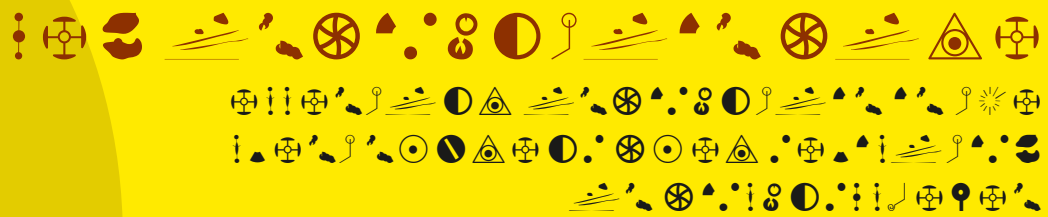
KEY INFORMATION FILE

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



SHARE IMAGINE RENEW

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PART I:

SUMMARY AND INTRODUCTION

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.

INTRODUCTION

This Key Information File contains the most important information about the Spent Fuel Repository in Forsmark, Sweden. This planned Spent Fuel Repository is to hold 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. The 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 prevent unintentional human intrusion to the repository and ensure future generations are able to make informed decisions about its management. By reading this document you will get guidance about the danger of radioactive exposure, and where to find more information about the Spent Fuel Repository in Forsmark.

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

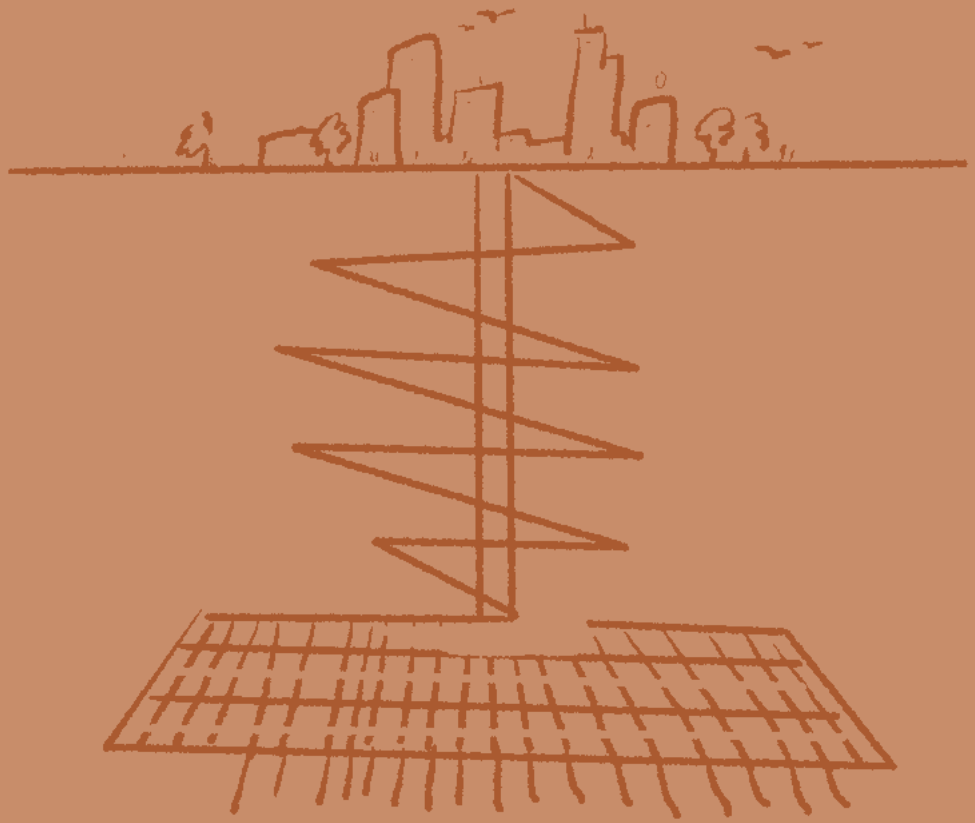
of critical importance that this Key Information File is kept updated and relevant to inform future generations.

This Key Information File proposes the SHIRE method – or Share, Imagine, Renew – as one approach to ensuring that the critical information in this document can be kept alive into the future by mobilising your capacity as a reader.

In what follows you will find information about four main things: 1) what radioactivity is; 2) what this Spent Fuel Repository is; 3) how to update this Key Information File for the safety of future generations; and 4) where to find more information. This document also outlines a number of challenges and recommended responses in keeping this critical information updated and remembered.

PART II:

CRITICAL INFORMATION



WHAT IS RADIOACTIVITY?

Radioactivity occurs in unstable atoms. An atom is the small particle of energy found in all elements of the universe. An atom is unstable when it is energetically imbalanced according to the number of protons and neutrons in its 'nucleus' – the dense central region of an atom. This imbalance causes the atom to decay, emitting particles and losing energy from its nucleus.

There are four main types of radioactivity: alpha, beta, gamma and neutron radiation. They all emit radiation but have different characteristics and affect the body differently.

WHY IS RADIATION DANGEROUS?

Radiation can directly affect humans and other organisms by killing organic cells in a body. Brief exposure to high levels of radiation in the body can result in radiation sickness whose symptoms include nausea, vomiting, diarrhoea, headache, and fever. These symptoms occur a few hours after exposure.

A larger exposure is likely to be lethal, but with medical treatment there is a chance of survival. The stronger and longer the exposure to radioactive materials, the higher the likelihood is of severe harm or death.

Limited to a certain body part, a very high dose of exposure might not be lethal, but instead result in other effects. For example, a dose absorbed by the human skin might cause a painful reddening. A dose absorbed by the reproductive organs might cause sterility.

Radiation can also affect humans and other organisms indirectly. Small exposures to radiation can lead to mild, severe, and lethal health problems several years after exposure. The indirect effects of radiation can sometimes be harder to determine as

these health problems – including cancers (that is, uncontrollable cell growth) – can also be caused by other genetic and environmental factors.

When radiation damages the sperm or egg cells, it can induce mutations. Experiments on mice have shown that radiation can cause mutations that are passed on to offspring. Therefore, the risk of hereditary diseases in humans should not be overlooked.

Beyond human bodies, radiation can also pose a danger to other living organisms and the environment. For example, a potential uncontrolled spreading of radioactive material could cause mortality among coniferous plants and soil invertebrates. Chronic genetic effects can also occur in certain plants.

HOW CAN RADIATION BE DETECTED AND MEASURED?

Radiation is not possible to detect with human bodily senses. Radiation cannot be seen, heard, touched, or smelled. To detect and measure radiation, one needs special tools. At the time of writing, these tools include instruments like a Geiger counter.

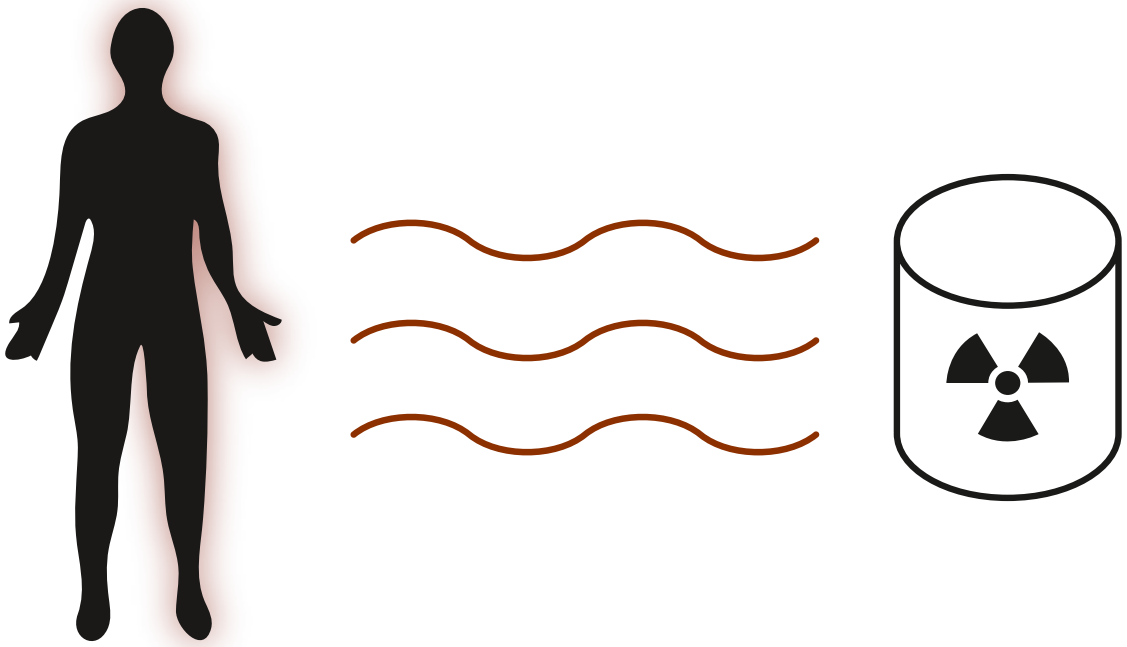


Figure 1. Illustration of the threat of radioactive materials on the human body.

THE SPENT FUEL REPOSITORY IN FORSMARK

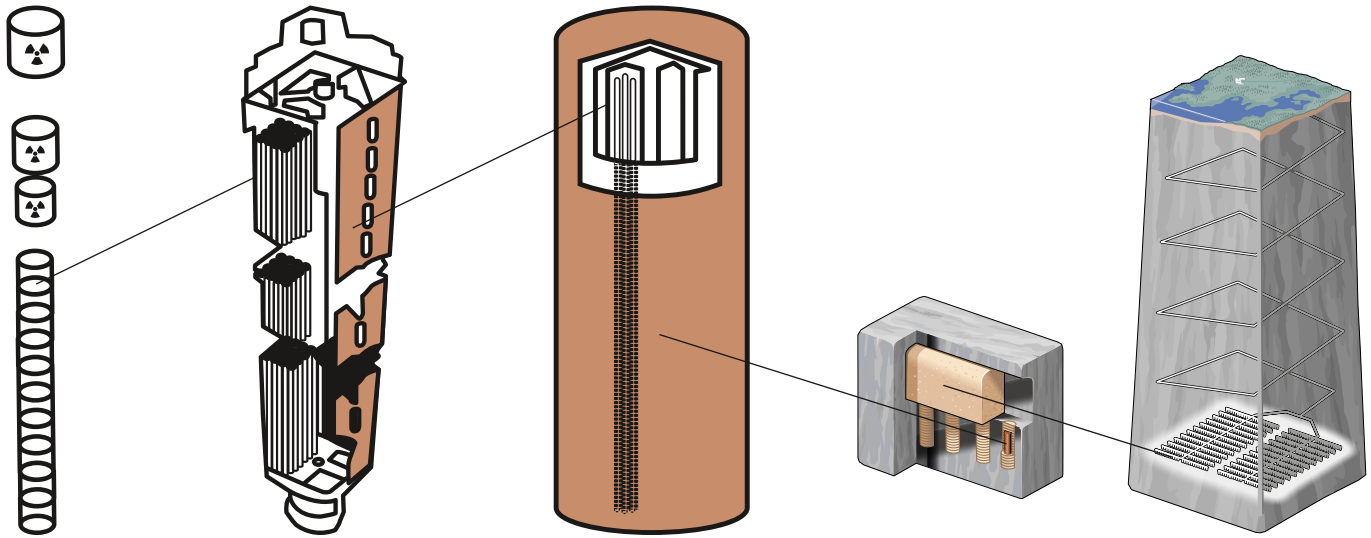
Spent nuclear fuel originates primarily from the earth element uranium, which is mined and transformed into nuclear fuel. At the time of writing, nuclear fuel continues to be used in nuclear power plants in Sweden and elsewhere to produce energy. To extract the energy, a process called nuclear fission is employed. Fission means splitting. In the energy production process, a neutron particle of the uranium atom is used as a projectile. The neutron projectile is shot on a uranium atom nucleus, which causes it to split. When the uranium nucleus splits, energy of the uranium is transformed into heat. In the process of splitting, many neutrons are released at high speed, which continue to split other uranium nuclei. When this sequence becomes a self-sustaining chain-reaction, it forms the source of nuclear energy production.

Nuclear fuel is often in the form of pellets. The pellets are put together into rods that are put together into several metres bundles, as in Figure 2.

The rods are put into the nuclear reactor where the heat from the fission process is used to boil water, which then propels a turbine to produce electricity. When the fuel stops producing enough heat to create electricity it is considered 'spent' or waste.

Spent nuclear fuel gives rise to alpha, beta, gamma and neutron radiation. After 1 000 years, much of the radiation will have disappeared, but the spent nuclear fuel will still present a danger if it comes into close contact with a living organism. 100 000 years is the time frame used by SKB to indicate when the spent nuclear fuel will return to a level of radioactivity comparable to the natural element of uranium from which it was originally made. Therefore, this spent fuel needs to be kept apart from humans and other organisms for at least 100 000 years – until the year 102 100 AD. However, it is possible this spent fuel could be dangerous to organic life beyond this time.

At the time of writing, Sweden has decided to put all highly radioactive spent nuclear fuel produced by currently existing nuclear power plants in a repository deep underground called a Spent Fuel Repository, or what is also sometimes referred to as a permanent geological repository for nuclear waste, or Kärnbränsleförvaret in Swedish. This Spent Fuel Repository will be located in the village



Nuclear fuel pellets in a rod.

Nuclear fuel rods in a metal frame making up a fuel assembly.

Copper canister with several fuel assemblies.

Copper canister placed in underground tunnel, backfilled with bentonite clay.

Cross section of the Spent Fuel Repository, illustrating its depth.

Figure 2. Spent nuclear fuel pellets placed into a metal assembly and copper canister, then placed in bedrock and backfilled with bentonite clay in the underground spent fuel repository.

of Forsmark in Sweden. Forsmark is in Östhammar municipality – around 150 km north of Stockholm (Figure 3 and 4).

One of the main reasons why Sweden opted to store highly radioactive spent fuel underground for 100 000 years is that this plan was judged by experts at SKB and at the Swedish Radiation Safety Authority – Strålsäkerhetsmyndigheten (SSM) in Swedish – as a safe and responsible approach that avoids burdening future generations with managing the spent nuclear fuel.

The design of this Spent Fuel Repository is based on layers. The design is called KBS-3 which aims to safely contain the spent fuel into the distant future without any human monitoring.

At the centre is the spent fuel. In the first layer, the spent fuel is surrounded by specially treated iron. The iron is surrounded by a second layer of copper. The copper is in the form of a canister with a sealed lid at one end. Copper was chosen by SKB as the material to contain the spent nuclear fuel as it is deemed a stable material resistant to degradation. The copper is surrounded by a special type of clay – bentonite clay – which may prevent the passage of water and other liquids. The clay is surrounded by bedrock, consisting mainly of granite. Each layer works as a barrier to isolate the spent fuel from the surroundings.

The Spent Fuel Repository in Forsmark is planned to contain around 12 000 tonnes (or 12 000 000 kilograms) of spent nuclear fuel placed inside around 6 000 canisters. The canisters are then placed in interconnected tunnels that are 500 metres below the earth's surface within the area indicated on Figure 4 and 5. This Spent Fuel Repository is to be constructed by SKB. The regulations guiding its development are produced by SSM.

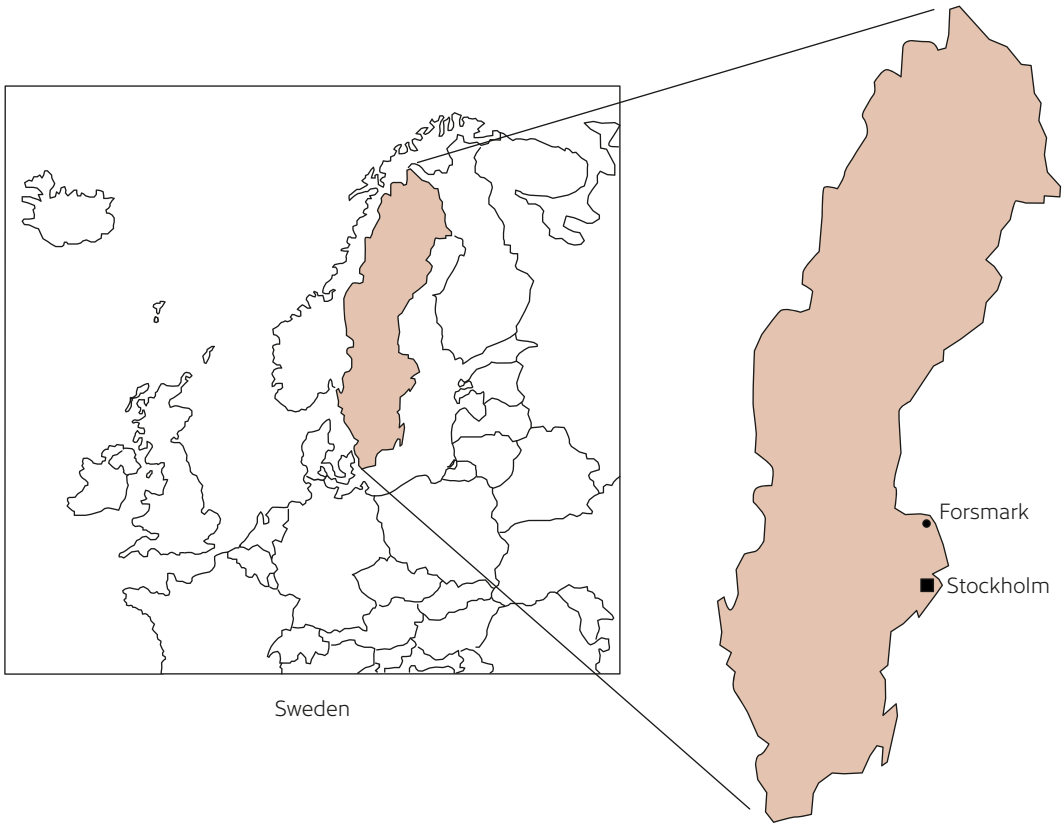


Figure 3. Map of the region, with the Spent Fuel Repository in Forsmark and the Swedish capital of Stockholm.

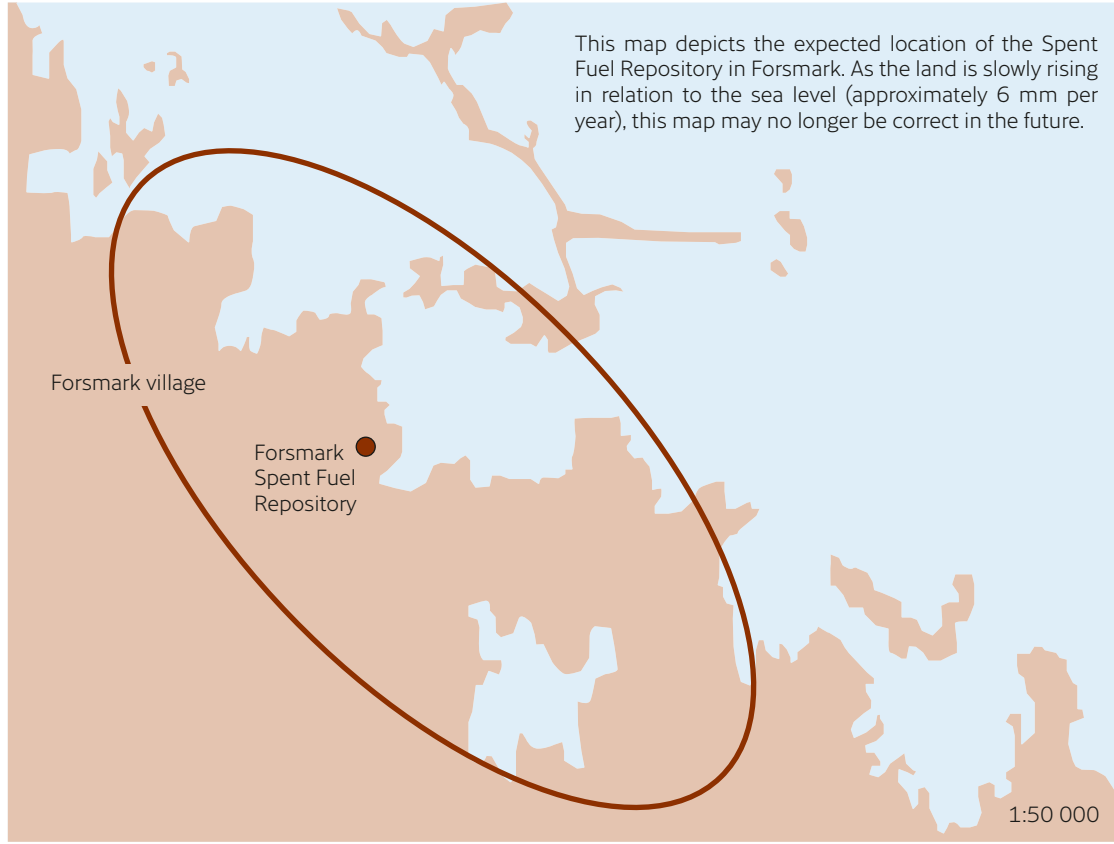


Figure 4. Map of the planned location of the Spent Fuel Repository in Forsmark.

This repository has been designed to keep the spent fuel apart from human activities, and to prevent contact between the spent fuel and water. Nevertheless, there remains numerous risks connected to this Spent Fuel Repository, including:

- **ACCIDENTAL INTRUSION** into the repository caused, for example, by accidental drilling due to construction or research, or intrusion caused accidentally in the event of a war.
- **INTENTIONAL INTRUSION** into the repository caused, for example, by intentional drilling – such as those in search of materials like copper, or due to military attack.
- **TECHNOLOGICAL FAILURE** such as failure to the KBS-3 barriers to contain the radioactivity of the spent nuclear fuel and prevent its spreading into the surrounding clay, water, rock and soil.
- **EXISTENTIAL SOCIETAL CHANGE** since the 100 000 year timeframe of this Spent Fuel Repository means it is likely there will be major societal changes in the future that could entirely change how humans relate to the earth and the contents of this repository. Such future existential social changes might include rapid climate change, world wars and technological revolutions that transforms the value of what today is understood as nuclear waste.

In the light of these risks, it is of critical importance to update this Key Information File and keep it relevant and remembered. In the next section we outline how this Key Information File can be updated and propose the SHIRE method as a potentially fruitful approach.

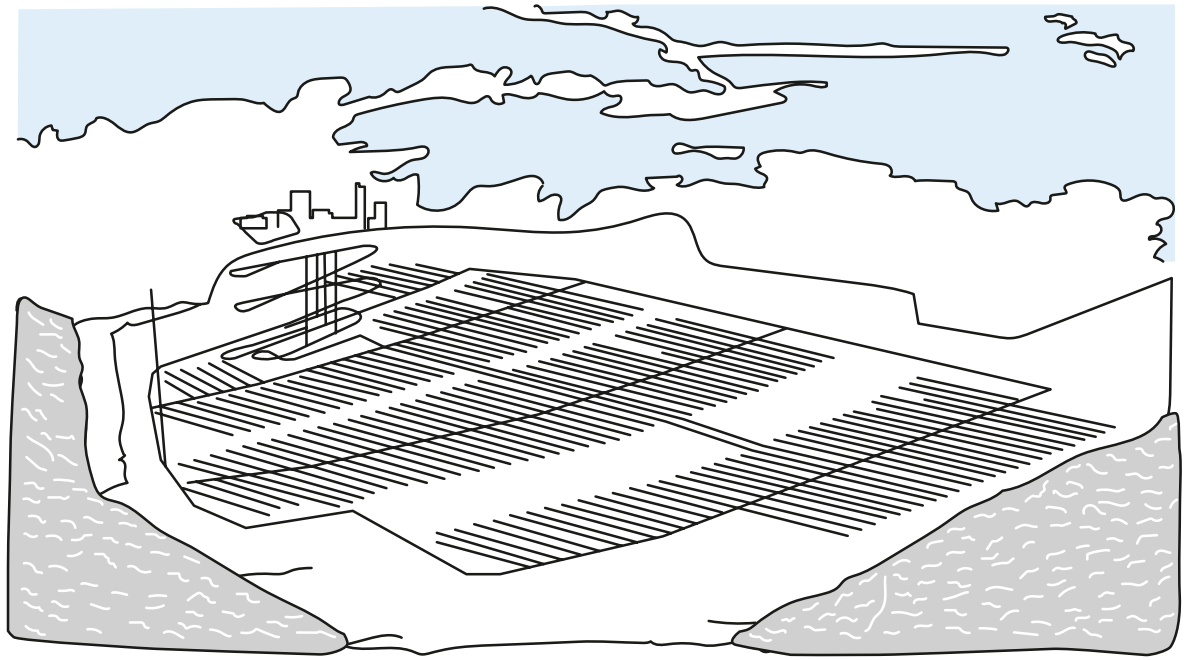


Figure 5. Cross section of the Spent Fuel Repository, illustrating its horizontal scale.

UPDATING THIS KEY INFORMATION FILE

The content, format and media of this Key Information File needs to be regularly reviewed and updated to ensure its survival through time. For the period up until the planned closure of this Spent Fuel Repository, we, the authors, contend this Key Information File should be updated at least every 10 years.

The updates should make sure: (a) that the language is understandable and aligned with contemporary forms of expression; (b) that it is translated into the most commonly used languages in the country or region hosting the Spent Fuel Repository; (c) that the figures, such as maps, photos and signs, are correct in relation to current circumstances; (d) that any changes to the Spent Fuel Repository design are acknowledged; (e) that potential new knowledge about radiation or other relevant issues is incorporated in a way that is understandable to a non-expert reader; and (f) that this Key Information File is available in a contemporary media format (paper, digital etc) that is widely used and is durable with the potential to stay intact through time.

To meet these criteria, it is important that those updating this Key Information File in the future have a background and appropriate experience in a variety of expertise beyond nuclear engineering and the physical sciences. Crucial expertise to draw on in updating this Key Information File includes, but is by no means limited to: archivists, historians, geographers, anthropologists, archaeologists, those in science and technology studies, artists, those in heritage studies, linguists, semioticians, and those in future studies.

At the time of writing, no organisation is formally responsible for updating and safeguarding this Key Information File. The Swedish Nuclear Fuel and Waste Management Company (SKB) has expressed its willingness to continue contributing to this task.

SHIRE METHOD

At the time of writing, no organisation is formally responsible for updating this Key Information File. SKB has expressed its willingness to continue contributing to this task in the future. Given this uncertainty regarding responsibility, we, the authors, encourage you, the reader, to engage in keeping memory of this Key Information File alive into the future. Keeping memory alive means using the SHIRE method where "SHIRE" stands for Share – Imagine – Renew.

The SHIRE method involves your personal role as reader to:

- **SHARE**: Share this document with another person or a group of people.
- **IMAGINE**: Imagine new ways this Key Information File can be kept relevant given the current circumstances. Central here is to ensure that the Key Information File will continue to provide relevant information of this Spent Fuel Repository through time.
- **RENEW**: Take steps to ensure this Key Information File is updated to match current knowledge, contemporary media, and societal organisation. This could mean contacting at least one of SKB, SSM, the Swedish government, or the party currently holding formal responsibility for updating this Key Information File, to make sure they continue to renew the contents of this document.

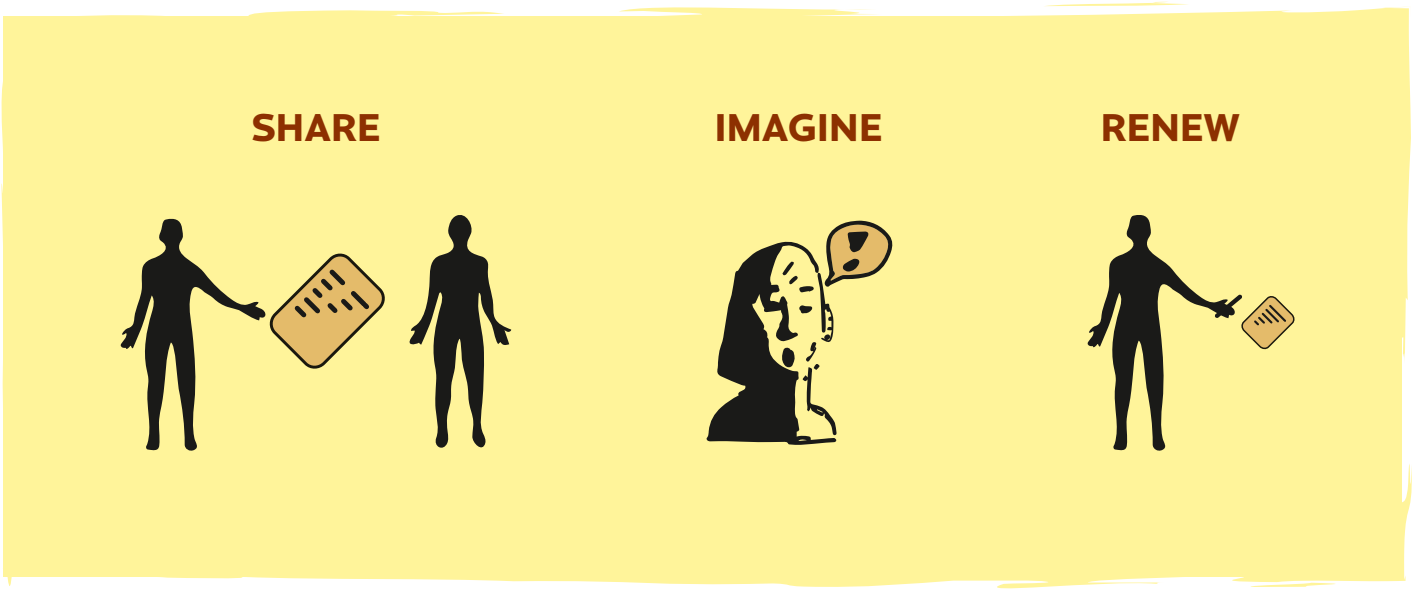


Figure 6. It is of critical importance to keep this Key Information File relevant and remembered. The SHIRE method encourages you, the reader, to share this document with others, and to imagine ways to keep it relevant and remembered.

The purpose of the SHIRE method is to mobilise the capacity of a reader who has come across this document at a time when societal memory of the existence of the Spent Fuel Repository in Forsmark has been lost, or is in danger of becoming lost. The SHIRE method works, therefore, as a memory tool that can be passed onto other authorities and institutions by drawing on the actions of you as the reader here and now.

For this Key Information File to stay relevant, it is critical that those who update this document do not presume that what is deemed important and valuable today will necessarily continue to be important and valuable in the future. Rather, the focus should be on providing a wide variety of essential information in an easily accessible way, with particular emphasis on placing trust in future generations to decide how best to continue updating and communicating this Key Information File.

Those who update this Key Information File should, therefore, maintain an openness to including different kinds of information that future human beings may need to know, including alternative 'uncommon' knowledge that is not necessarily valued or deemed essential at the time of writing.

To ensure that copies of this Key Information File are safely stored and managed through time, it is crucial that this document is reproduced in multiple formats that are stored in multiple locations. Essential sites to store this Key Information File include:

- at the entrances to the Spent Fuel Repository in Forsmark, both above ground and below ground;
- at the organisation constructing the Spent Fuel Repository – SKB;
- at the Swedish Radiation Safety Authority – SSM;
- at the Swedish National Archives, Riksarkivet;
- at the Swedish government.

Other sites for storing this Key Information File should also be considered in addition to these essential sites.

If this Key Information File is not updated and shared at regular intervals, it will not stay understandable, relevant and remembered. If this happens, future generations will not be able to act in an informed way in relation to the potential radioactive hazards posed by the Spent Fuel Repository in Forsmark.

WHERE TO FIND MORE INFORMATION

This Key Information File is one part of a bigger information system about the Spent Fuel Repository in Forsmark. Thus, this Key Information File is supposed to act as a guide to find more extensive and detailed information. SKB is currently storing much of this information and plans to pass this onto a suitable host archive. At the time of writing, the National Archives in Stockholm, Sweden, is discussed a suitable host but this extensive archive has not yet been created.

The extensive and detailed information concerning the Spent Fuel Repository is planned to be organised over two levels.

The first level is the Set of Essential Records (SER), which provides detailed technical information about the Spent Fuel Repository for experts and decision makers. It is to be stored permanently. The SER is managed by SKB until the closure of the repository and is yet to be completed. This detailed information will include, amongst other things: technical descriptions of the design of the underground storage; geological descriptions of the bedrock surrounding the repository; and geological archives including rock samples.

The second level includes other records relevant to the Spent Fuel Repository, comprising of thousands of different documents and archival materials stored temporarily for experts. The preservation period of these records depends on Swedish national regulation and this regulation is yet to be produced.

COORDINATES OF SPENT FUEL REPOSITORIES

- Forsmark, Sweden. Coordinates: 60°24’1.67”N, 18°11’1.58”E – currently under development. Managed by SKB.
- Onkalo, Finland. Coordinates: 61°14’06”N 21°28’56”E / 61.23513°N 21.4821”E – currently under construction. Managed by Posiva.
- Cigeo, France. Coordinates: 48°48’45”N, 5°35’61”E – currently under development. Managed by L’Agence nationale pour la gestion des déchets radioactifs (Andra).

PART III:

PAST, PRESENT, FUTURE

KEY INFORMATION FILE CHALLENGES AND RECOMMENDED RESPONSES

At the time of writing, the Key Information File is a relatively new concept, and there are numerous challenges associated with its ability to inform future generations about the Spent Fuel Repository in Forsmark.

The overarching way to respond to these challenges is to connect the Key Information File to other forms of memory communication in Sweden and internationally. In what follows we, the authors, outline a number of societal challenges associated with this Key Information File, and also suggest some recommended responses.

- **CHALLENGE: LACK OF LEGAL FRAMEWORKS.** Legal and regulatory frameworks are one significant way memory communication of this Spent Fuel Repository can be organised and continued in the future. At the time of writing there are no formal commitments in Sweden concerning memory communication of the repository, or for maintaining this Key Information File. A ***recommended response*** to this challenge is to introduce legal commitments for updating the Key Information File into Swedish law. It is desirable to develop a formalised legal framework in Swedish law for the inheritance and succession planning of future versions of this Key Information File. For instance, this legal commitment could resemble the one written and currently in place in French law.

- **CHALLENGE: DESTRUCTION OR LOSS OF DATA**. Certain technological media protect data better than others. This Key Information File will be printed on archival paper, which stays intact much longer than other types of paper. This Key Information File will also be saved digitally, which is more vulnerable but facilitates a wider readership and distribution. However, any media format risks physical destruction, such as through a fire in an archive or the break-down of digital infrastructures. There is a risk that organisations updating this Key Information File will cease to exist or stop caring for it. There is also a risk of data loss that could occur through: changes in media culture, lack of updates, or purposeful corruption of its contents. A ***recommended response*** to this challenge is to develop social practices. Involving non-experts in the content of this Key Information File improves the accessibility of the essential information in this document. We suggest the challenge of communicating memory of this Spent Fuel Repository might be included in national school curriculums (see Figure 7). Young persons' education, especially, forms a technique of memory communication between generations. As well as education, it is important to allow other cultural organisations to engage with the contents and themes of this Key Information File. This response points to the importance of cultural institutions and community practices. It might include incorporating the information and practice of updating the content of the Key Information File into theatre performance, religious practices and community events, or national events and holidays.

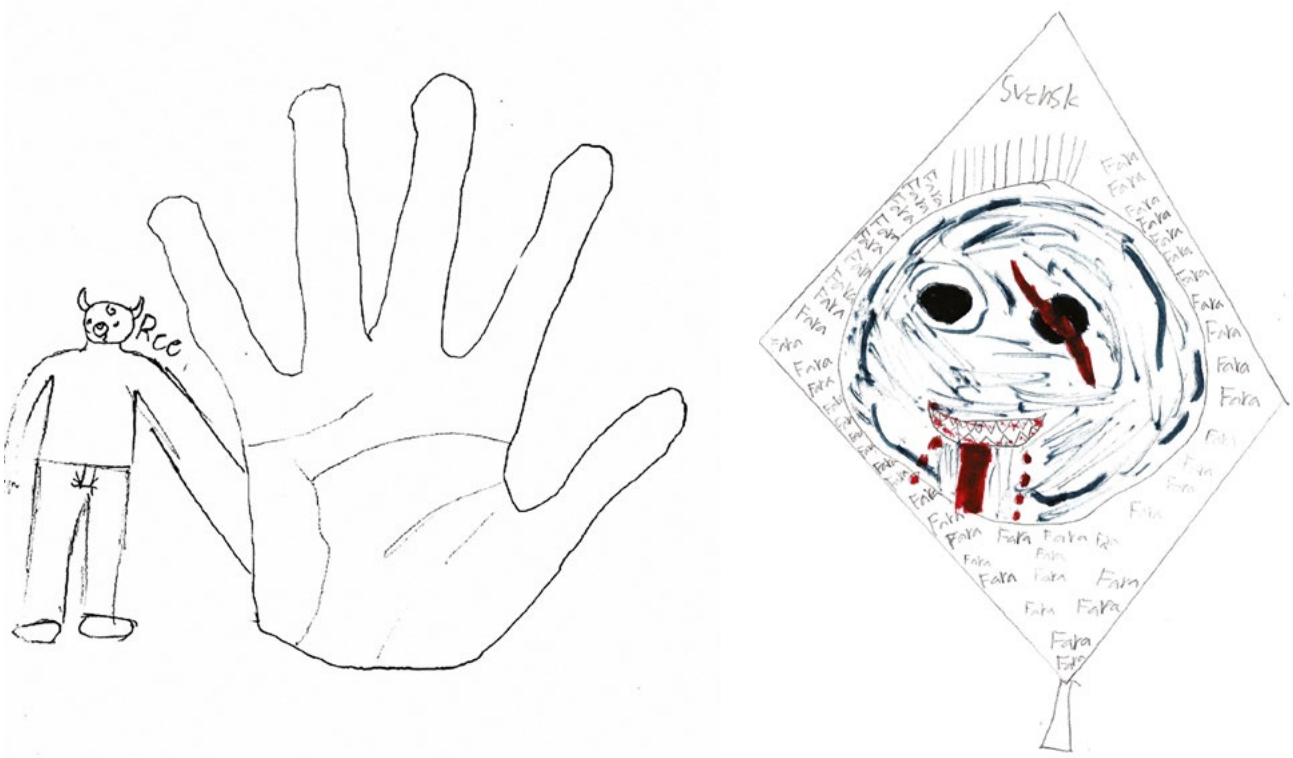


Figure 7. Example of young people engaging in memory communication around the Spent Fuel Repository in Forsmark, here through the Östhammar municipality school drawing competition on warnings for nuclear waste.

Figure 8. Example of social practices of memory communication around the Spent Fuel Repository in Forsmark, here through the theatre play *The Secret of the Copper Box*. Promotional image created by Elin Jonsson.

- **CHALLENGE: LOSS OF SOCIETAL MEMORY.** What societies remember is an outcome of a range of factors. For example, following widespread societal change there is risk that transfer of knowledge between generations and societal organisations is interrupted. Some of the oldest forms of memory in human society have occurred through artwork, mythology, and religion. These old forms of memory relate closely to the human body and to acts of ritual. Questions emerge, therefore, about how this Key Information File might join up to new and/or existing social forms of memory – such as rituals – to increase the likelihood it is remembered in the future. One ***recommended response*** is to employ environmental traces and artwork. Memories are not only communicated by humans. Rather, environments and non-human materials engage in acts of memory communication that is of relevance to this Key Information File. For instance, geological and biological entities preserve traces of the past and provide clues to different events through time. The existence of this Key Information File and its location should, therefore, connect to environmental things. Such environmental things include physical markers situated on the landscape above the Spent Fuel Repository. One ***specific recommendation*** includes a design conceptualised by the artist Gunilla Bandolin: namely, of using rock material excavated from the blasted tunnels of the Spent Fuel Repository to produce a trace, which would speak not only about a human altered landscape, but through the amount and composition of the rock material, also speak specifically about the size and location of an underground void. This trace of the repository could be used as the foundation for additional artworks or semiotic signs. The aim of such environmental traces and artwork is to prevent accidental intrusion into the repository – including through digging or drilling, and to act as a wider trigger for awareness and memory communication about the repository in a non-textual form.

- **CHALLENGE: LACK OF INTERNATIONAL ALIGNMENT.** The Key Information File is conceptualised as an international document, including cross-referencing between Key Information Files of different Spent Fuel Repositories in multiple countries. Today, there is international collaboration on the topic, but not yet any alignment in terms of how to manage information redundancy of Spent Fuel Repositories through international cross-referencing. One ***recommended response*** is to create an international network that focuses on the following items: expert management of the translations of all Key Information Files internationally into a set of agreed languages; conceptual alignment of key terms; standardised intervals for updating; management of how to guide readers between Key Information Files around the world; international alignment regarding best media formats; and advising how Key Information Files can be included in wider international waste management discussions and new nuclear energy project planning in the future.

- **CHALLENGE: LOSS OF EXPERT KNOWLEDGE.** In Sweden, and internationally, there are relatively few people working on memory communication in the context of spent fuel repositories. This lack of capacity poses substantial risks of losing knowledge and/or of failing to update the Key Information File in the future – particularly due to existing experts retiring, due to death, due to professional reorganisation, or due to the possible dissolution of nuclear management organisations like SKB and SSM. This loss of expert knowledge due to institutional reorganisation has recently occurred with both the dissolution of the Swedish Office for Nuclear Waste Review (MKG) in the year 2023, and the dissolution of the Swedish National Council for Nuclear Waste in the year 2022. One ***response*** is to ensure funding: It is strongly recommended to commit some of the financial reserves in the so-called Nuclear Waste Fund, currently managed as a governmental authority, to support future updates of the Key Information File. This funding should address some of the social and technical challenges of nuclear memory communication raised in this document.

- **CHALLENGE: CONCEPTUAL LIMITATIONS INCLUDING COMPETING TIME HORIZONS.** This is a summary document of essential information about a Spent Fuel Repository that does not exist yet. Furthermore, the purpose of this summary document is to help a reader locate a wider archive with more extensive information that does not yet exist. Similarly problematic are the competing time horizons implied by this Key Information File concept – such as the differing imperatives to protect information over 10 years (proposed interval for regular updates), 100 years (the approximate time of the repository closure), and the period of 100 to 100 000 years (between the repository closure and the time it is expected to take for the spent fuel to return to safe levels of radioactivity). Each of these time horizons imply different ways of communicating requiring different institutional, legal, and cultural processes.

- **CHALLENGE: LACK OF A PRECEDENT IN HUMAN HISTORY.** There are no examples in human history of a message being communicated over 100 000 years. There are some examples of messages being communicated over a few thousands of years, but in those cases the message is often: no longer understandable; no longer deemed relevant; or deliberately or accidentally ignored or misinterpreted. This includes, for example, for the Tsunami stones (approximately 600 years), burial sites with human remains such as the Sarcophagus of Eshmunazar II (2 455 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). They share the use of art and aesthetics as a form of communication, an interest in spirituality or religious practices, and a sense of warning or foreboding about the future. At the time of writing widespread religious texts – such as the Rigveda, Torah, Bible, and Quran – have also successfully communicated messages over hundreds and thousands of years. Part of their capacity for being remembered, to give just one reason, is that they connect to human

rituals that ensure the information they contain is repeatedly communicated and interpreted between generations. However, none of these examples serve as obvious correlates for communicating into the future the kind of information essential to the Spent Fuel Repository in Forsmark. Indeed, the lack of a similar example reveals the clear fragility of this information, and the need to create other supports to keep this Key Information File updated and relevant in the future.

Acknowledging these challenges and limitations, and possible ways to respond to those issues, it should be noted that this Key Information File is being written at a specific moment in time. Significant context to this Key Information File includes the 2022 decision to approve the construction of the Spent Fuel Repository in Forsmark, Sweden, followed almost at the same time by an upsurge in support for nuclear energy production in Europe and North America due to various geopolitical and environmental changes. This context means that this Key Information File inherits some of these situated events – events that should be acknowledged to inform how this Key Information File becomes updated in the future.

HISTORICAL BACKGROUND OF THIS SPENT FUEL REPOSITORY

In the 20th and 21st centuries, the energy production in nuclear power plants in Sweden occurred largely at four sites: Ringhals, Barsebäck, Oskarshamn and Forsmark. The uranium used to produce energy was mined to a small extent in Sweden, but mainly in other countries like Australia, Russia and Canada. Initially, the nuclear energy program was linked to Sweden's military program. Nuclear power plants are but one of several different ways that society currently produces electricity. During the time of writing, electricity is also produced by other means – for example by utilising sun, wind, and hydropower.

When the nuclear fuel stops producing enough heat to create electricity it is considered waste. When the waste spent fuel is removed from the reactor, it is highly radioactive and very hot. Therefore, the spent fuel is put into water-filled pools to cool down for at least nine months. Often the waste will remain in a water pool for a number of years. Whilst remaining in the pool, the radioactivity of the spent fuel declines. However, even after losing much radioactivity, the spent fuel continues to be highly dangerous to organic life.

After this initial cooling, the spent fuel is transported by ship to an interim storage in Oskarshamn, Sweden, called Clab or Central Interim Storage Facility for Spent Nuclear Fuel. Here the spent fuel is stored again in a water pool around 30 metres underground. After about 30 years, the spent fuel is planned to be transported by ship to the Spent Fuel Repository in Forsmark.

The decision to approve the design of the Spent Fuel Repository in Forsmark was made by the Swedish government in the year 2022. Yet the question of what to do with Sweden's radioactive waste has been a contested question since the 1970s. Therefore, the process of choosing the site for the Spent Fuel Repository was largely a political procedure. Some places in Sweden supported the idea of storing nuclear waste locally underground, whilst others expressed their discontent about potentially hosting a nuclear waste repository.

In 1992 SKB asked all Swedish municipalities if they were interested in hosting an underground nuclear waste storage facility. Both Oskarshamn and Östhammar emerged as likely places. Many scientif-

ic investigations were then performed to determine the best technological design for the Spent Fuel Repository and its compatibility with the bedrock and landscape characteristics. Forsmark, in Östhammar, was eventually chosen and confirmed by the Swedish government as the site for the Spent Fuel Repository.

One reason was technical. According to SKB, there are certain technical safety features associated with Forsmark, including favourable geological, fluvial and chemical conditions in the bedrock at the repository depth. These favourable conditions include the presence of granite bedrock with low seismic activity, low frequency of fractures, and water salinity that would ensure stability of the bentonite clay barrier within the selected area at Forsmark.

Another reason for choosing Forsmark in Östhammar was social. Forsmark already had nuclear power infrastructure and residents with social connections to nuclear energy industry. These social connections led to a sense of collective support for the spent fuel repository plan.

The technology that is planned to be used to bury the nuclear waste is called KBS-3, which stands for Kärnbränslesäkerhet 3 or Nuclear Fuel Safety version 3. The design was developed during the 20th century by SKB. The funding came from the Swedish Nuclear Waste Fund, based on annual fees paid by the nuclear energy companies and monitored by the Swedish National Dept Office.

During the development of the KBS-3 design there was disagreement within Sweden about three main things. First, there was disagreement about if the KBS-3 design was the best alternative compared to other possible storage techniques – such as, for example, bore holes reaching very deep below ground. Second, there was disagreement about where the Spent Fuel Repository should be built. This disagreement concerned which type of bedrock was most suitable for underground storage and whether or not the people living near the site would support this plan. Third, there was disagreement about whether the different barriers of the KBS-3 design would stay intact across 100 000 years. One key issue concerned whether or not the copper canisters would avoid corrosion from the groundwater that flows through bedrock in Sweden.

After around 40 years of discussions and investigations, KBS-3 was deemed to be safe for the

required time period of 100 000 years. Safety was documented by SKB, reviewed by national and international experts before a statement from SSM supported a government approval.

The chosen KBS-3 design of the Spent Fuel Repository in Forsmark can be understood in terms of two key design principles.

First is the principle of passive safety that describes how KBS-3 is supposed to function without human intervention and without active input of materials or energy. The aim of passive safety is so that the spent fuel can be left underground without the need for continual human monitoring of the nuclear waste after the Spent Fuel Repository in Forsmark is sealed. Therefore, no checks will be carried out on the integrity of the copper canisters for potential leakages of radioactive particles into the groundwater or into the air, or for the potential movement of the bedrock surrounding the underground repository. One reason for this design decision is to avoid the enormous economic and political burden on future society of continual monitoring over 100 000 years. Yet, a lack of monitoring leaves open the possibility of a problem going undetected in the future.

Second is the question of retrievability. Retrievability refers to a technological ability for future generations to re-open the repository to once again access the spent nuclear fuel. One of the motivations behind a retrievability option is that it remains open to innovations in the future that might be able to harvest more energy from the spent fuel. However, the KBS-3 technology used in the Spent Fuel Repository in Forsmark is designed to never be re-opened after closure. Non-retrievability is perceived by SKB as a way to avoid passing on the burden of nuclear waste management to future generations. Hence, whilst it is not technically impossible for future generations to retrieve the radioactive spent fuel materials from the Spent Fuel Repository in Forsmark, it will be potentially resource-intensive and costly.

Nuclear power plants produce different types of radioactive waste. The types differ depending on the level of radiation they emit (low, intermediate, high) and in relation to how long they will be radioactive (short-lived, long-lived). The spent nuclear fuel is the most dangerous type as it is both high-level and long-lived. Nevertheless, less dangerous radioactive waste also needs to be kept apart from humans and other living organisms for specific periods of time.

Indeed, next to the planned Spent Fuel Repository there is a Final Repository for Short-Lived Radioactive Waste (SFR) built in the 1980s and, at the time of writing, being expanded to be able to store additional amounts of nuclear waste. SFR consists of blasted tunnels and caverns 60 metres below the Baltic Sea seabed.

ORIGIN OF THIS KEY INFORMATION FILE

The concept of the Key Information File is an outcome of an international collaboration between authorities, companies, and organisations involved in the management of spent nuclear fuel. Principally, this includes Key Information File concept reports written within the framework of the Preservation of Records, Knowledge and Memory (RK&M) Across Generations initiative, later succeeded by the Expert Group on Awareness Preservation (EGAP), under the Nuclear Energy Agency (NEA) and the Organisation for Economic Co-operation and Development (OECD).

This Key Information File text was originally written by researchers Thomas Keating and Anna Storm of Linköping University, Sweden, within a project commissioned by SKB. This project benefited from generous input from academic, artistic, industrial and civil society expertise as well from the local community in Östhammar and non-experts in other parts of Sweden, through interviews, review comments, workshops and other kinds of interaction.

APPENDIX

Possibly to be included in future versions of this Key Information File: list of figures; map of the location of this Key Information File stored nationally and internationally including detail about the number of copies, format, and responsible institutions; map of the location of the SER relative to the Spent Fuel Repository in Forsmark, Sweden.

LIST OF ABBREVIATIONS

Andra: L'Agence nationale pour la gestion des déchets radioactifs, or the French National Agency for Radioactive Waste Management.

Clab: Central Interim Storage Facility for Spent Nuclear Fuel in Oskarshamn.

EGAP: Expert Group on Awareness Preservation within the Nuclear Energy Agency & Organisation for Economic Co-operation and Development.

MKG: The Swedish Non-Governmental Organisation Office for Nuclear Waste Review.

NEA: Nuclear Energy Agency.

OECD: Organisation for Economic Co-operation and Development.

SER: Set of Essential Records archive containing detailed information on the Swedish Spent Fuel Repository.

SFR: Final Repository for Short-Lived Radioactive Waste in Forsmark.

SKB: Svensk Kärnbränslehantering AB, or the Swedish Nuclear Fuel and Waste Management Company.

SHIRE: Share, Imagine, Renew method for updating this Key Information File.

SSM: Strålsäkerhetsmyndigheten, or the Swedish Radiation Safety Authority.

RK&M: Preservation of Records, Knowledge and Memory, project within Nuclear Energy Agency & Organisation for Economic Co-operation and Development.

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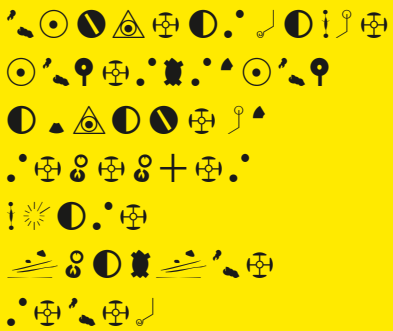

At the time of writing, year 2025, no organisation is formally responsible for updating and safeguarding this Key Information File. The Swedish Nuclear Fuel and Waste Management Company (SKB) has expressed its willingness to continue contributing to this task.