (KIF)

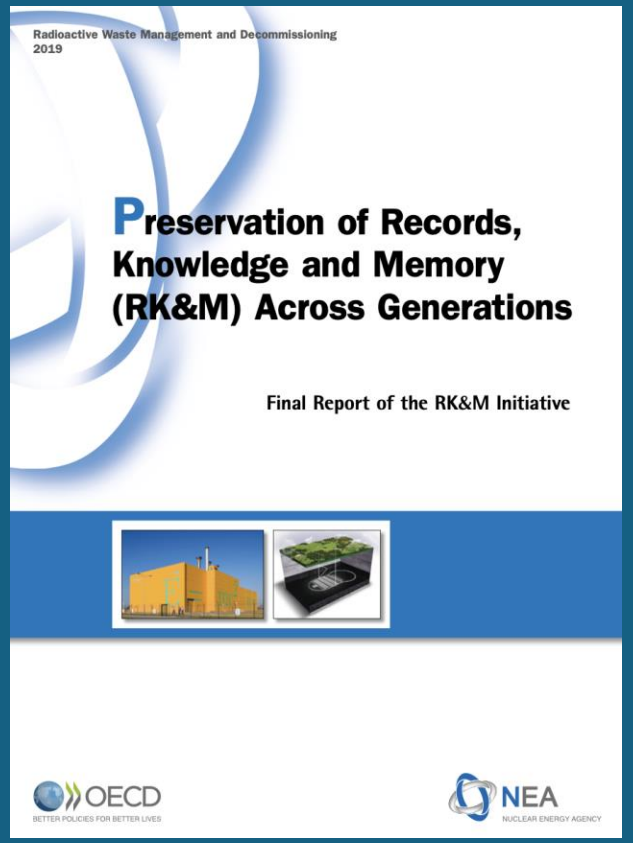


Key principles

The following key principles have been established for the development of the KIF:

1. The KIF should provide relevant information to future generations, to help protect the passive performance of the disposal site and to enable any necessary decision making.
2. The KIF should identify the hazard presented by the waste, describe the reduction in hazard with time, and set out the engineered and natural barriers that prevent human contact with the radioactive wastes.
3. The KIF should be written, as much as possible, in a succinct and non-technical manner. Where necessary, technical context should be provided to prevent ambiguous interpretations of the information.
4. The KIF should be produced in an internationally standardised format, be distributed widely and be available in the local language plus any other official language of the country. Parts of it may also be provided in multiple languages, typically the international "official" languages used by the United Nations (currently Arabic, Chinese, English, French, Russian and Spanish).

KEY INFORMATION FILE (KIF)



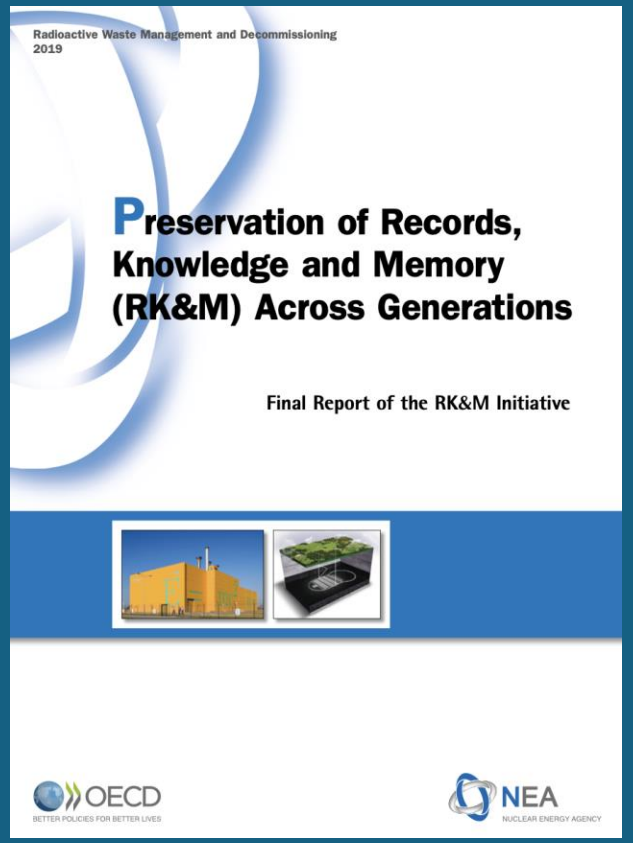
5. The KIF should be preserved as a publicly available document, with copies preserved in formats and locations that are easily located and accessed, so that it is readily available to all potentially interested parties.

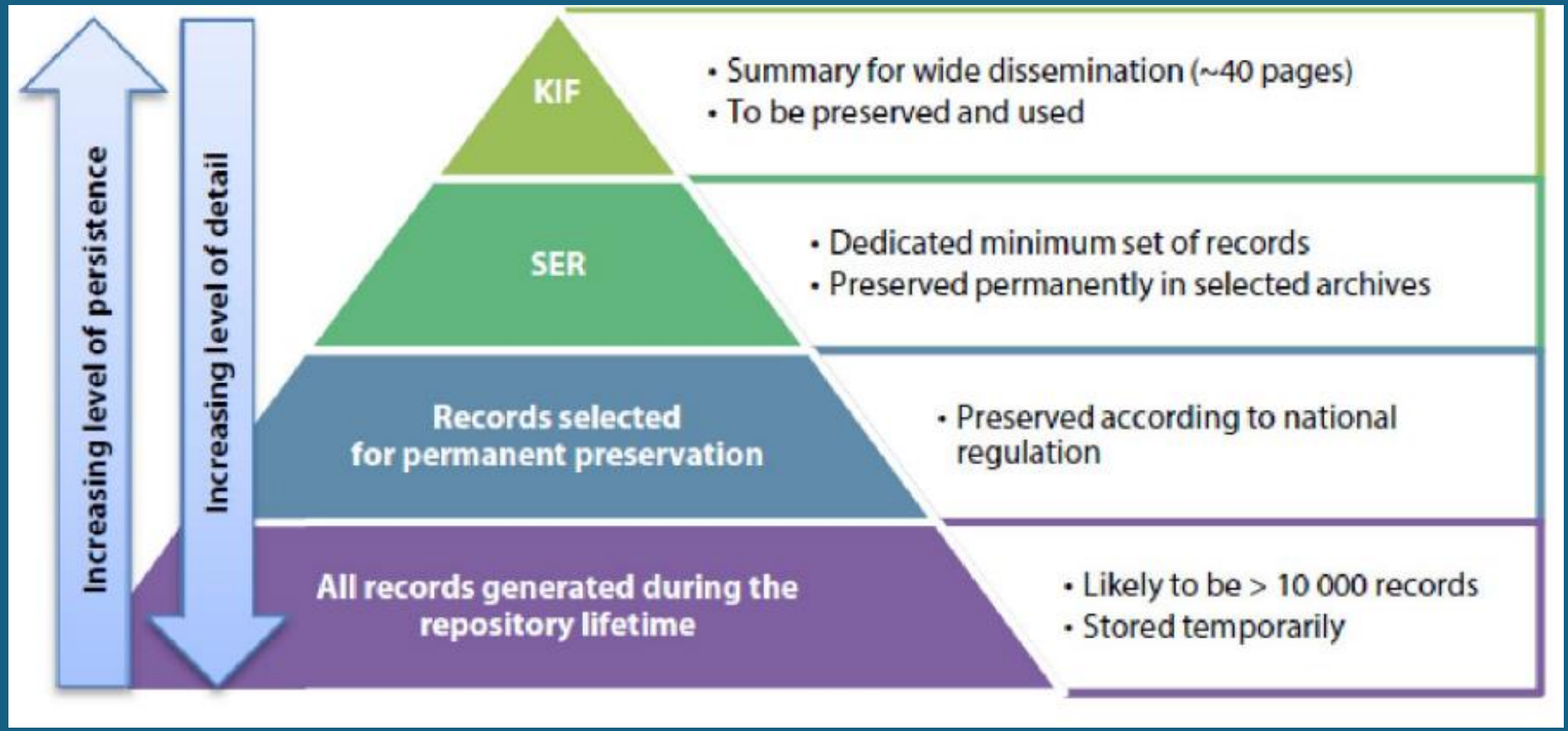
6. The KIF should point to the planned preservation of more detailed information about the disposal facility, its content and associated safety case.

7. The KIF should be managed using available and suitable records management system techniques as appropriate. Noting that the peculiarities of the KIF concept pose unique challenges to its proper management, a dedicated "KIF management system" may need to be formulated and installed.

8. Since the KIF should tell the story of the disposal facility and aims to be widely available and comprehensible, a multidisciplinary and participatory process is recommended for its development, testing and dissemination. The process of developing and disseminating the KIF should receive as much attention as its content.

KEY INFORMATION FILE (KIF)





Source: NEA 2019

KEY INFORMATION FILE

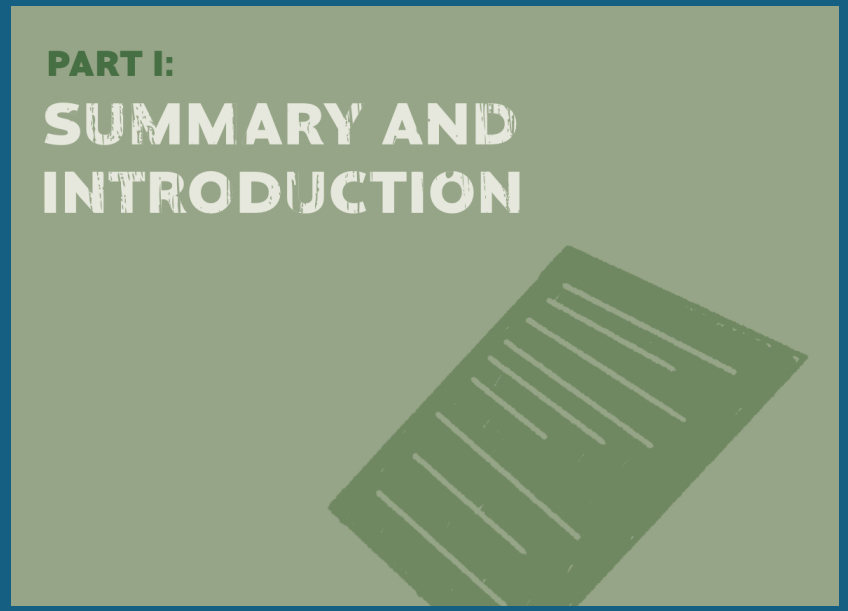
Essential Information on the Spent Nuclear Fuel Repository in Forsmark, Sweden

SHARE

IMAGINE

RENEW

THE KEY INFORMATION FILE (KIF)



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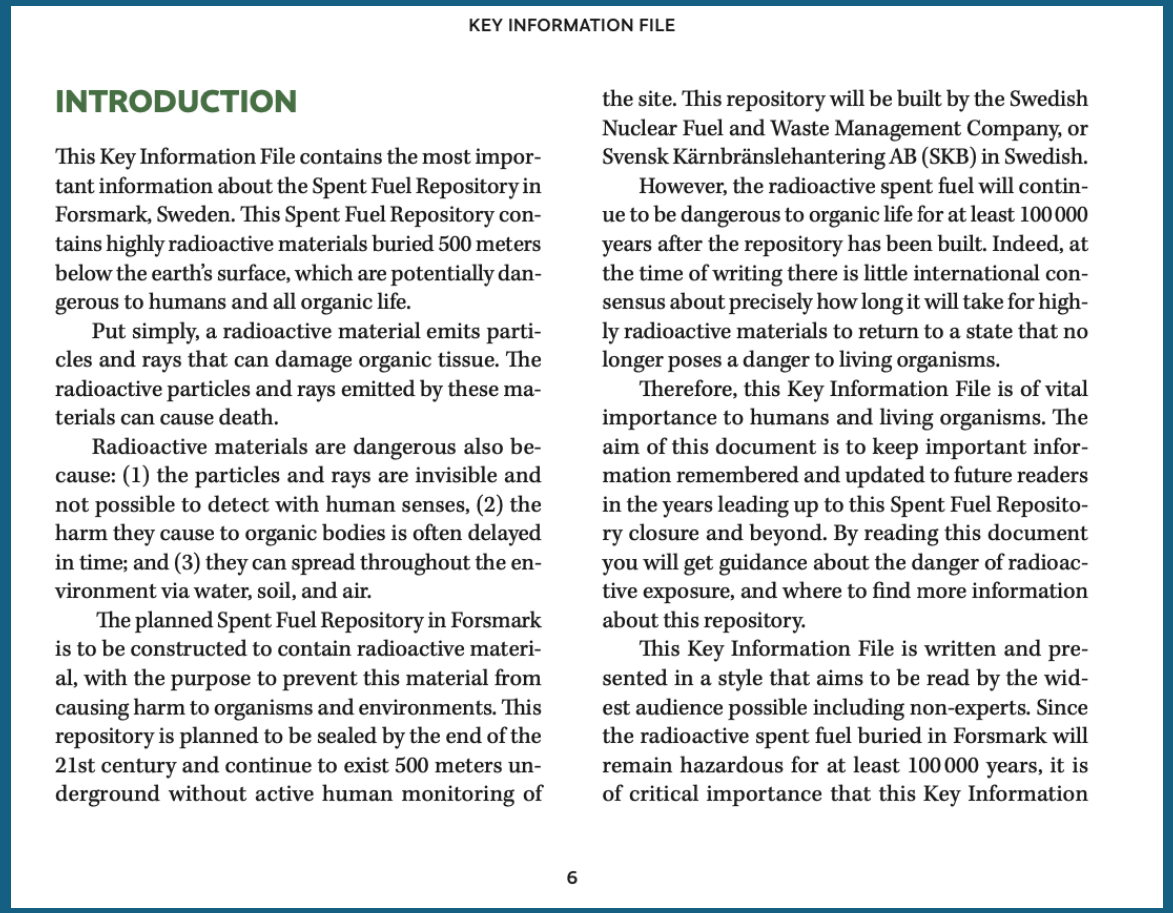
- Key Information File, Sweden (2024) – written by Thomas Keating and Anna Storm
  - Alongside France as the first one written internationally
- Focuses on the under development Swedish geological repository for high level long lived radioactive waste: spent nuclear fuel
- This repository not yet under construction; planned to be finished around the end of this century

THE KEY INFORMATION FILE (KIF)

- Crucial information needed for future readers – including in the event of future information loss
- Emphasis on clarity of expression
- Technical information is in the service of informing the most essential information – critical and clinical



INTRODUCTION

This Key Information File contains the most important information about the Spent Fuel Repository in Forsmark, Sweden. This Spent Fuel Repository contains highly radioactive materials buried 500 meters below the earth's surface, which are potentially dangerous to humans and all organic life.

Put simply, a radioactive material emits particles and rays that can damage organic tissue. The radioactive particles and rays emitted by these materials can cause death.

Radioactive materials are dangerous also because: (1) the particles and rays are invisible and not possible to detect with human senses, (2) the harm they cause to organic bodies is often delayed in time; and (3) they can spread throughout the environment via water, soil, and air.

The planned Spent Fuel Repository in Forsmark is to be constructed to contain radioactive material, with the purpose to prevent this material from causing harm to organisms and environments. This repository is planned to be sealed by the end of the 21st century and continue to exist 500 meters underground without active human monitoring of the site. This repository will be built by the Swedish Nuclear Fuel and Waste Management Company, or Svensk Kärnbränslehantering AB (SKB) in Swedish.

However, the radioactive spent fuel will continue to be dangerous to organic life for at least 100 000 years after the repository has been built. Indeed, at the time of writing there is little international consensus about precisely how long it will take for highly radioactive materials to return to a state that no longer poses a danger to living organisms.

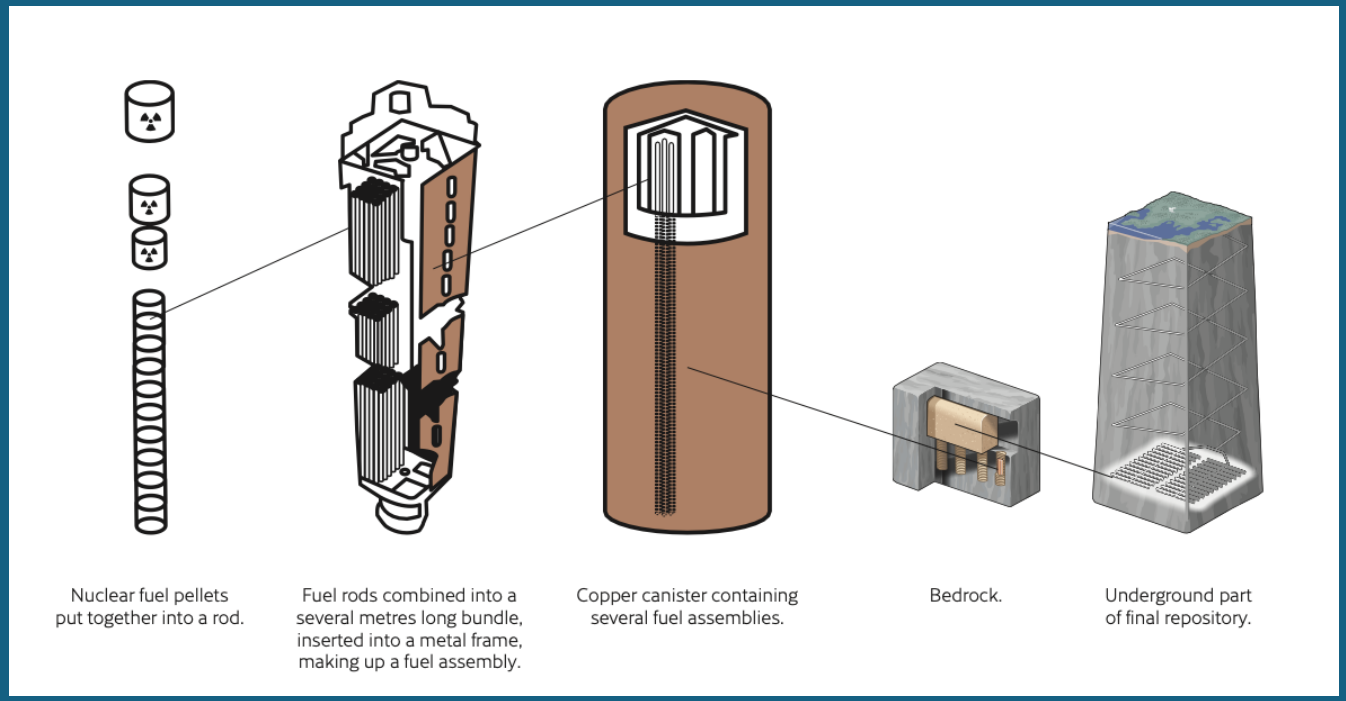
Therefore, this Key Information File is of vital importance to humans and living organisms. The aim of this document is to keep important information remembered and updated to future readers in the years leading up to this Spent Fuel Repository closure and beyond. By reading this document you will get guidance about the danger of radioactive exposure, and where to find more information about this repository.

This Key Information File is written and presented in a style that aims to be read by the widest audience possible including non-experts. Since the radioactive spent fuel buried in Forsmark will remain hazardous for at least 100 000 years, it is of critical importance that this Key Information

SUMMARY

- There is a repository located near the village of Forsmark, Sweden buried 500 meters underground. It contains materials that are dangerous to humans and other living organisms.
- The materials are spent nuclear fuel, which are waste leftovers from energy production. They are dangerous because they are radioactive, and radioactivity is not possible to detect with human senses.
- This document contains crucial information about the repository and how to prevent its content causing harm today and in the future.

THE KEY INFORMATION FILE (KIF)



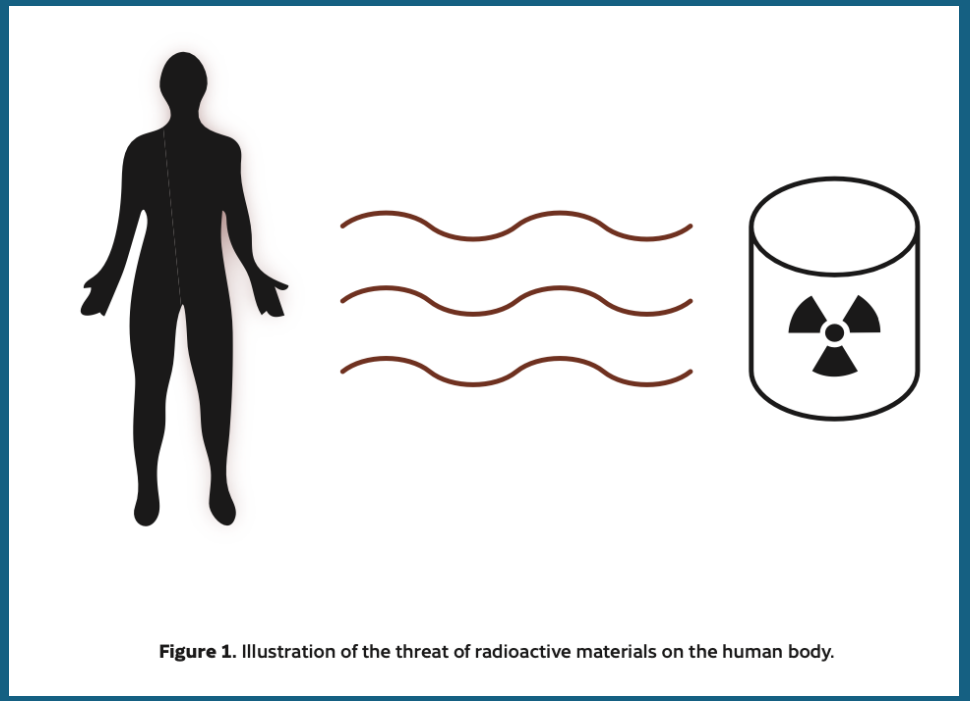
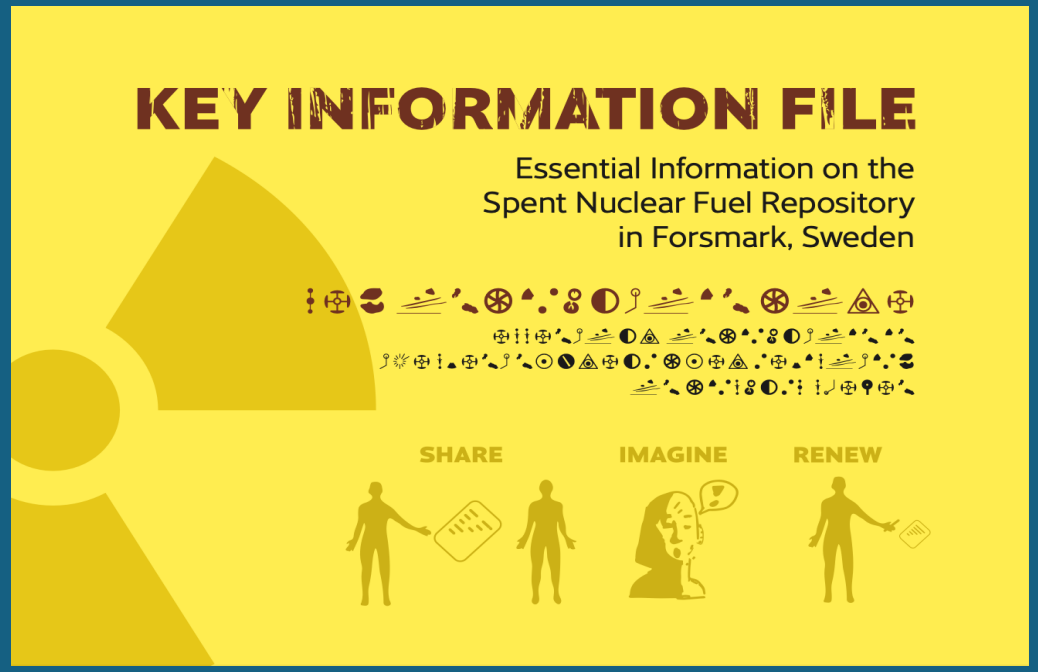


Figure 1. Illustration of the threat of radioactive materials on the human body.

THE KEY INFORMATION FILE (KIF)



- Cover aims at being performative – like an airline safety manual
- Images and graphics can convey an idea *immediately* without reading the text – this is a tool that needs to be utilised in the Key Information File
- Presented in a style that is open to a wide, non-expert audience to bolster readability

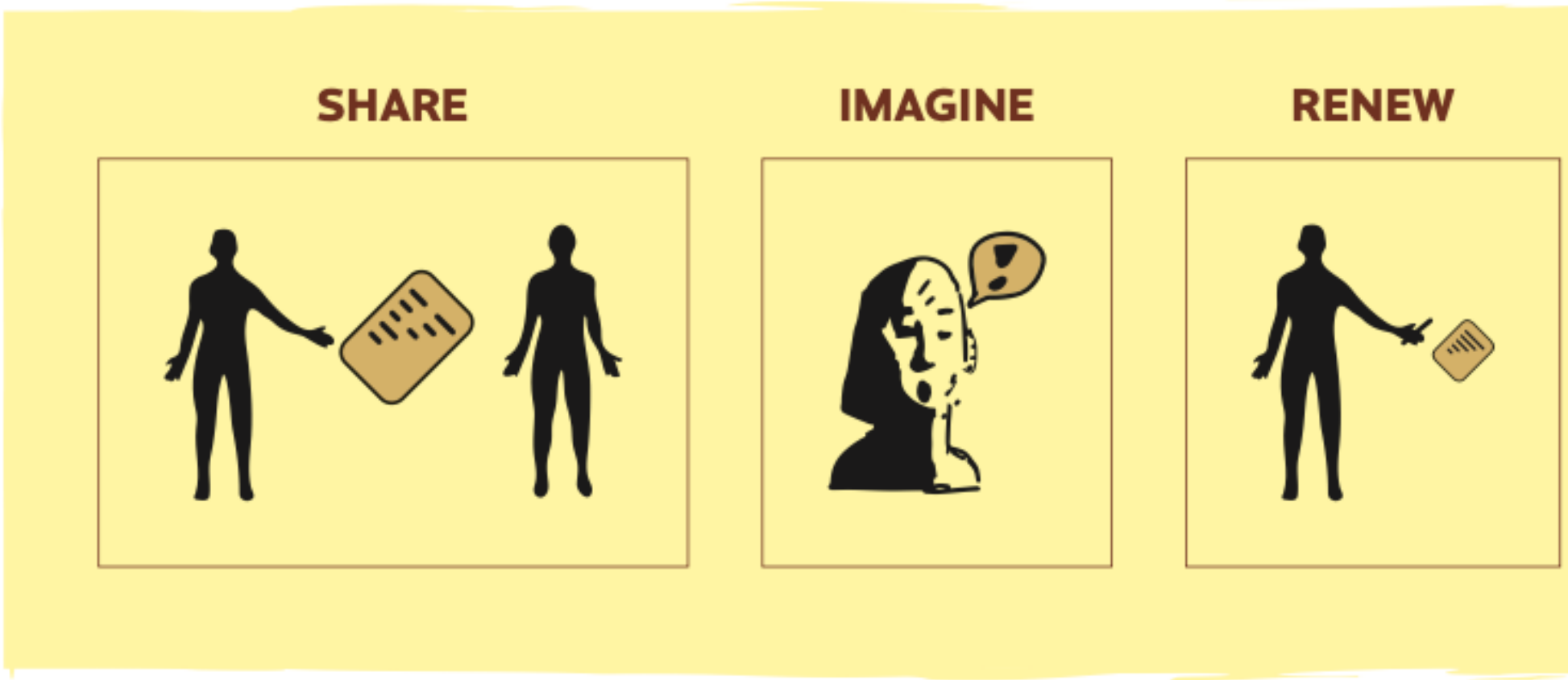
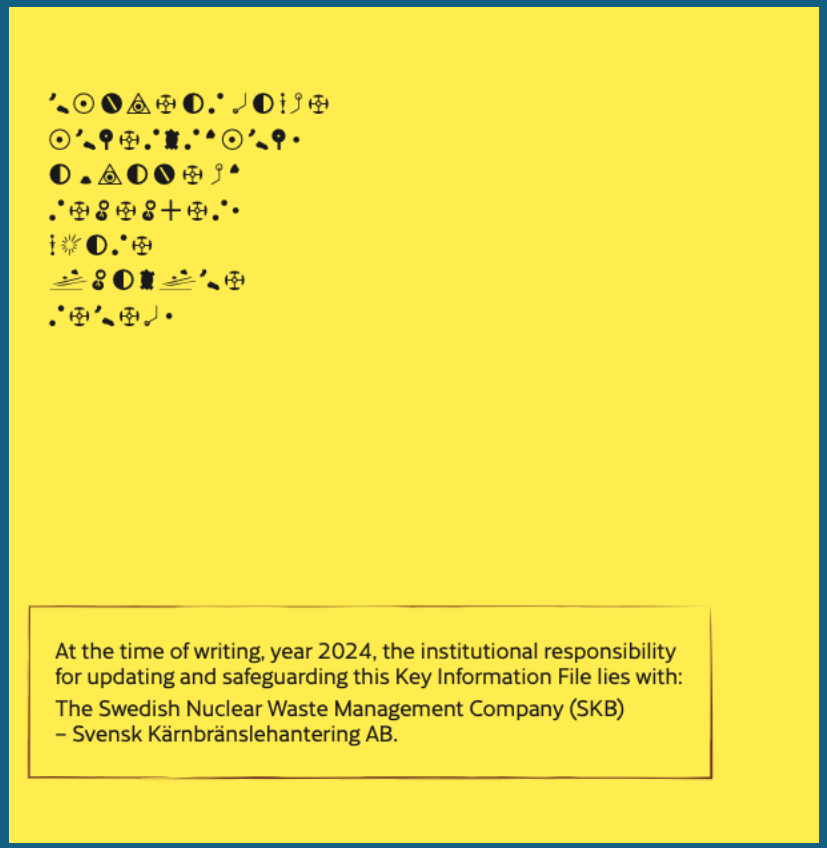
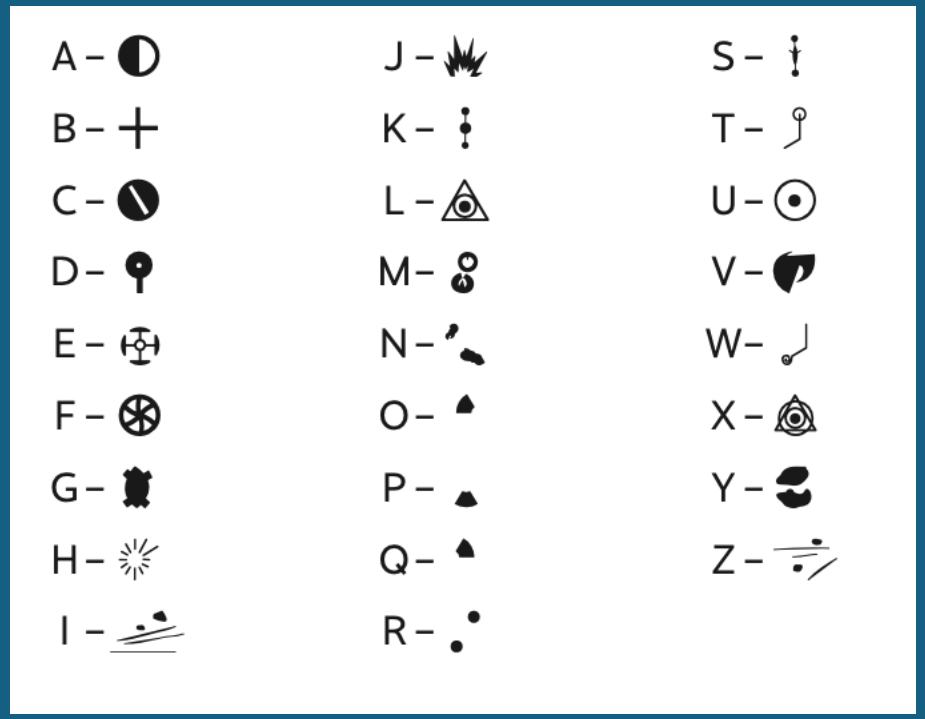


Figure 6. SHIRE method pictogram. Summarising the SHIRE method in relation to the Key Information File.

Cypher & Role of Playfulness in Memory Communication



At the time of writing, year 2024, the institutional responsibility for updating and safeguarding this Key Information File lies with:
The Swedish Nuclear Waste Management Company (SKB)
– Svensk Kärnbränslehantering AB.

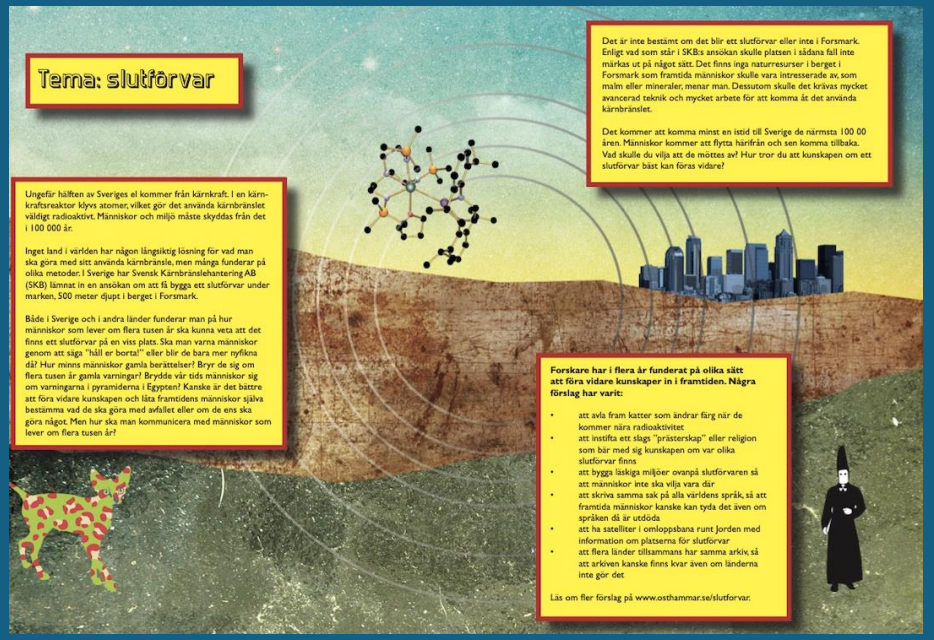


ONGOING KIF CHALLENGES

Time Management

- The temporal scale of archiving for nuclear waste repositories is immense
  - There are no examples in human history of a message being communicated over 100,000 years

- Vast international differences in the time horizon being applied between spent fuel repositories
  - e.g. Germany (1m years), Sweden & Finland (100k years), USA (10k years)



ONGOING KIF CHALLENGES

Funding and expertise

- Recent loss of expertise through retirement or death

- Limited funding and work capacity on nuclear memory communication tasks like the KIF both domestically and internationally

- Institutional reorganisation causing a loss of expert working groups e.g. Swedish National Council for Nuclear Waste; MKG

CONCLUSIONS

- The KIF is a document that needs to take memory communication seriously
  - Cannot be treated as just another technical report
- Unique and manifold of challenges in writing the KIF – updating, media, institutional responsibility etc.
- KIF is a living document: needs to be kept alive
  - We propose a10 year cycle of renewal
- Nuclear memory approaches must draw on a range of methods if a message is going to be kept alive over 100 millennia

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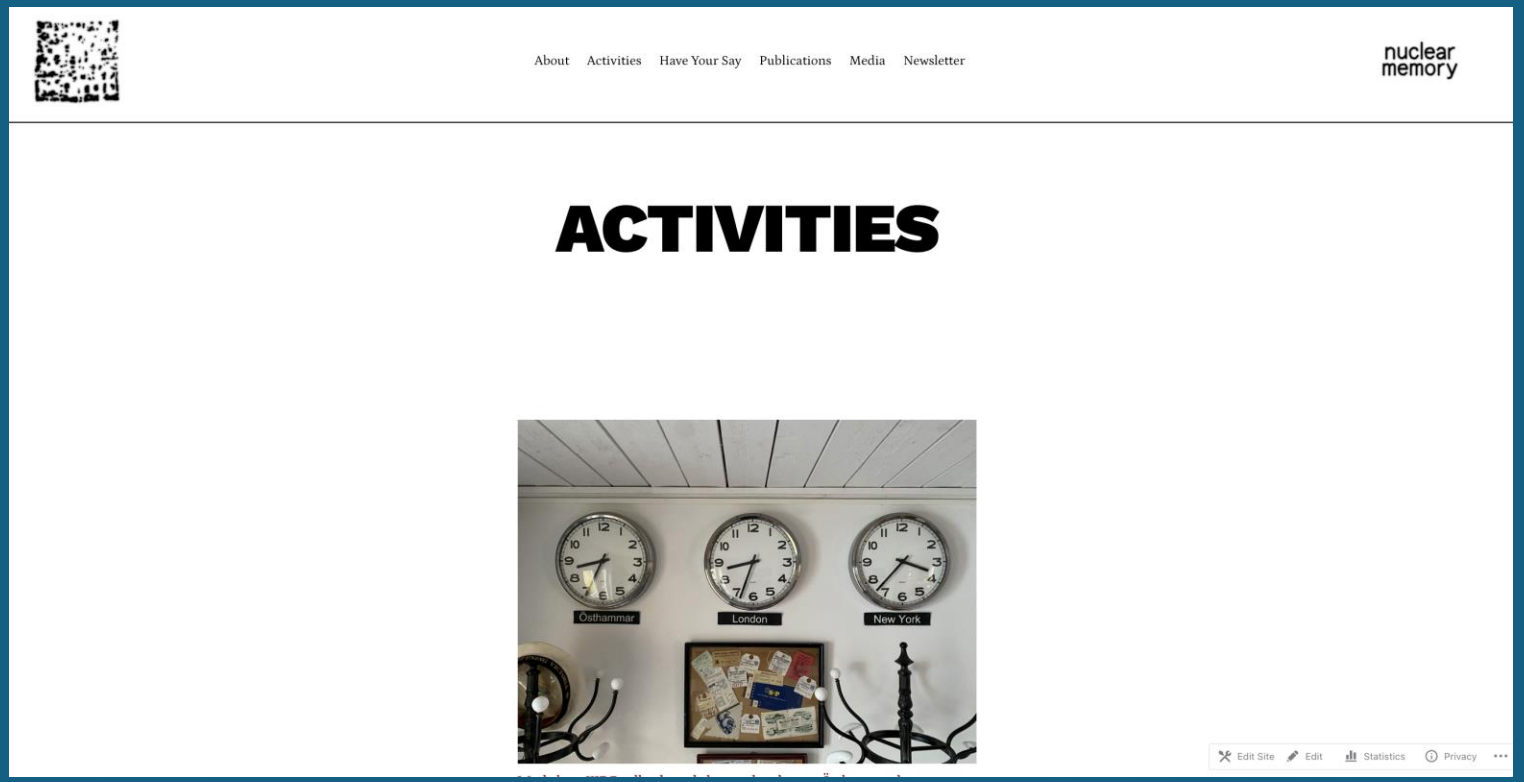
PROJECT WEBSITE



https://nuclearmemory.wordpress.com/