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Monitoring in Geological Disposal & Public Participation:

A Stakeholder Guide

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and Anne Bergmans

MONITORING IN GEOLOGICAL DISPOSAL & PUBLIC PARTICIPATION:

A STAKEHOLDER GUIDE

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CONTENTS

INTRODUCTION

INTRODUCING THE 'WHAT' AND 'WHY' OF THIS GUIDE

Welcome to the stakeholder guide to monitoring in geological disposal and public participation. Today, a growing number of countries across the world are developing and implementing plans to store their high-level and long-lived radioactive waste and spent fuel from nuclear power plants deeply underground. This process is called geological disposal, a huge project that entails various technological and societal challenges. This guide aims to introduce the process of geological disposal and some of its challenges to a broader audience.

After introducing **geological disposal** in general (Chapter I), we will take a closer look at two dimensions that might be of interest to those involved in similar projects in their local area: monitoring and public participation. **Monitoring** (Chapter II) concerns the installation of sensors in and around the underground disposal facilities so that scientists and society as a whole can monitor (for a period of time) whether everything is progressing as expected. **Public participation** (Chapter III) refers to the processes of dialogue and communication between those who are building the underground installations, often called 'repositories', and societal stakeholders, such as political decision-makers and citizens living near the repositories.

This stakeholder guide was written as part of the **Modern2020 research project**[1], which brought together scientific experts and local citizens from Belgium, Finland, France and Sweden to think about these issues together (see below for more information about the project). The guide has **two aims**. Firstly, it presents the **state of the art of monitoring technologies and strategies** for high-level nuclear waste repositories in an accessible way. Secondly, it is intended to serve as **a source of inspiration for local stakeholders** who are involved in the decision-making process regarding nuclear waste management.

By introducing monitoring in geological disposal as a SOCIOTECHNICAL CHALLENGE and reflecting on the what, how and why of public participation processes, this guide hopes to provide the reader with helpful insights and tools for reflecting on and discussing nuclear waste management, geological disposal and monitoring. The target audience for this guide is diverse and includes journalists, policy-makers in the field of nuclear waste management, NGOs and interested citizens who already have some basic knowledge of nuclear power and the management of radioactive waste.

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1 ~ Online: www.modern2020.eu

HOW WAS IT MADE?

The two aims of this stakeholder guide stem from the fact that it was informed not only by scientific work, but also by the experiences of local citizen stakeholders. The guide was developed in collaboration with some of the Modern2020 partners. We gathered their input through participatory workshops, discussions with an editorial board consisting of experts and public stakeholders, and written feedback on earlier drafts of this guide. This document is thus the result of **an interactive and iterative process** which brings together various perspectives on monitoring in the context of the geological disposal of high-level nuclear waste.

SOCIOTECHNICAL THINKING

How does technology influence your day-to-day life? Do you think managing and disposing of radioactive waste is a purely technical issue?

The development of technology both affects and is affected by our social lives. For instance, the emergence of social media has brought about new patterns of communication between people. This is not just the case for social media, but for a range of other technologies. Yet, we often think of technology as being in a 'sphere of its own', separate from our 'social lives'. Over the last few decades, social scientists have argued that we must study both **the social foundations of technology** and its **social implications.** Sociologists, anthropologists, philosophers and many others have developed theories which help us do just that. One key outcome of this work, broadly speaking, is **Socio-Technical Theory**. This theory offers a framework for understanding the 'social' and the 'technical' in relation to each other.

This may sound abstract, so let's take a specific example of the theory's relevance to nuclear waste management.

It's clear that **plans to develop monitoring technologies for geological disposal sites vary significantly from country to country:** some countries are planning to implement extensive monitoring, but others are not. Why is this? A single focus on 'the technical' cannot answer this question – we need to look at 'the social' as well. In fact, when developing monitoring technologies, existing plans for waste management, the needs of local residents, legislation, and so on all have to be taken into account, which explains the variation between countries.

In other words, Socio-Technical Theory can help make it clear why different countries have different ambitions and make different choices when it comes to the future monitoring of nuclear waste repositories. In this guide, Socio-Technical Theory will be an important aspect of our discussions of nuclear waste management, monitoring technologies and public participation.

WHAT IS THE MODERN2020 PROJECT?

Modern2020 is an international, interdisciplinary research project running from June 2015 until June 2019. It builds on the work of the earlier MoDeRn project [2] and was funded by the European Commission via the Euratom research and training programme. Modern2020 brings together scientific experts from Belgium, the Czech Republic, Finland, France, Germany, Italy, Japan, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Its participants include representatives of nuclear waste management organisations, regulators, consultants, academics and local citizen stakeholders, as well as specialists from different scientific disciplines like engineering, geology, nuclear physics and social sciences.

The main idea behind the project is that monitoring has the potential to respond to **technical and societal needs** related to the management and disposal of high-level radioactive waste and spent fuel. The project focuses on the research, development and demonstration of monitoring strategies and technologies for high-level nuclear waste repositories. It aims to establish common ground for monitoring activities within the EU.

KEY OF THE GUIDE	
	CRITICAL INSIGHTS
	QUESTIONS & EXERCISES
	EXAMPLES

2 ~ Online: www.modern-fp7.eu

STRUCTURE AND CONTENT OF THE STAKEHOLDER GUIDE

CHAPTER I
RADIOACTIVE WASTE AND GEOLOGICAL DISPOSAL: A MATTER OF EXPERT AND PUBLIC CONCERN

The first chapter introduces the problem of nuclear waste, with geological disposal as a possible solution. A description of all the actors involved in nuclear waste management makes it clear that this is a matter of concern for both experts and the public. It is argued that the viewpoints, needs and expertise of these different stakeholders should be included in the various phases of decision-making when building geological repositories for radioactive waste.

CHAPTER II
MONITORING IN GEOLOGICAL DISPOSAL

The second chapter starts with an overview of the different types and strategies for monitoring geological disposal sites. We also discuss views on why, how and to what extent waste repositories should be monitored. Lastly, a selection of state-of-the-art monitoring technologies are presented.

CHAPTER III
PUBLIC PARTICIPATION IN MONITORING R&D. HOW TO ENGAGE PEOPLE?

The last chapter draws on the real-life experiences of citizen stakeholders involved in the Modern2020 project to reflect on why and how the public can participate in different types of technology development. As we identify and explore a variety of strategies and methods for public stakeholder involvement and dialogue in the research and development (R&D) of monitoring geological disposal, readers are offered some concrete tools to help them engage reflexively in similar participation processes themselves.

CHAPTER I

RADIOACTIVE WASTE AND GEOLOGICAL DISPOSAL: AN EXPERT AND PUBLIC MATTER OF CONCERN

THE 'WHAT' AND 'WHY' OF RADIOACTIVE WASTE [I, II, III]

Radioactivity occurs at the level of the **atomic nucleus**. Most atoms are stable, and their nuclei do not change. However, some atomic nuclei do tend to undergo a certain amount of change spontaneously in the search for a new and better state of stability. During this process, excess energy is released as **ionising radiation** in the form of **particles or waves** which cannot be felt, seen, smelled or tasted. It is this phenomenon which we call radioactivity. The best-known forms of ionising radiation are **alpha, beta and gamma radiation**, which have quite different characteristics. An important portion of this ionising radiation is naturally occurring background radiation, which comes from the things all around us: the air, soil and rock, cosmic radiation, water, plants, building materials, and so on. As such, human beings are continually exposed to a certain amount of ionising radiation. However, radioactivity can also be **induced artificially by human activities**, such as during the production of energy in nuclear power stations or the use of radioactive material in the medical, agricultural and industrial sectors.

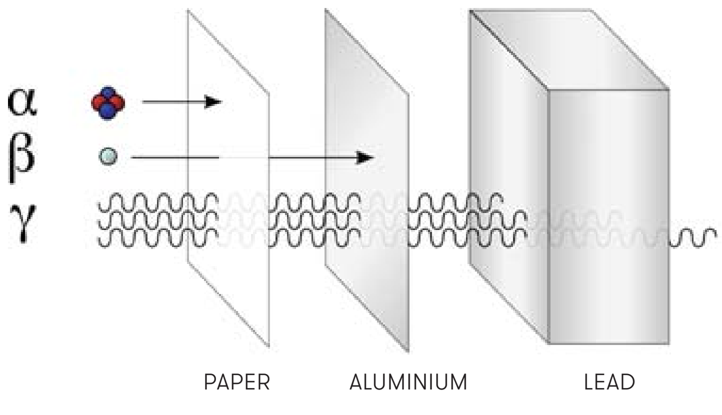


Figure 1 - The penetration power of three types of radiation

These processes often generate **waste as a by-product.** Materials that have no further use and that are contaminated by radioactivity above the levels defined in national, international and European legislation are classed as radioactive waste. However, some radioactive substances or objects are not classified as waste since they may serve a useful purpose in the future. The reprocessing of spent nuclear fuel, for example, can help us recover uranium and plutonium which is useful for producing new fuel.

Radioactive waste is **classified into different types**. The main criteria used in this classification are the **activity level** of the waste and its **half-life**, which is the time it takes for half of the radioactivity in the waste to disappear. This time can range from milliseconds to thousands or even millions of years.

The CATEGORIES used for radioactive waste depend on national legislation and thus differ from country to country[IV].

Exposure to a certain dose of radioactivity can be **harmful for living beings**, since energy-dense radiation can cause changes in the matter it passes through.

Affected cells can die off or multiply in modified forms at abnormally high speeds, which may lead to the development of cancer. The seriousness of the health risks linked to radioactivity exposure depend on the **duration** of the exposure as well as on the **intensity** and the nature of the radiation.

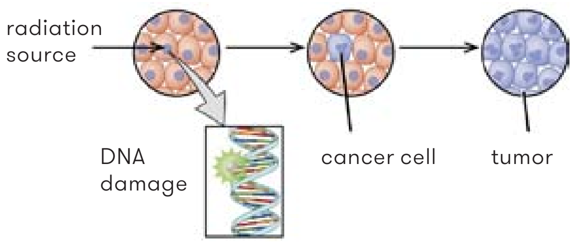


Figure 2 - Illustration of how radioactivity can be harmful to living beings

Until the radioactivity in nuclear waste decreases to a level which is acceptable for public health, we have to be rigorous in ensuring that the ionising radiation cannot cause any harm to human beings or the environment.

This makes it even more important to find a safe, long-term solution for disposing of high-level nuclear waste, which remains dangerously radioactive for between 1000 and 100. 000 years.

DIFFERENT CLASSIFICATIONS OF RADIOACTIVE WASTE

Countries which are member states of the International Atomic Energy Agency (IAEA) base their classification systems for radioactive waste on this agency's **international guidelines,** but they also **adapt them to the local context** before passing them as national laws.

To illustrate this, we briefly compare the **classification systems of France and Belgium:**

In France, there are **6 official categories of nuclear waste:**

1. wastes of very weak activity (TFA)
2. wastes of weak and intermediate activity with a short lifespan (FMA-VC)
3. wastes of weak activity with a long lifespan (FA- VL)
4. wastes of intermediate activity with a long lifespan (MA-VL)
5. wastes of high activity with a long lifespan (HAVL)
6. 'other' waste whose physical and chemical characteristics do not match the other categories

In Belgium, on the other hand, there are only **three categories:**

1. wastes of weak and intermediate activity with a short lifespan (waste-category A)
2. wastes of weak and intermediate activity with a long lifespan (waste-category B)
3. wastes of high activity with a long lifespan (waste-category C)

If you would like to know how radioactive waste is categorised in your country, have a look at the website of your country's nuclear waste management organisation.

WHAT IS GEOLOGICAL DISPOSAL?

Introduction

At the moment, in most countries, high-level nuclear waste is stored in **above-ground interim storage systems.** However, these systems are generally considered to be **temporary and unsatisfactory** solutions due to the unpredictability of human society over long time spans. In comparison to 'above-ground' (biosphere) solutions, **'underground'** (geosphere) solutions are thought to be **more stable and reliable** environments for safely protecting life in the biosphere from radiation. Underground disposal facilities are therefore deemed more appropriate for disposing of waste once and for all.

THE 'SAFETY CASE' OF A GEOLOGICAL DISPOSAL CONCEPT

How can we be sure that underground nuclear waste storage will be safe for at least 100 000 years?

In order to create a 'passively safe' environment in the underground, the long-term safety of the geological disposal system has to be proven in advance. To do this, all possible known scenarios are carefully assessed, as are the relevant materials and infrastructure, and reported in an extensive document called the 'safety case'. The safety case thus contains evidence, analyses and arguments that back up the claim that a disposal facility will be safe after closure. The document is updated periodically throughout the lifetime of the repository, both before and after an operational licence is granted.

Geological disposal has gained currency as a 'technological fix' for the challenge of managing nuclear waste, which has often been described as the Achilles' heel of the nuclear industry [V]. Its appeal lies largely in its ability to keep the dangerous waste in a **'passively safe' environment,** namely in the geological layers of the earth where time runs much slower in the sense that conditions remain very stable over the long term compared to the above-ground environment.

A geological repository aims to isolate waste through **a system of human-made barriers,** which is called the 'engineered barrier system' (EBS), and the **geological barrier** of the host rock. These are both assessed in a SAFETY CASE to make sure that residual radioactive substances can only reach the biosphere when the concentrations have become harmless for life on earth (which takes thousands of years in the case of high-level nuclear waste).

Figure 3 from the Belgian Nuclear Waste Management Organisation (ONDRAF/NIRAS) illustrates the **several safety functions of a geological disposal system** for radioactive waste.

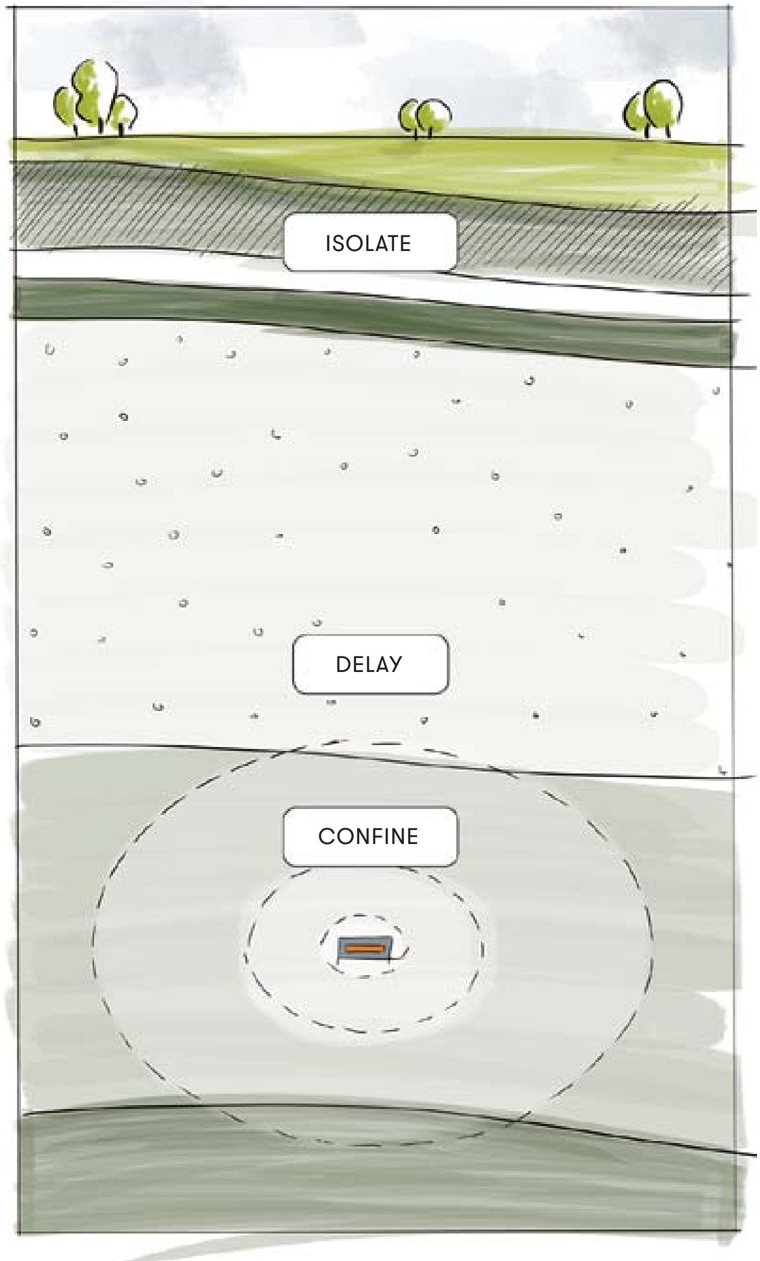


Figure 3 - Safety functions of geological disposal for radioactive waste (Source: ONDRAF/NIRAS)

First, the canisters in which the waste is stored should prevent the release of radionuclides **(contain/confine)**. If these canisters fail, the EBS and the host rock should **delay** the movement of radionuclides. The system as a whole is also located in a deep geological layer to **isolate** it from the earth's surface and make it less accessible.

As pointed out in the introduction to this guide, finding a solution for the safe storage of radioactive waste over a very long period of time is a sociotechnical challenge. As such, disposing of waste in underground repositories can be seen as a **socio-technical project.**

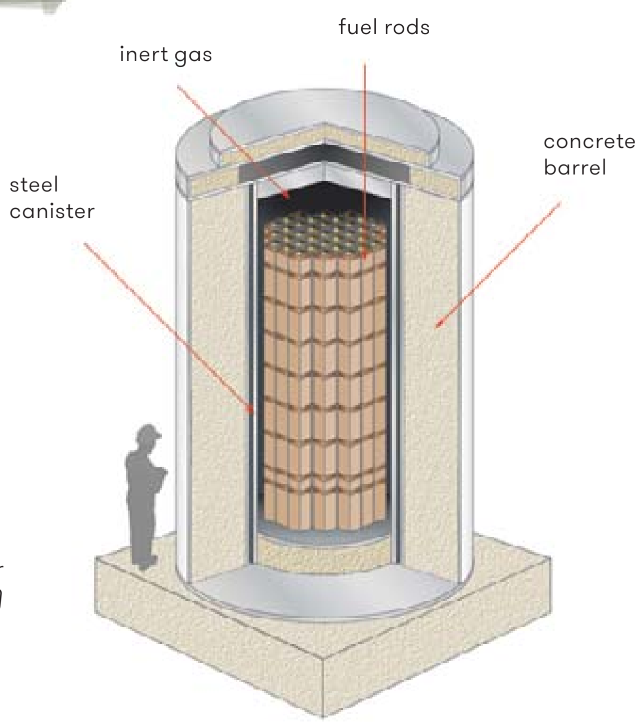


Figure 4 - Example of a canister (Source: Discover Magazine)

Obviously, designing and implementing a geological disposal site requires a lot of fundamental *technical* work, but the process of developing and implementing the repository also includes many decisions that have a strong *social-political* dimension, for instance:

- The disposal site's location
- The different phases of developing and licensing the geological repository
- Questions about whether or not the waste may be retrieved from the repository
- How and for how long the site will be monitored

Decisions like these depend on various things, such as legal regulations, the needs of civil stakeholders and interactions between national and international institutions. For that reason, this chapter discusses both the basic concepts and technical components of geological disposal as well as the broader ETHICAL QUESTIONS, the actors involved and public concern for reversibility, retrievability and safety.

ETHICAL PRINCIPLES IN THE MANAGEMENT OF NUCLEAR WASTE [VI]

The challenges of dealing with radioactive waste raise several ethical questions, such as: How can we ensure the safety of the waste management system in the very long term? Who is responsible for financing and implementing the disposal system? How should we deal with the intergenerational dimensions of this very long-term 'mega-project?'

The Swedish scholar C.R. Bråkenhielm (2015) has identified **four ethical principles** which should be taken into account in the management of high-level nuclear waste and spent nuclear fuel:

The **safety principle** is fundamental to international regulatory frameworks for nuclear waste management and states that a repository for nuclear waste should be able to protect people and the environment from the harmful effects of ionising radiation, both now and in the distant future.

The **responsibility principle** is sometimes also called **'the polluter pays principle'**. It states that those who produce and use electricity (generated in nuclear power plants) should pay for managing and disposing of high-level nuclear waste safely. Because we are the ones profiting from the use of nuclear energy now, we (producers and consumers) should make sure not to pass on the responsibility of dealing with nuclear waste to future generations.

The **principle of intergenerational autonomy** holds that future generations should be able to decide for themselves how to deal with the nuclear waste which is generated today. In a few hundred years, people may have different opinions, knowledge and attitudes about how to solve the waste problem and may want to apply new solutions. This is one of the reasons why reversibility and retrievability (see box p30) are sometimes built into disposal concepts.

The conservation and sustainability principle states that our use of natural resources, with regard to producing and consuming energy and to the construction of nuclear waste repositories, should be as efficient as possible to minimise the burden on the environment. We should aim to reduce, reuse and recycle.

It can be **difficult to combine all these principles in practice.** Following one principle could mean that another one is violated. For example, the responsibility principle states that current generations should be the ones responsible for the financial, managerial, technical and social aspects of dealing with nuclear waste today. But if we develop and implement a certain disposal solution, this may limit the decision-making space of future generations, who according to the principle of autonomy should be able to decide for themselves.

In an extreme case, future generations might choose to leave the waste untreated and out in the open, which may then cause subsequent generations harm. Here, then, the autonomy and safety principles are in conflict.

Despite possible conflicts, we should explore these ethical questions carefully since they are **often the underlying issues at stake in the debate** about nuclear waste. Thinking about what is most important to you may provide you with a kind of anchor in discussions with other actors in nuclear waste management.

A system of galleries underground

The deep geological disposal of high-level radioactive waste means building **a system of galleries and caverns** several hundred metres under the earth's surface in a suitable host rock. This carved-out system of galleries in which canisters containing the waste are stored is often **backfilled with bentonite,** a type of clay.

Experts generally consider **three types of host rock** suitable for geological disposal:

- Salt
- Clay
- Granite

All countries in the EU have at least one of these types of rock at their disposal, though not necessarily in the quantities or quality needed to use it as a host rock for a repository. This is important, because all EU countries are advised to take care of their own waste inventories [VII] .

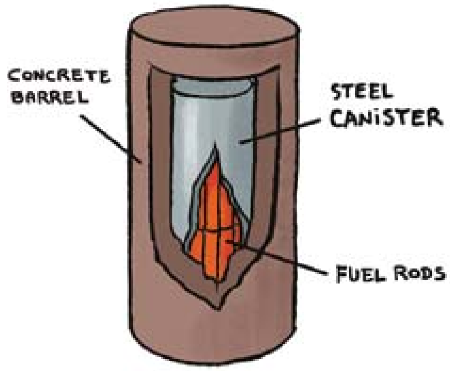
Different host rocks – different repository concepts

The canisters which the waste is placed in before it is stored in the repository are designed in such a way that they match the EBS and the host rock, so that the combination of host rock (geology), canisters and the buffer, backfill and seals (EBS system) form a safe barrier to prevent radionuclide releases and the contamination of the human environment.

Different disposal systems rely on the **shielding and retaining capacities of their host rocks** to different extents. **Clay** layers, which are available in Belgium and France, for instance, are known for being good geological barriers. Like clay, **rock salt** is also good at enclosing and retain radionuclides. Suitable rock salt formations are found in Germany, for example, where adapted repository concepts have been developed. Nuclear waste management organisations which develop geological disposal systems in clay or salt geologies rely on their strong natural containment capacities.

Granite, on the other hand, which is used as a host rock in Sweden and Finland, **lacks such capacities**. In those cases, granite geology is mainly seen as a barrier for protecting the geological disposal system against

human intrusion and keeping the waste far away from the biosphere, rather than for containing radionuclides. In Swedish and Finnish systems, radionuclide containment is **guaranteed by the KBS3V canister**. This canister consists of iron and copper coatings supported by a bentonite buffer. According to SKB (Sweden) and Posiva (Finland), the countries' nuclear waste management organisations and operators of the repositories, the integrity of the canisters can be guaranteed for 100 000 years. After this period, the process of radioactive decay will have made sure that the radioactive substances have become harmless for humans and the environment.



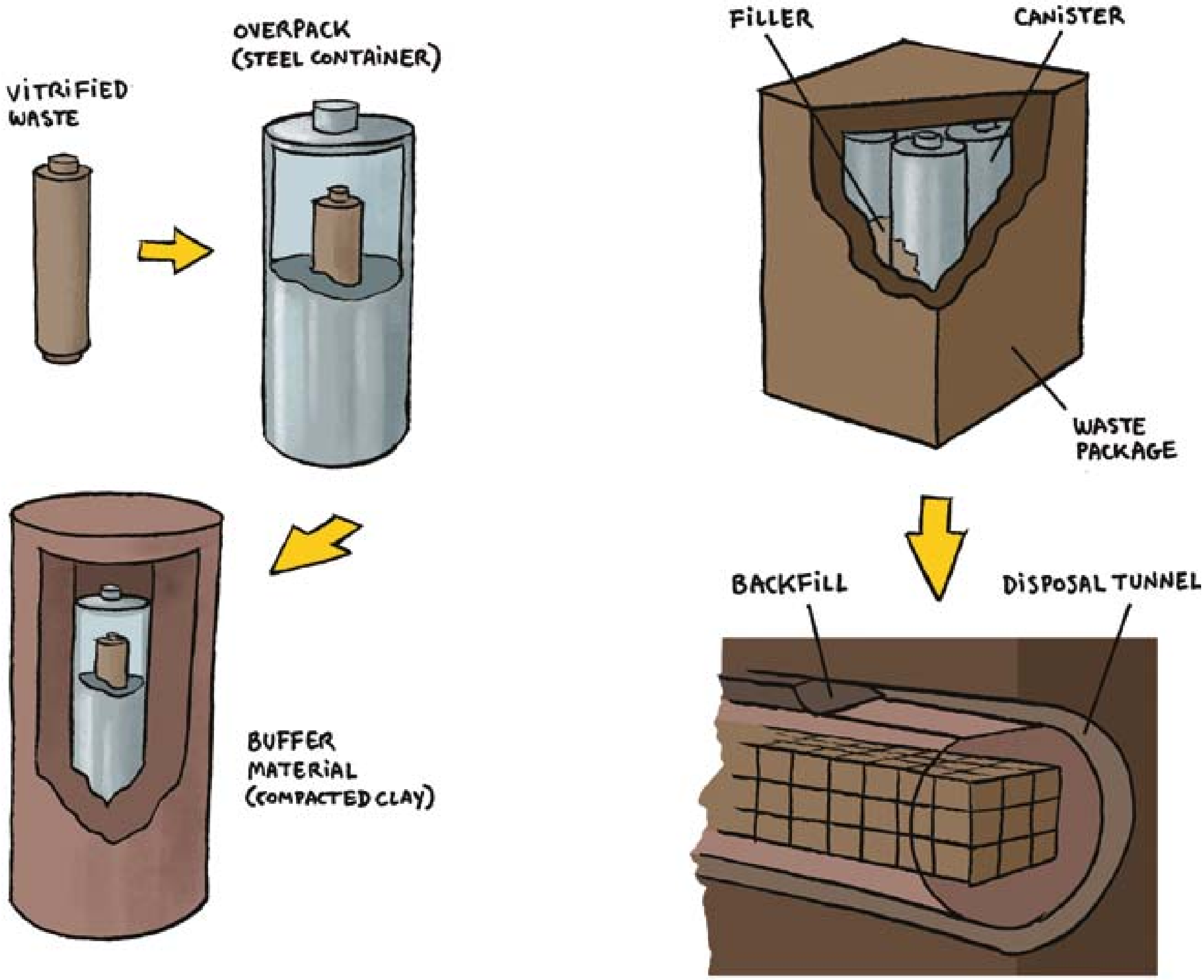


Figure 5 - Some of the techniques for producing storable waste canisters.

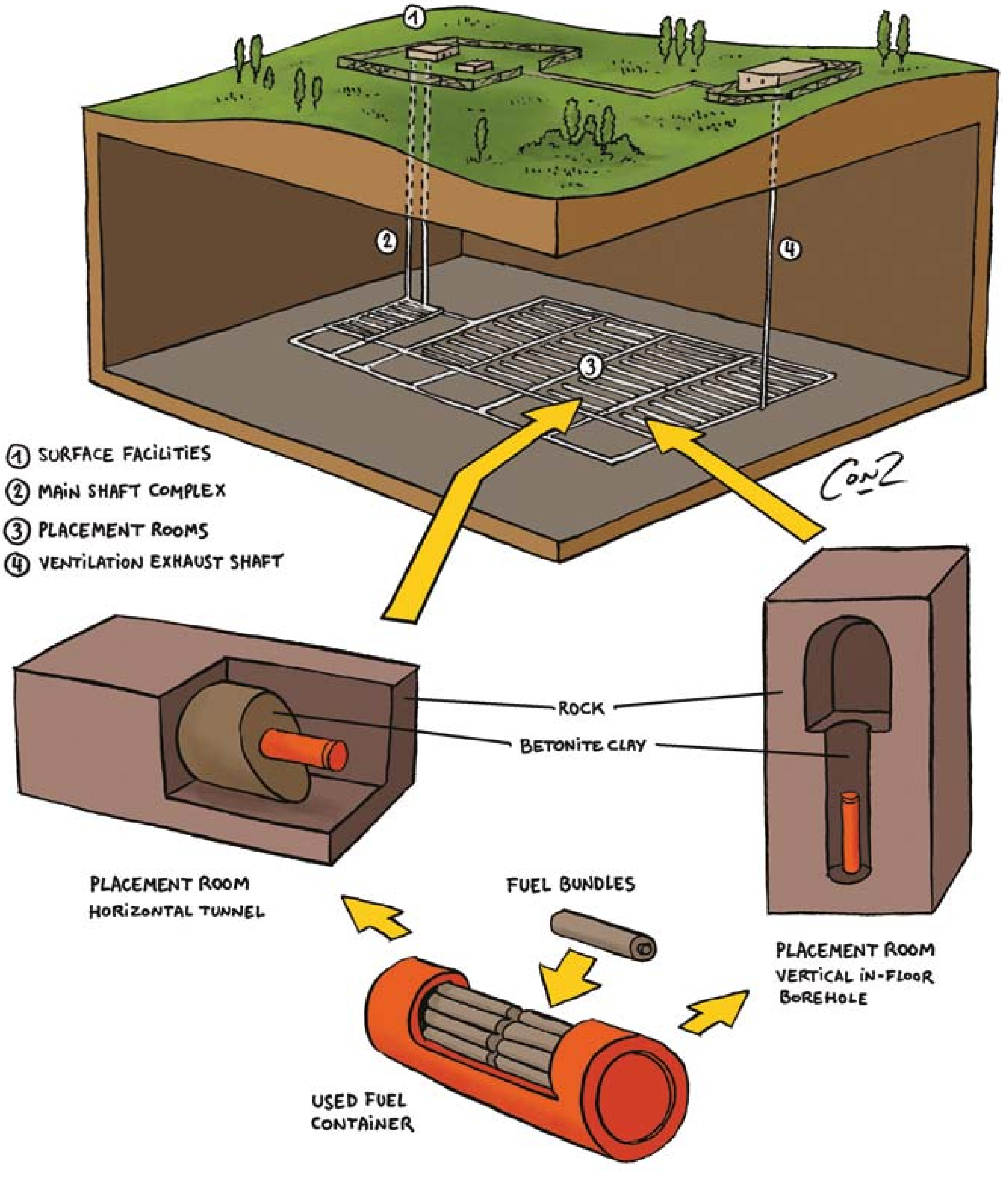


Figure 6 - Generic illustration of a geological repository for nuclear waste and some of the techniques for producing storable waste canisters.

KEY ACTORS IN NUCLEAR WASTE MANAGEMENT

Licensing and implementing an underground repository is a complex process which largely depends on the agreements of decision-makers at national and, for many issues, local level, including the representatives of various stakeholder groups (see box: WHO IS THE PUBLIC?).

One of the main actors in a geological disposal system is the **nuclear industry** that produced the radioactive waste we are talking about, since the costs of storing nuclear waste geologically are largely covered by nuclear power plant operators and energy consumers. This idea is regulated by the **polluter pays principle,** which exists in most nuclear nations (see box p18: ETHICAL PRINCIPLES).

Nuclear waste management organisations, which are responsible for designing, building and operating future repositories, are planned to be funded by the nuclear industry according to the same polluter pays principle.

Geological disposal programmes are operated by these nuclear waste management organisations and supervised by national nuclear regulation authorities, often referred to simply as 'regulators'. **Regulators** watch over operations under government-issued nuclear and radiation protection laws, environmental laws and other related principles, and are responsible for issuing licences for the construction and operation of geological disposal facilities.

Some of the laws regulators use are based on **guidelines drawn up by intergovernmental**

WHO IS THE PUBLIC? ON THE CRITERION OF REPRESENTATIVENESS [VIII] .

When involving civil stakeholders in science and technology policy through public participation efforts, the **question of who to include** arises. Some authors argue for the **'criterion of representativeness',** according to which public participants should be a broadly representative sample of the group affected.

This principle emphasises the **inclusion of poorer and marginalised societal groups** in the participation process, so that the self-interested and unrepresentative elite does not intensify existing tendencies to place high-risk projects in **'peripheral communities'.** But representativeness is also about the distribution of views within the groups involved, so that it is not only the majority who are represented. Even though there are problems with achieving representativeness in practice – for example, **how can we include 'hard to reach' communities?** – a representative public participation exercise increases credibility among decision-makers.

organisations such as the IAEA (UN organisation) and the NEA (OECD agency), which both support their member states in building their technical capacity for their nuclear programmes, including for the management and disposal of radioactive waste.

In some countries, regulators and nuclear waste management organisations may consult expert institutions such as **technical support organisations**, like the IRSN in France and Bel V in Belgium, or experts from research entities, such as the SCK-CEN in Belgium.

Lastly, **NGOs** and **local participation groups** have also become important actors in the nuclear waste decision-making process, especially since the recent PARTICIPATORY TURN in nuclear waste management. Because a certain degree of societal support is necessary when developing and implementing solutions to the radioactive waste problem, it is essential that concerned citizens (whether or not they belong to an institutionalised participatory organisation) are meaningfully involved in the nuclear waste management processes.

THE 'PARTICIPATORY TURN' [IX]

For decades, nuclear waste management was considered a matter for technical experts only. Over time, people began to see this arrangement as **technocratic and undemocratic.** During the 1970s, 80s and 90s, there was a lot of local resistance and political conflict about nuclear power and its waste. The 'participatory turn' refers to a point in time in **the late 1990s** when it became clear that a sole focus on technical issues would not solve the waste problem: public opposition was simply too strong.

As a result of this movement, citizen representatives, whether local or not, are now increasingly invited to be part of the nuclear waste management processes. **Local public participation initiatives** are often set up in the early stages so that local stakeholders can express their concerns and put forward their own ideas before all the decisions have been made.

Exactly how to achieve public participation remains a difficult issue, as **some questions** cannot be answered hypothetically but need to be resolved within a specific context, such as:

- What should the role of non-technical stakeholders be in deciding where and how to dispose of the waste?
- What type of influence should non-technical stakeholders have over the technological concepts in nuclear waste management?
- How much influence should the technical experts have?

So, while there has been a 'turn' towards public participation in nuclear waste management, the issues above continue to create discussion about the place and role of non-technical citizen stakeholders

Figure 7 - Illustration of the main actors involved in nuclear waste management

DECISION-MAKING PHASES IN NUCLEAR WASTE MANAGEMENT

The international expert community considers the geological disposal of high-level nuclear waste a **phased procedure,** meaning it is divided into different phases or steps. Each phase lasts for several years and satisfactory results have to be provided before authorisation is given to move onto the next phase. In this guide, the phases appear to follow each other in a rather linear fashion, but in reality there is often quite some overlap and the occurrence of setbacks is the rule rather than the exception. **Public participation** is viewed by most EU countries as **indispensable in various phases** of this lengthy procedure. According to the NEA, the advantage of the phased process lies in the opportunities it creates to continuously collect scientific information at and around the disposal site, with the aim of arriving at a better understanding of the site and its behaviour. During several phases of the process, nuclear waste managers have to provide proof through DEMONSTRATORS that the geological disposal concept is actually working.

THE WORK OF THE 'DEMONSTRATORS'

Demonstrators, which simulate parts of a geological disposal facility at real (or close to real) scale, are an essential step in the development process for such facilities. They serve **different purposes:**

1. **upscaling of scientific work from the lab,** e.g. by monitoring the test set-up and comparing it with the predicted behaviour;
2. **development of operational aspects** (e.g. installation procedures for waste forms, backfilling, etc.);
3. **technical development,** such as the reliability of monitoring equipment.

As such, a demonstrator might also be a requirement **imposed by the regulator** as part of a licensing procedure. The monitoring activities related to a demonstrator offer several **opportunities for citizen stakeholders** to become engaged in the development and decision-making processes related to geological disposal.

Constructing and operating a demonstrator means there is a **tangible environment** in which to present a facility, and this can help to increase the **transparency** of the whole development process. A typical demonstrator covers aspects that range from specialised areas like monitoring technology through to the decision-making process based on monitoring input. Getting a closer look at monitoring technologies allows citizen stakeholders to appreciate the potential of different sensor technologies in the (often harsh) environment. This way they can develop **realistic expectations** about sensor performance and recommend, where needed, the R&D necessary to increase measurement capacities.

Below, we briefly present the **major phases of repository development**, roughly following the NEA's definition [X] .

CONCEPTUAL & TECHNICAL DEVELOPMENT	• National 'decision-in-principle' on geological disposal as the country's preferred solution for disposing of nuclear waste • Investigation of potential host rocks (salt, clay and granite) in dedicated underground research laboratories (URLs) in order to test the conditions for disposal.
SITE-SCREENING	• The search for a suitable repository site, taking into account the geology, the repository system that the nuclear waste management organisation prefers and public approval, especially among citizens living close to a potential site.
SURFACE AND IN-SITU CHARACTERI-ZATION STUDIES	• In-depth investigation of the potential sites selected in the previous phase. • Scientific studies of the sites' surface environment and geology. • The local population is increasingly informed and consulted by the nuclear waste management organisation so as to get a view on their requirements for the repository. • The construction and operation of a pilot facility (or "on- site underground research laboratory") could also be a part of this phase.
SELECTION OF A SITE	• Based on the results of the in-depth characterisation studies and the participation procedures, a SITE IS CHOSEN for the repository. • The nuclear waste manager provides a safety case for the geological disposal site, 'proving' that the repository's state of passive safety can be achieved.
OBTAINING A CONSTRUCTION AND OPERATIO-NAL LICENSE	• The operator needs to obtain both a construction licence and an operational licence in order to start construction and operation at the site. • The regulating authorities work with nuclear waste management organisations to issue frameworks containing extensive technical requirements for obtaining licences. • This licensing process is also related to political decision-making and negotiations with local citizen stakeholders. Citizens' ability to influence these processes differs from country to country.

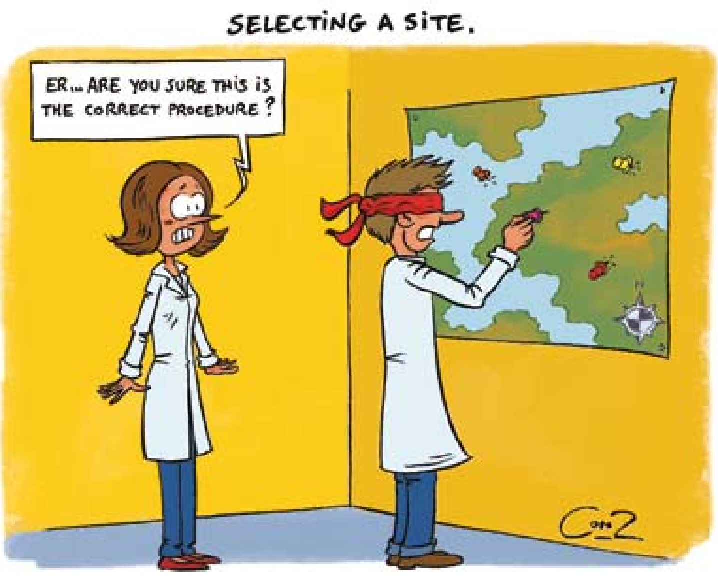
CONSTRUCTION AND OPERATION (WASTE EMPLACEMENT) OF AN UN-DERGROUND FACILITY	• •	The ‘operational’ phase of the repository includes both the construction of the facility and the placement of the nuclear waste in its tunnels, which are then backfilled. This phase is considered to take around 100 years in most disposal concepts.
CLOSURE: SEALING OF ALL ACCESS	• •	If the repository functions as expected during an appropriate observation phase, defined by national legislation, the repository can and should be closed. A political decision is then taken to backfill all underground facilities.
DISMANTLING OF SURFACE INSTALLATIONS	•	In this phase, which marks the end of the closure phase and the beginning of the post-closure phase, all installations above ground are dismantled.
PASSIVLY SAFE POST-CLOSURE PHASE	• •	The repository is left in its state of passive safety without the need for human surveillance or monitoring. In the early years of the post-closure phase, however, there may be interest in monitoring the repository. This is called ‘post-closure monitoring’ and it is often related to the option of retrievability, though there may be other reasons for it.

SELECTING A SITE FOR GEOLOGICAL DISPOSAL [XI, XII]

How do we decide where to site a nuclear waste repository? What criteria have to be met?

Selecting a site for implementing and constructing a geological repository for nuclear waste is **by no means a straightforward procedure.** Key actors in nuclear waste management have developed step-by-step procedures for siting new repositories, but in practice the siting process is much more complex than generic procedures can reflect. While a range of criteria have to be met to establish the **technical feasibility** of a geological disposal facility, gaining the **support of concerned parties** – including the public – is often at least as important. In the past, however, siting procedures were mainly followed from the **top down,** with a sole focus on the technical side of the story. When a site had to be selected for storing and disposing of low- and intermediate-level nuclear wastes (LILW) in Belgium, for example, the nuclear waste manager, ONDRAF/NIRAS, met with so much local resistance that the process for siting the repository was changed to a **voluntary** one.

Potential host communities had to declare that they were prepared to study and discuss the possibility of hosting



such a facility. Their engagement in this stage of the siting process also remained completely non-binding, which gave the municipalities a de facto **right to veto** and the opportunity to stipulate the conditions for becoming a host community.

What followed in this Belgian case was a sort of **hosting competition** between three different municipalities. The organisational structures of the partnerships allowed the local populations to become involved in the decision-making processes. In the end, two of the volunteering municipalities developed a joint project proposal which the Belgian government then used to choose a location for the LILW repository.

As this Belgian story is not an isolated case, nuclear waste management organisations in various countries like Sweden, Finland, Switzerland and others have abandoned the classic 'decide-announce-defend' approach to selecting a disposal site and have instead introduced **a stepwise implementation process** in which social and technical aspects are both addressed in a participatory way. However, local and national differences make each siting process unique, and each one has its own obstacles and challenges.

The public can be involved in various steps of this waste management chain. In the phase of site selection, especially, the participation of the general public is considered indispensable by most EU countries. After all, the success of finding a suitable site for final disposal depends on the willingness of local communities.

However, the process of public participation does not stop at this stage of the disposal project. During the operational phase of the repository, beginning with the construction of the site and ending when closure is fully completed, the role of the local community evolves from 'siting' the repository to **'hosting'** it [XIII]. This changing role inevitably raises new challenges.
The local level of democratic decision-making becomes all the more important, as a new range of local actors emerge with whom national governments and implementers have to collaborate if the geological disposal project is to be realised. When a community hosts a repository, the disposal site becomes **part of the everyday decision-making** in the community and must be included in all of its decisions and plans.

The local community will also be confronted with new challenges, such as how to maintain local knowledge about the disposal project and interest in participation. Keeping the surface buildings open as research facilities, museums, visitor centres and spaces for decision-making could help in this regard.

Previous nuclear waste disposal projects have shown that host communities which have been actively involved in a siting process are not content to become passive audiences during the decades of activity taking place underground.
As indicated by the issues of REVERSIBILITY AND RETRIEVABILITY, as well as monitoring, the local public generally wishes to stay involved during a repository's operational phase.

THE CONCEPTS OF REVERSIBILITY AND RETRIEVABILITY [XIV, XV]

Worldwide, experts agree that geological disposal should develop linearly and in phases, but it rarely happens like this in reality.
There are a variety of factors that could influence or even stop the process, like political decision-making or scientific developments.
This brings us to the topics of reversibility and retrievability – important features of geological disposal systems in some EU countries.

The concepts of reversibility and retrievability are easily confused, but they have distinct meanings. Broadly speaking (refer to national legislation for more detail), **reversibility** means giving future generations the ability either to continue the construction and operation of a repository or to **reassess previously made choices** and find new solutions for disposing of the waste. The idea of 'reversing' the repository relates not only to the waste packages and the repository facility itself, but also to the overall approach to managing nuclear waste.
Retrievability, on the other hand, is about the **technical ability to recover waste** or entire waste packages once they have been emplaced.

In Germany, France and Belgium, the inclusion of reversibility and/or retrievability in the operational phase of the repository is required by law. This commitment does not exist in other countries, like Sweden for instance.
The **political decision** whether or not to include reversibility and/or retrievability in the geological disposal design is informed by 'public concerns' and the aforementioned principle of 'intergenerational autonomy', not by 'technical necessity'.

CHAPTER II

MONITORING IN GEOLOGICAL DISPOSAL

INTRODUCTION

The classic definition of monitoring is "to watch, keep track of, or check usually for a special purpose". Etymologically, the term stems from the Latin word *monere*, meaning 'to warn'. Thus, it refers not only to taking measurements, but also to a broader idea of **observing and checking the development or quality of something over a period of time.** In other words: keeping something 'under systematic review'.

The noun 'monitor' describes a device that produces pictures, graphs or other depictions of things or processes that would otherwise not be visible [XVI]. As such, the notion can also be linked to '**transparency**'. Today, monitoring is increasingly used in various fields, including healthcare, as a tool for informing decision-making [XVII]. With regard to nuclear waste management, the IAEA requires that:

> "a monitoring and surveillance programme is put in place aimed at confirming that the disposal system is performing as expected. Monitoring may also be carried out to enhance confidence in, and therefore acceptance of, the disposal process." [XVIII]

This **confidence building** is aimed at both scientists and the broader public. It is believed that increasing transparency about what happens inside a repository during the operational phase (and perhaps the early parts of the post-closure phase) can play a part in stakeholder engagement and dialogue.

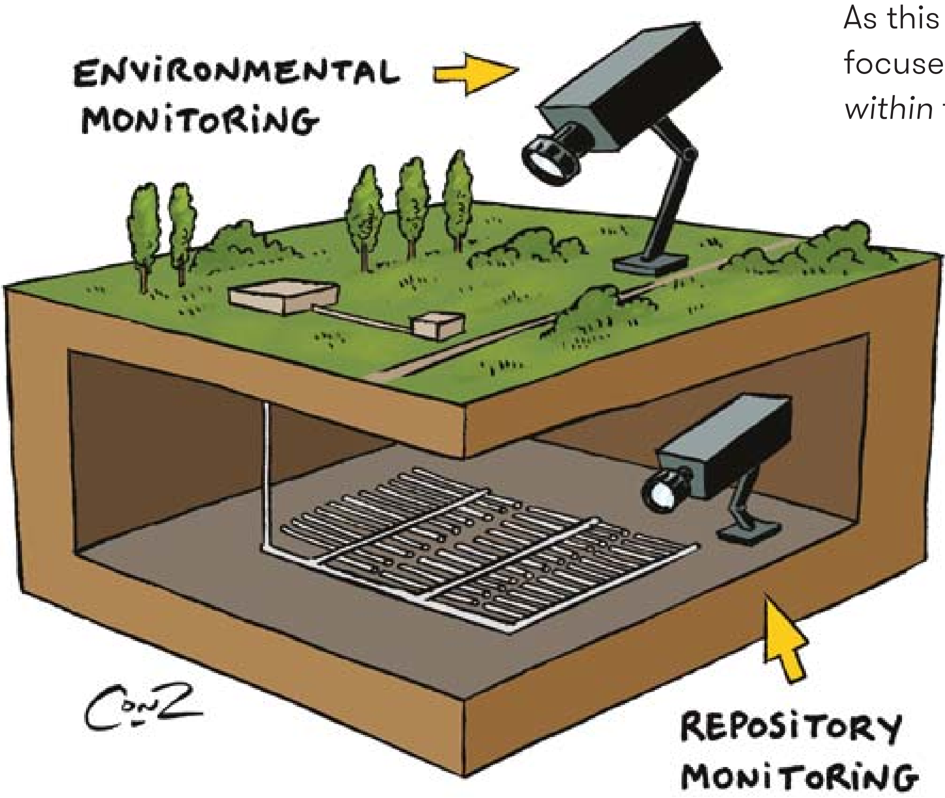
In the context of geological nuclear waste disposal, there are **various possible strategies for monitoring**, each with different purposes. Some of them are discussed in this chapter. After considering 'where' to monitor, we explore 'why' and 'how' monitoring is required and/or desired, from the perspectives of experts and local stakeholders. Lastly, we give some examples of repository monitoring technologies which were developed in the framework of the Modern2020 project.

DIFFERENT STRATEGIES FOR MONITORING GEOLOGICAL DISPOSAL

Where to monitor?

With regard to the question of *where* monitoring should take place in the geological disposal facility, a general distinction is often made between **'far-field'** and **'near-field' monitoring.**

Near-field monitoring takes place **inside the geological repository** as well as in the **surrounding host rock,** which can be damaged by excavation or subjected to higher temperatures emitted by the waste. Because this type of monitoring takes place within the repository and its immediate surroundings, it is often called **'repository monitoring'** or 'in situ monitoring'. The term 'EBS monitoring' is also used to refer more specifically to monitoring the passive engineered barrier system which insulates the nuclear waste.



The **far field,** then, includes the remaining host rock which remains unaffected by the repository construction and waste emplacement. It thus involves monitoring the **surrounding environment of the repository,** such as the geology, air, soil, plants and rivers. In line with the Modern2020 research project, this guide focuses on **near-field repository monitoring.**

The far-field approach to monitoring is commonplace in high-level nuclear waste management and an integral part of all repository systems across Europe. Near-field or repository monitoring, in contrast, is a comparatively new technology and slightly more controversial, especially when it comes to the monitoring of engineered barriers. As this type of monitoring focuses on developments *within* the repository itself, some nuclear waste management organisations have pointed out that it could threaten the repository's safety, since monitoring sensors are seen as a DISTURBING FACTOR IN THE FACILITY'S PASSIVE SAFETY SYSTEM.

As such, repository monitoring could have an impact on the long-term integrity and safety of the geological disposal facility. It is worth noting that repository monitoring is comprised of **a range of possible monitoring technologies** (with a strong emphasis on wireless technologies) which measure different parameters to check not only the repository's barriers, but also the waste sealed within these barriers. Installing such repository monitoring sensors allows us to follow up on the development of the repository and to gather real-time data on a location that will later become inaccessible.

When to monitor?

Another distinction can be made between 'operational safety monitoring' and 'post-closure safety monitoring', which have different purposes. **Operational safety monitoring** takes place during the repository's construction and operation phase, which spans several decades. This type of monitoring is mainly concerned with guaranteeing the safety of workers on site and

ACTIVE MONITORING VERSUS PASSIVE SAFETY?

For decades, the ambition in nuclear waste management has been to achieve a 'final' disposal solution for nuclear waste that did not require surveillance or monitoring. This ambition to 'walk away' is often referred to as '**passive safety**'. However, this situation changed slightly when technology emerged which enables what was previously impossible, namely the installation of monitoring equipment inside or in very close proximity to the repository itself.

This apparent contradiction between the goal of passive safety and the new possibility of active monitoring may **not be so clear-cut or contradictory at all**, however. After all, in the period before we 'walk away' from the repository and achieve passive safety, monitoring can provide valuable insights into the dynamics and processes going on in the repository. Here, monitoring is both a **learning tool** and an instrument for achieving the desired goal of passive safety.

AS THE ANCIENT PHILOSOPHER RADIUS ACTIVUS SAID:

following up on how the construction of the repository and the emplacement of the waste is affecting the direct environment. Examples include monitoring the danger of collapsing drifts or water running into the excavation site.

Post-closure safety monitoring, on the other hand, can begin in the operational phase but may also continue into later phases of the repository's life and has a different goal. This kind of monitoring might involve installing sensors in the engineered barrier system to observe different kinds of processes and parameters within the repository in order to acquire a deeper and fuller understanding of the repository's behaviour in its post-closure state.

SOME QUESTIONS (ABOUT NEAR-FIELD MONITORING IN GEOLOGICAL DISPOSAL FACILITIES)

- Should monitoring be performed only before the final closure of the geological disposal facility? Or should it also take place after closure? Does it make sense to keep on monitoring for what seems an endless period of time?
- What are the reasons for monitoring the nuclear waste which is stored in the geological disposal site? What are we trying to achieve through repository monitoring?
- Should monitoring only take place around the repository, or is it necessary to monitor inside it as well?
- What kind of monitoring results should be used to make decisions about future repositories? Who should review and manage the monitoring data?
- How much should a repository monitoring programme cost?

Discussing the concept and principles of monitoring

Despite these well-known distinctions, the concept of monitoring is sometimes surrounded by **conceptual confusion** in the world of nuclear waste management. Nuclear waste management organisations have made efforts to produce standardised concepts, but the notion of monitoring is not always clear, as different actors ascribe different meanings to it. What exactly constitutes monitoring is sometimes the subject of disagreement, not least with regard to the challenges it entails to monitor a repository for decades, or even centuries.

In short, *why* monitoring should be done, *what* to monitor, *how long and where* to monitor, *who* should do the monitoring and *how* the monitoring should be carried out are QUESTIONS WITHOUT CLEAR-CUT ANSWERS. We explore some of these questions in the next section.

WHY, WHERE, WHEN AND WHAT TO MONITOR IN A GEOLOGICAL REPOSITORY? EXPERT AND PUBLIC POINTS OF VIEW

Answers to the questions about near-field repository monitoring vary greatly depending on who you ask. As our experiences within the Modern2020 project have shown, diverging approaches and perceptions of monitoring exist not only among technical experts and public stakeholders, but also among nuclear waste managers and experts themselves.

Here we explore these divergent opinions on repository monitoring by **comparing** the opinions of representatives from the **European expert community** with what **public stakeholders** from Belgium, Finland, France and Sweden had to say about the topic during the Modern2020 project and its predecessor MoDeRn. We have opted to compare 'the experts' with 'the public stakeholders' because this guide is mainly aimed at local stakeholders who might be interested in the viewpoints of their fellow public stakeholder groups and how these relate to the opinions held by technical experts.
Of course, not all experts and local citizen stakeholders have the same views on monitoring. The table below is based on real interviews, but we focus very much on the differences in opinions in order to draw sharper distinctions.
The purpose is not to fuel controversy, but to show the various lines of reasoning and views that exist within these discussions and to illustrate that differences in views between actors often depend (at least in part) on their professional and societal positions.

REPOSITORY MONITORING IN GEOLOGICAL DISPOSAL FACILITIES [XIX]		
	TECHNICAL EXPERTS INVOLVED IN MODERN2020	PUBLIC STAKEHOLDERS FROM BELGIUM, FINLAND, FRANCE AND SWEDEN
WHY MONITOR?	The technical experts involved in the Modern2020 project gave the following reasons for monitoring a geological repository, which are comparable to the ones formulated in IAEA reports: ~ Repository monitoring can **enhance understanding** of the behaviour of the repository system and its environment.	Like the experts, public stakeholders' perceptions and opinions about the use and purposes of monitoring in geological disposal vary not only from country to country but also within countries: ~ Somewhat in contrast to the expert idea of the purpose of monitoring, public stakeholders perceive repository monitoring

	TECHNICAL EXPERTS INVOLVED IN MODERN2020	PUBLIC STAKEHOLDERS FROM BELGIUM, FINLAND, FRANCE AND SWEDEN
WHY MONITOR?	~ Monitoring offers **confirmation of the disposal system** and hence, of its long-term safety. However, experts do not wish to rely on monitoring as a basis for ensuring safety, since the safety case should already have proven the long- term safe performance of the repository (see box p40: MONITORING AS ADD-ON SAFETY) ~ It **provides information** on the repository system for decision-making now and in the future, which supports a step-wise implementation of geological disposal. ~ When the safety of the repository is confirmed by monitoring data, monitoring can **support public confidence** and social acceptance of the geological disposal project.	as a way to **check the expected behaviour of the repository** as well as the quality of the safety case and the disposal system, because of its unpredictability over several hundreds of thousands of years. ~ Like the technical experts, public stakeholders also see repository monitoring as a means of **supporting public confidence** and social acceptance of the geological repository. ~ Public stakeholders who have lower levels of trust in institutions such as the nuclear waste management organisations or regulatory bodies sometimes emphasise the **need for independent monitoring** carried out by explicitly autonomous agencies.
WHY NOT MONITOR?	There are also reasons why some European nuclear waste managers question the use of repository monitoring in geological disposal: ~ The monitoring sensors may jeopardise the overall safety of the repository system, since they may cause a **physical intrusion** into the barrier system. ~ There are also risks of **inaccurate and misleading reading of monitoring data,** which may lead to ill-informed decision-making about the disposal programme.	In countries where public stakeholders already have a great deal of trust in the nuclear waste manager, as well as in expert judgment and the safety case, stakeholders tend to agree with experts who warn about the potential danger that monitoring may cause because of its **intrusion into the repository's barrier system.**

	TECHNICAL EXPERTS INVOLVED IN MODERN2020	PUBLIC STAKEHOLDERS FROM BELGIUM, FINLAND, FRANCE AND SWEDEN
WHERE?	Opinions vary about where the monitoring in and around geological disposal facilities should be situated (often depending on national regulations and contexts), but experts generally agree that far-field environmental monitoring should always take place. **Near-field repository monitoring** is surrounded by more controversy and disagreement, however. After all, repository monitoring is not always defined as an integral part of nuclear waste disposal programmes in national legislations and it is sometimes perceived as a **breach of the passive safety standards** of geological disposal.	In general, public stakeholders tend to **focus more on far-field, environmental monitoring** since this type of monitoring can offer clear indications about how their local environment is being affected by the repository and whether they should worry about certain health impacts. Besides the biophysical world, stakeholders also raise the possibility of **monitoring the socioeconomic environment,** since they often worry about the impact of the geological disposal site on their local region in social and economic terms. They also consider near-field repository monitoring to be necessary – though to a lesser extent than environmental monitoring – for example in order to enable thorough **surveillance of the waste packages** that will be placed into the repository.
HOW LONG?	Technical experts believe it is necessary to implement monitoring technologies during the **construction and operation phase** of the geological repository. However, the end point of monitoring should also be related to the monitoring objectives. For example, if monitoring is intended to confirm or disprove an expected evolution, then in a case where the expected evolution ends before the monitoring period does, monitoring could end early as well.	The **opinions** of public stakeholders about how long to monitor are **more mixed.** Some agree with the technical experts that post-closure monitoring is unnecessary since it conflicts with the passive safety standards of the geological disposal system and with the idea that future generations should one day be able to forget about the existence of the repository. Others, however, do express a desire for post-closure monitoring but are not sure about what type of monitoring should be carried out in this final phase.

	TECHNICAL EXPERTS INVOLVED IN MODERN2020	PUBLIC STAKEHOLDERS FROM BELGIUM, FINLAND, FRANCE AND SWEDEN
	Monitoring during the post-closure phase is mostly viewed as **technically unnecessary,** although it may be valuable if it can reassure other stakeholders.	
WHAT and HOW?	With regard to **what parameters should be monitored** in the repository and how this should be done, technical experts identify **two challenges.** These reflect the variety of monitoring strategies and technologies in use in different countries. ~ The first challenge is **how to identify measurable processes and parameters** in the relatively short period before closure which could serve as a basis for predicting long-term system behaviour. Nuclear waste managers develop their own parameter selection processes with which to identify measurable parameters. However, the selected parameters are likely to remain few in number. ~ Another challenge is how to organise monitoring **without compromising the fundamental safety barriers of the repository.** Resolving this issue requires the development of new monitoring technologies. This was the focus of the Modern2020 project (see 'Chapter II - Monitoring in Geological Disposal' in this guide).	Public stakeholders appear to be somewhat **less interested in knowing the exact parameters** that will be monitored, since this is often considered to be too technical. However, they would like nuclear waste management organisations to monitor as many parameters as possible, and to focus on parameters that monitor the consequences of the repository for local populations in terms of radiation protection. With regard to **monitoring technologies,** some public stakeholders feel that these technologies should be **tested in situ** (for example in an underground research laboratory) before being applied in real life. They also believe that these monitoring systems should evolve over time and be able to adapt to new conditions.

REPOSITORY MONITORING AS 'ADD-ON' SAFETY [XX]

How do experts see the relationship between repository monitoring and site safety when they say that monitoring should 'confirm' the safety of the disposal system?

In order for a nuclear waste repository to be licensed, its long-term safety has to be demonstrated in advance. Therefore, all possible future scenarios are carefully considered alongside critical assessments of materials and infrastructures and gathered in an extensive document called the **'safety case'.** This safety case is intended to provide strong evidence based on expert knowledge, predictive modelling and calculations that the geological repository will be safe in the very long term. We might assume that monitoring the conditions, processes and dynamics going on within the nuclear waste repository could provide information to help us check (or challenge) the calculations and models made by technical experts and make judgements about its actual safety.

However, the European expert community stresses that monitoring and the safety case are in fact separate, and that we should consider **monitoring as an 'add-on' technology, not as a safety parameter in itself.** Since the safety of a geological repository is verified and validated in the safety case, on the basis of which the construction and operation licences are granted, monitoring in geological disposal should primarily be used to *confirm* that everything in the repository is performing as predicted in the safety case.

Along these lines, monitoring is seen as an add-on technology in the sense that the disposal facility can be assumed to be safe, with or without monitoring, because a licence has been granted. Still, experts recognise that **monitoring can provide additional insights** into the dynamics and processes taking place within the repository which may inform future decision-making.

Technical background

One of the reasons for technical experts to insist on this distinction between monitoring and the overall safety of the repository is that **certain monitoring parameters are not always related to the safety of the disposal facility as a whole.**

An example is how water flowing past the plugs in the repository is not necessarily related to the erosion of buffer material in deposition holes. In the worst case, with a very dry deposition tunnel, significant water inflow through a deposition hole and subsequent significant buffer erosion would not result in flow through the plug. Conversely, in a well-saturated tunnel there may be relatively high flow through the plug, but not necessarily any erosion of the buffer material. Instead, buffer erosion is mainly dictated by the distribution and magnitude of groundwater inflow to the deposition holes and tunnel, which can be measured directly. Therefore, the parameter in this example should not be seen as having a strong link to the plug safety function. Nevertheless, a tight plug is considered beneficial for post-closure safety, so its long-term maintenance capacities will already have been guaranteed and proven in the safety case.

What happens next?
About monitoring and decision-making

Once the questions of why, when, where and how to monitor have been settled and data collection has started, **new questions emerge**:

- Who is responsible for maintaining and managing the monitoring data?
- Should the data be made available to all interested parties?
- Who decides which monitoring values are to be considered irregular and/or potentially problematic, and which actions are to be taken on the basis of this data?
- Who is responsible for supervising this process?
- Should local public stakeholders be involved in these decisions, and if so, how?

Technical experts working within the Modern 2020 project attempted to find an answer to (some of) these questions. They worked on **identifying monitoring results that would require action** to be taken and considered **appropriate responses** if something develops differently than planned. Approaches (methods, tools, workflows) for using monitoring data in decision-making were also studied and developed.

This expert community sees **monitoring as only one source of input for decision-making**, in the sense that monitoring does not feed the decision-making process directly, but instead guides the discussions between the nuclear waste management organisation, the regulator and the political world. Monitoring data **do not trigger important decisions directly**. If some measurements turn out differently than expected, raising suspicion that something could be wrong, a so-called **'root cause analysis'** needs to be done to understand why this is the case. This scientific analysis is crucial for assessing what further actions should be taken. With regard to which decisions require the involvement of local public stakeholders, technical experts argue that monitoring measurements which need action should be communicated to a broader audience.

Local public stakeholders emphasise the importance of knowing what will happen if irregular monitoring measurements are recorded. According to them, **a detailed decision-making plan** should be put in place to clarify which actions are to be taken in which cases. Opinions about whether irregular monitoring results should be made public vary among local stakeholders from different countries.

In France, for example, local stakeholders draw a parallel between monitoring and the control system for nuclear power plants managed by the French regulatory body, ASN, in which every deviation is automatically made public. They argue that a similar kind of ‘**alarm system**’ should be put in place for geological repositories. Finnish public stakeholders, on the other hand, do not express a strong interest in having access to all of the monitoring data recorded. They do not believe they could contribute much to the decisions necessary at that point and trust that the nuclear waste managers and regulators will handle it and inform them when necessary.

MONITORING TECHNOLOGIES

There are **several challenges** in developing monitoring technologies:

- Typical **constraints** imposed on monitoring equipment are the **environmental conditions** in the repository, which may include high temperatures, high pressure, humidity and/or submersion, chemically aggressive environments and levels of radiation that may affect the performance of electrical and optical cables.

- Typical **requirements** include the longevity of the monitoring technology (without any real possibility of being able to maintain the equipment), a high level of confidence in signal reliability and the absence of interference with barrier performances, especially with regard to long-term safety.

There are also **different approaches** to taking measures in a repository. **Classical wired sensors** are the most widely used and represent a standard, reliable and well-known solution in most cases. Nevertheless, there are some arguments against installing monitoring technology inside the repository which should be taken into account into the research and technical development of such technologies. One of the most important drawbacks is that monitoring sensors might jeopardise the passive safety standards of the repository system. This could be the case when sensors need wires for energy supply and data transmission which run through the repository’s barriers. As a solution, experts are currently trying to improve and develop **wireless data transmission systems** as well as sensors that run on batteries with exceptionally long longevity.

Another challenge is that, as recent tests with fibre optic cables have shown, for example, repository monitoring sensors deliver **vast amounts of data** which have to be processed and analysed thoroughly in order to be able to draw appropriate conclusions about the condition of the repository and the waste and the safety of the repository.

In what follows, we explore how the monitoring technologies developed in the Modern2020 project seek to respond to these challenges.

1. New sensors

First of all, the Modern2020 project aimed to develop new monitoring sensors which are more suitable for monitoring within a 'harsh' environment such as an underground repository and to provide an alternative and back-up for standard sensors. **Optical fibre sensors**, in particular, are a promising technology for the following reasons:

- They enable us to place the instrument **far from the measuring points** in an accessible location where electricity is available
- They **eliminate the high costs** associated with wires (a single fibre contains several measuring points)
- They are **long-lasting** compared to electronics (the fibre itself is the sensor)

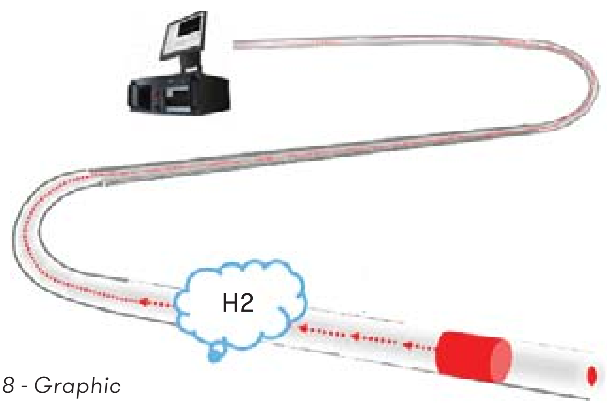


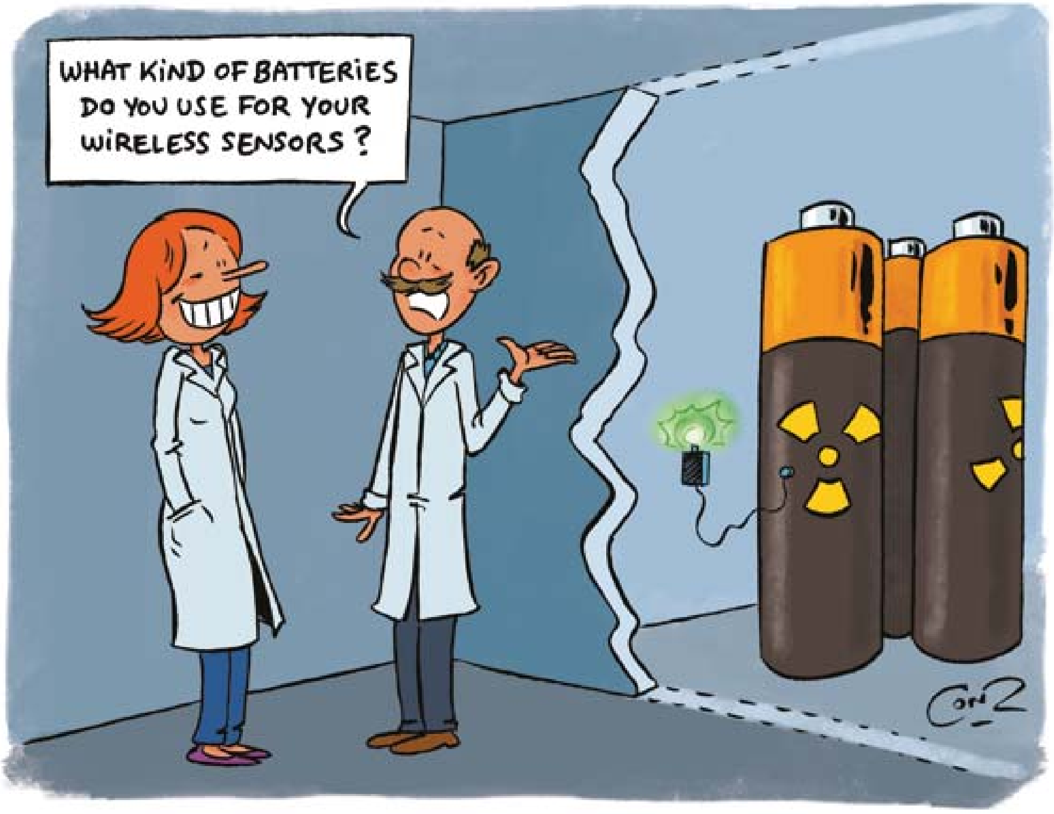
Figure 8 - Graphic example of an optical fibre sensor (Source: Modern2020)

Of the various types of optical fibre sensors, one is especially attractive: **distributed sensing.** In such devices, measurements can be taken along the whole optical fibre (= linear sensor), not only at a few sensing points. This fibre optic cable is a very robust sensor which is immune to corrosion and electromagnetic disturbance.

2. Wireless technology

Once new monitoring sensors have been developed, the question is how the resulting data should be transmitted to a central computer. There is much interest in developing **wireless data transmission technologies**, because they enable monitoring behind safety-relevant barriers without jeopardising the safety function of these barriers through the use of wires. Although high-frequency data transmission techniques are already being used in a large number of industrial and consumer applications, their limited propagation through solid materials like the host rock or barrier materials make them unsuitable for monitoring geological repositories.

Low-frequency magnetic fields, on the other hand, can transmit data over longer distances through solid materials underground. Keeping in mind some European countries' requirement of waste retrievability, the Modern2020 partners investigated wireless data transfer systems which are able to transmit monitoring data from the waste disposal system deep underground to the surface after closure.



3. Alternative power supply sources

Wireless monitoring equipment placed behind barriers needs **autonomous power supply solutions** to be able to operate over a long period of time. Batteries are widely used for supplying power, but the life spans of commercial batteries is limited – less than 30 years. Because many safety-relevant processes in geological waste repositories evolve rather slowly, wireless monitoring of these processes depends on the availability of alternative supply options that can provide electrical power over several decades. As a result, the Modern2020 project studied and developed a number of alternative power supply systems, including **thermo-electric generators** (TEGs).

4. Geophysical methods

A final group of technologies developed during the Modern2020 project were geophysical methods, which are used to measure the **overall performance** of a repository. This includes both the canisters and the engineered barrier system, as well as the surrounding host rock that has been affected by the construction and operation of the repository. Specific examples of these technologies include **seismic full-waveform inversion** (FWI) **technologies** and **anomaly detection algorithms** that can identify subtle changes in the monitoring data.

CHAPTER III

PUBLIC PARTICIPATION IN MONITORING R&D. HOW TO ENGAGE PEOPLE?

INTRODUCTION

In recent years, the concept of 'public engagement' has gained importance in many policy issues and public mega-projects. Similarly, the 'participatory turn' in nuclear waste management has led to the introduction of various public engagement initiatives in decision-making processes and projects related to the radioactive waste problem. In that spirit, the Modern2020 project aimed to take into account the expectations and opinions of local public stakeholders- when developing and implementing an effective repository monitoring system. Local stakeholders (from Belgium, Finland, France and Sweden) were involved in the project in various ways:

- A small core group of engaged local community representatives regularly attended project meetings and workshops organised at European level.
- Social scientists also organised workshops or 'home engagement sessions' [3] in the home communities of interested public stakeholders in order to discuss their concerns and opinions about monitoring in nuclear waste repositories.
- The same local public stakeholders also had the option to share experiences and opinions about their involvement in the project by participating in an online survey, organised in two rounds.
- In addition, the local stakeholders had the opportunity to meet with the technical experts involved in Modern2020 during a workshop specifically designed for this purpose. The two-day 'Local Stakeholders Workshop' organised in September 2018 aimed to bring together local stakeholders and technical experts in a space of mutual understanding in which both groups were encouraged to reflect on, communicate and discuss their opinions of local stakeholder engagement in Modern2020.
- Lastly, the local stakeholders were regularly consulted for feedback on this Stakeholder Guide, as well as on other output produced during the project (such as workshops and research reports).

3 ~ Overview of the various 'home engagement sessions' per country:

- Three 'home engagement sessions' were organised near Mol, in Belgium, and were attended by 12, 7 and 13 local citizens respectively.
- One home engagement session was organised in each of the municipalities of Östhammar (Sweden), Eurajoki (Finland) and Bure (France), with 20, 8 and 5 participants respectively.

Despite the Modern2020 project's clear objective to "take into account the expectations and opinions of local public stakeholders in the development of monitoring systems", achieving 'good' stakeholder involvement is easier said than done. This exercise raised **some important questions about why, when and how** public participation should be organised in such a research and development (R&D) project.

This chapter draws on the **real-life experiences of local public stakeholders** involved in the Modern2020 project in order to reflect on these questions further. We first take a closer look at the specific country contexts of the local stakeholders from Belgium, Finland, France and Sweden before further exploring their opinions and concerns about public participation in the Modern2020 project.

WHO WERE THE LOCAL STAKEHOLDERS IN MODERN2020?

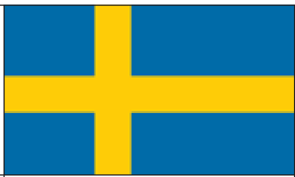
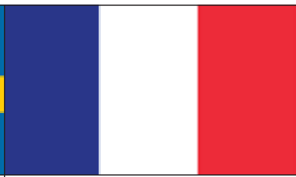
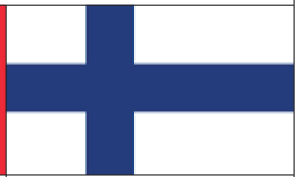
In the Modern2020 project, local stakeholders from the communities engaged in the national waste management programmes of **four different European countries** were actively involved in participation activities. In Finland, France and Sweden, nuclear waste disposal management options were chosen and formally decided upon. The participants were from the local communities near the sites where these preferred management solutions (i.e. geological disposal) would be implemented. In Belgium, no 'decision in principle' has so far been made by the government about the preferred solution for high-level waste. However, Belgian local stakeholders were invited to participate in Modern2020 because of their ongoing experiences with public participation in low- and intermediate- level nuclear waste management from which interesting lessons can be learnt.

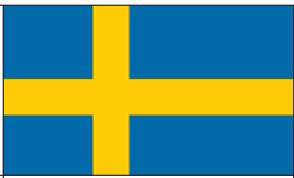
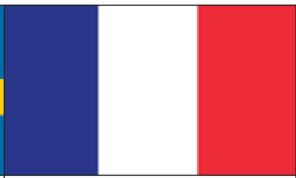
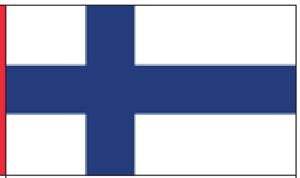
In order to learn meaningful lessons from comparing different countries, it is **important** to take into account the **differences** between them. Our four countries, for example, have very different legal and institutional frameworks, different experiences with public participation and different cultures in general. To better understand these crucial national differences, we briefly present some key features of each of the Modern2020 countries and FOUR CASE-STUDIES showing how public participation is put into practice there.

Sweden: taking public stakeholders seriously

Together with Finland, Sweden is internationally recognised as a frontrunner in using nuclear waste management technology, and is among the few countries in the world that have identified sites for spent fuel repositories. In June 2009, the **Swedish Nuclear Fuel and Waste Management Company** (SKB) – responsible for developing the technology and proposing the site for the final disposal of spent nuclear fuel – announced that it would file an application to site **a final waste repository in the municipality of Östhammar.** Leading up to this announcement, SKB had carried out site investigations in both Östhammar and another volunteer municipality, Oskarshamn. Over a period of 8 years, SKB managed to arrange a steady stream of consultation meetings in both communities. The unprecedented outcome was that the two municipalities ended up competing to host the repository. In March 2011, SKB applied to the government for permission to start constructing a final repository

PUBLIC PARTICIPATION IN PRACTICE
FOUR CASE-STUDIES

				
GENERAL (NUCLEAR) CONTEXT	Sweden has three operational nuclear power plants, with **10 operational nuclear reactors,** which produce about **35-40%** of the country's electricity. The local community of **Östhammar** is about **20 km** from Forsmark, the planned location for the Swedish geological repository. The community of Östhammar has a population of about **4500** people.	France has **58 operational nuclear reactors,** spread across 19 nuclear power plants, which produce about **75%** of the country's electricity. The local community of **Bure** is about **2 km** from the planned site for Cigéo, the French nuclear waste repository. Bure currently has **82 inhabitants.** As a reference, the closest city (39 km from Bure), Bar-Le- Duc, has a population of about 15 500 people.	Belgium has 2 nuclear power plants, with **7 operational nuclear reactors,** which generate about **50%** of the country's electricity. In Belgium, a site for the final disposal of high-level radioactive waste has **not yet been selected.** However, the communities of **Mol** (36 **500** inhabitants) and **Dessel** (**9000** inhabitants) are hosting a surface-level repository for Belgium's low- and intermediate-level radioactive waste.	Finland currently has **4 operational nuclear reactors,** located at two nuclear power plants, which provide about **30%** of its electricity. **Two new nuclear reactors** will raise the nuclear contribution to about 60%. The local community of **Eurajoki** is located about **20 km** from the Olkiluoto peninsula where the geological repository is being built. Eurajoki has a population of about **9500** people.
STATE OF DEVELOP-MENT	Site selected (Östhammar); construction licence pending (since 2011)	Site selected (Bure); application for construction licence in preparation	No 'decision in principle' for geological disposal; no site selected	Site selected (Eurajoki); construction licence for ONKALO facility obtained
HOST ROCK AND DISPOSAL CONCEPT	Granite (hard) Repository safety relies on the **KBS3V** canister.	Clay (plastic) Safety concept partly relies on relative plasticity of host rock.	No final disposal concept but research on geological disposal in poorly indurated clay has been ongoing since the 1970s	Granite (hard) Repository safety relies on the **KBS3V** canister

				
LOCAL PUBLIC PARTI-CIPATION	Östhammar Municipal Council Three working groups Veto right	CLIS de Bure Principal goal: providing information Proactive role: counter-expertise + additional assessments	No specific local stakeholder group for high-level nuclear waste MONA and STORA: 20 years of invol-vement in low-level nuclear waste fa-cility + follow-up of research in generic URL (HADES) in Mol Veto right	Eurajoki Municipal Council 'Nuclear culture' / 'Culture of trust' Veto right

based on the **KBS multi-barrier geological disposal system** in Forsmark, part of Östhammar municipality and host to the country's low- and intermediate-level waste disposal facility. This application has since been reviewed by both the national regulator, the **Swedish Radiation Safety Authority** (SSM), and the **Land and Environment Court.** Due to inconsistencies in the evaluations made by SSM and the Land and Environmental Court, however, a governmental evaluation is still pending.

Local citizen stakeholders in Östhammar are mostly engaged in nuclear waste management at the **municipal level.** Local representatives are organised into three different working groups: the long-term safety committee, the environmental impact committee and the reference committee. Their tasks range from following up on SKB's R&D programme to reviewing the Environmental Impact Assessment process and organising dialogues with the general public. These activities are funded by the **Swedish Nuclear Waste Fund,** a government authority whose mission is to receive and manage the fees paid by the nuclear power companies and owners of other nuclear facilities in Sweden. The fees are intended to cover future costs related to managing and disposing of spent nuclear fuel, including local participation initiatives.

In contrast to the French case, for example, the municipality of Östhammar holds a **veto right** with regard to the nuclear waste disposal facility that is to be built in their community throughout the application and licensing phase of the repository. This means that the municipality has the right to 'say no' and therefore prevent the construction of a repository in their community. The existence of local powers of veto at municipal level has also made it necessary for experts and political decision-makers to pay serious attention to the interests and opinions of local citizens and their representatives. The municipality can set certain conditions for accepting the nuclear waste disposal facility, one of which being continued participation in the various phases of the nuclear waste disposal process.

In order to respond to these needs and involve the local communities more closely, SKB has in the past (from 2004 to 2011) run a social science programme during the siting procedure in which both the municipalities of Östhammar and Oskarshamn were involved.
To provide more insight into the social aspects of the final repository, researchers from the social and behavioural sciences dealt with four different areas of research: socio-economic impact, decision-making processes, psycho-social impact and changes in the surrounding world. In short, the aim of the programme was to study the impact of the final repository project on the surrounding community and to find out what the decision-making processes on such important issues might look like. In collaboration with local residents, SKB gathered more information about the local conditions for the nuclear fuel project in order to improve decision-making.

France: neutral public involvement with a proactive twist

In France, the Cigéo deep geological radioactive waste disposal project is being developed by the autonomous public body ANDRA, which is in charge of proposing the final disposal concept, managing the siting process and implementing it as a long-term solution. Created in 1979, the agency is supervised by three Ministers: the Ministers for Ecology, Industry and Research.
The regulatory body (Agence de Sûreté Nucléaire – ASN) and its technical support organisation (Institut de radioprotection et de sûreté nucléaire – IRSN) supervise and give final authorisation for the disposal facility. In France, these bodies are commonly referred to as the 'nuclear policemen'. The Cigéo facility is being paid for by the main waste producers (public companies and the Centre de l'Energie Atomique – CEA) who have ultimate responsibility for providing a safe solution for their waste.

This radioactive waste disposal process is being monitored and assessed by several national and local bodies.
The CNE2 (Commission Nationale d'Evaluation) was formed to assess the progress made in research into the management of radioactive materials and waste on an annual basis. This assessment results in an annual report written for the French Parliament, which is submitted to OPECST (Office parlementaire d'évaluation des choix scientifiques et technologiques), which has been following up on the nuclear waste process since 1990.

The independent administrative authority, the **National Commission for the Public Debate (CNDP)**, created in 2002, has also had a say in the disposal project since France decided to select the geological repository (Cigéo) as the main solution for nuclear waste management in 2005 about which they organised a national public debate on in 2013. At local level, public stakeholders can get involved in the disposal process by participating in the **Local Information Committee (CLIS de Bure)** in the municipality of Bure, where Cigéo will be constructed.

When it comes to citizen stakeholder involvement, it is most interesting for us to focus here on the Local Information Committee (CLIS) in Bure, established in 1994. What sets it apart is its composition. The CLIS is composed of local policy-makers, local opposition from environmental associations and local trade union representatives. A total of 91 **members** have been **appointed by law**, as has its funding, which consists of 50% public funding and 50% private funding from waste producers.

The main role and mission of the CLIS is to **keep the general public informed** about the Cigéo disposal project and the accompanying long-term decision-making process. In spite of this somewhat restricted role, some CLIS members have, over the last few years, become experts on the matter and now actively challenge certain aspects of the disposal process. They also raise **new technical questions** and order **new assessments** of the disposal concept. Local French stakeholders reported during the Modern2020 project that this intensified engagement on the part of the CLIS mainly resulted from an unfortunate chain of events in which ANDRA disregarded commitments it had previously made.

In short, while the main role of the CLIS is to be neutral rather than influencing the decision-making process directly, we can conclude that this role is being fulfilled with a proactive twist.
The dedicated members of the CLIS insist on a **diversity of information sources** and on the **availability of counter-expertise** about the Cigéo project. One outcome of this is that they have succeeded in receiving financial support for additional counter-expertise on the geothermal energy potential of the surrounding underground environment, since, in the French case, this energy potential would make the region unsuitable for deep waste disposal.

Besides the CLIS's substantial contributions in the form of counter-expertise and additional control, they also insist on **more transparency and coherency** on the part of the waste management agency. Another important value stressed by this local citizen organisation is **independency**. As such, some members of the CLIS de Bure [4] are of the opinion

4 ~ Consulted during one of the Modern2020 'home engagement meetings'.

that **monitoring** in geological disposal should fall under the responsibility of and be carried out **by an independent institution** which has the freedom to detect and monitor even the most unexpected events in geological disposal.

Belgium: a case of successful co-design

Although Belgium has a longstanding tradition of URL research into geological disposal, no clear policy decision has yet been taken (March 2019) to implement this long-term management solution for the country's nuclear waste. At present, **ONDRAF/NIRAS**, the national waste management agency, is considering how to design an appropriate governance process.

In contrast to this rather slow process regarding high-level waste, ONDRAF/NIRAS became a frontrunner in the late 1990s in terms of **local stakeholder participation in its low- and intermediate level, short-lived waste** (LIL-SLW) **programme**. In 1998, the organisation invited potential host communities to set up '**local partnerships**' that would bring together representatives from local civil society to perform joint technical and social feasibility studies into the hosting of a LIL-SLW repository. Over a period of five years, three such partnerships collaborated with ONDRAF/NIRAS to develop integrated concepts for repository projects, encompassing societal preconditions (including continuous participation through the partnership), and submitted positive reports to their municipal councils on the feasibility question. In two cases (the neighbouring communities of Dessel and Mol in the Flanders region) this led to actual candidacy for hosting the project. In 2006, the Belgian federal government chose **Dessel as the final site** and recommended that the partnership approach should continue during the development and implementation of the repository project, as well as during its operation (STORA in Dessel and MONA in Mol).

The partnership approach was intended to give potential host communities the opportunity to become **involved in the development of the repository project from the outset**, thus enabling them to determine for themselves the conditions for accepting such a drastic intervention in their immediate surroundings. The partnership thus became responsible for overseeing site investigations and the repository design, and dealt with all related issues, including safety. This led to a form of **co-ownership** between ONDRAF/NIRAS and its local partners of the outcome of the process.

The **disposal procedure for a surface repository** for LIL-SL waste includes the following steps: First, the waste is placed in concrete caissons and encapsulated in mortar to form 'monoliths'. Then, these monoliths are placed in 'modules'. A module is a concrete bunker with thick, reinforced walls. After backfilling, the modules are closed with a concrete cover.

Finally, after the completion of the operation phase and an extensive period of monitoring, the sealed disposal modules are covered with several natural layers and geomembranes to form a virtually water-proof final cover.

The main purpose of this final cover is to minimise water infiltration and to prevent damage to the disposal caused by animals or vegetation.

The local partnerships raised a number of important issues:

- The first local requirement was the integration into the **concept of a permanent roof** which would cover all modules before, during and after backfilling of the repository, to offer protection against weather conditions. The idea of a permanent, fixed roof was suggested by some of the local partners and subsequently introduced in the repository concept.

- A second issue was concern about the high groundwater levels in the area, and the subsequent risk of water seeping into the repository during the operational phase. ONDRAF/NIRAS first proposed that a two-metre elevation in the form of a huge concrete block be installed beneath the facility. This did not convince the partnership members, who instead suggested a 'cellar-like' structure which would serve as an **inspection gallery or monitoring area** and as a 'drip tray' or receptacle if water did come in.

  When the Federal Agency for Nuclear Control (FANC) raised a number of issues regarding the inspection gallery in a later stage (related to the security and long-term stability of the construction), further adaptions were made to the concept: the original gallery height of 2 meters (which allowed for visual inspection) was scaled down to about 1 meter to reduce potential stability problems and to make it less easily accessible. Consequently, the monitoring of the lower side of the repository will be carried out by a robot.

- Thirdly, local people asked that construction materials would be transported using the nearby canal whenever possible, which influenced the choice of location and added the **construction of a quay** to the repository project.

- Fourthly, the partnerships asked for a number of construction-related issues to be investigated in more detail; more specifically, a **programme of prototypes** would be used to test technical performance in advance.

These issues raised by the partnerships did not lead to ONDRAF/NIRAS's rejection of the basic proposals, but to a **number of changes being made to the design of the repository itself.**

Finland: a nuclear culture of trust

Finland is arguably the most advanced country when it comes to the geological disposal of spent fuel and long-lived, high-level radioactive waste. The Finnish have adopted the **Swedish concept of geological disposal in granite bedrock**, using copper canisters to dispose of the waste deep underground. A licence for construction was granted in November 2015 and construction of the disposal facility **ONKALO** has been ongoing on the peninsula of Olkiluoto, in the municipality of Eurajoki, since 2016. The start of the operational phase is planned for 2023.

After an **Environmental Impact Assessment (EIA)** in the late 1990s, the **Eurajoki Municipal Council** decided to approve the construction of the disposal facility on its territory in early 2000. This was the outcome of a long process of site selection that included both physical investigations and consultation with inhabitants. Similar to processes in Sweden and Belgium, there was some **competition** between possible host municipalities. The competition was mainly between municipalities that already had nuclear installations on their territories, like Eurajoki. In these municipalities, the inhabitants were already broadly accepting of the facilities, perhaps because they were also experiencing the related advantages such as fiscal benefits and job opportunities.

The relatively fast, smooth process of site selection in Finland reflects the **high overall level of trust** in the engineers and regulatory bodies in the country, the absence of major safety incidents and the virtual absence of independent counter-expertise or strong opposition through radical NGO activism. Besides these important factors, **the regulator, STUK, and the nuclear waste management organisation, Posiva**, in particular, have made significant efforts to communicate transparently and gain public acceptance. The efforts made by Posiva are generally considered **ambitious and extensive:** the organisation used a wide range of communication methods such as internet pages, videos, articles and newsletters as well as more direct forms of contact with the public like excursions, focus groups and public hearings.

Reflecting critically on these engagement initiatives, authors like Lethonen (2010) have concluded that the engagement efforts made during the EIA and afterwards were substantial, but actually had little impact on the decision-making. Lethonen claims that the authorities never invested major efforts in investigating alternative options or concepts. As mentioned earlier, this was perhaps because counter- expertise and opposition from activists was minimal and the average citizen had a high level of trust in institutions and scientists. In fact, many Finnish people are content to leave the decision-making to scientists and feel that **too much active citizen**

engagement could slow down the disposal process rather than improve it. While this attitude enables the more powerful decision-makers and experts to develop and implement their plans rather smoothly in comparison to countries like France, for instance, this almost automatic acceptance on the basis of trust can also be regarded as more problematic for those who believe in the importance of vigilant citizens who scrutinise decision-makers through opposition and counter-expertise.

This style of citizen engagement in Finland was confirmed during our interviews and focus group discussions in Eurajoki during the winter of 2017. Of course, some respondents were more concerned about potential negative effects on the environment, but **in general they showed a high level of trust** and pride in their engineers and legislation. They were also very much aware of the financial and employment-related benefits that the sector offers their community. In Eurajoki, we might say, **a 'nuclear culture' exists alongside a 'culture of trust'**. People are so used to living next to power plants and disposal sites that they rarely think about it anymore.

Furthermore, with friends and family working at the sites, they are less likely to distrust or demonise these companies. One respondent said that she did not really know why she trusted the nuclear sector, she just did, without reflecting on it much. Others emphasised the importance of the council's veto right in important decisions during the siting and licensing process of the facility, and the fact that no major incident had occurred to date.

The fact that STUK had delayed the process of finishing the new reactor on the Olkiluoto peninsula because of doubts about safety also strengthened the inhabitants' belief that the regulator and the nuclear waste managers were acting in their interest.

PUBLIC PARTICIPATION IN R&D

All of these groups of French, Swedish, Finnish and Belgian local stakeholders were offered the opportunity to participate in the Modern2020 project under the guidance of a group of social scientists. They actively supervised and contributed to the technical development of monitoring strategies and technologies, and communicated what they learnt to their fellow stakeholders at home.

Apart from this, the team of social scientists also encouraged the local stakeholders to reflect on how stakeholder engagement in the R&D of a new technology such as monitoring should be organised practically. After all, following up on and engaging in a decision-making process about a nuclear waste facility in your own community is completely different from interacting with technical experts about what an adequate and reliable monitoring system should consist of. This brings us to some TRICKY QUESTIONS about the organisation and content of local stakeholder engagement in R&D projects. Some of these questions may seem somewhat provocative or maybe naive, but it is important to reflect on them and raise awareness of what engagement entails.

	TRICKY QUESTIONS ABOUT PUBLIC ENGAGEMENT IN R&D
WHY should it be done?	• Should lay people **be given the right and opportunity to be involved** in a highly technical R&D project? Is the mere fact that this strengthens the democratic nature of the project valuable enough, regardless of what these participants can actually contribute to technology development? • What can these stakeholders add to the discussion? Only **social perspectives and concerns, or also technical and scientific input**? • Is involvement a way for technical representatives and local stakeholders to develop a **higher level of mutual trust and confidence**? • How can we make sure that local stakeholder involvement does not merely serve to **legitimise** a technical project?
WHO should be included?	• Should participating local stakeholders have a **basic level of expertise** in the nuclear field, and how can this 'basic level' of knowledge be determined and achieved? • Should **people who oppose** nuclear waste disposal projects in general be included in an R&D project? If not, how should we get them interested? • Do we want to involve local stakeholders who have **contrasting views** on the project at hand, or do we opt for efficiency by including only **like-minded people** who are willing to work on the topic? • Should the citizens be **a representative sample** of the local population, or should we primarily invite those who can contribute a significant amount of knowledge (e.g. as a result of their education, professional background or personal interest)?

HOW should it be organized?	• How can the socially oriented remarks and concerns of local stakeholders be integrated into a techno-scientific R&D project? • Should local stakeholders be given **the right to make certain decisions** within an R&D project, and therefore be jointly responsible for its output with the technical experts? • Should all project information be made available to local stakeholder participants? In other words, should there be **complete transparency**? • **What kind of communication** should be established between local stakeholders and technical experts? How often and in what contexts should this take place?
WHEN should local stakeholders be involved?	• Should local stakeholders be included in the **earliest stages of technology development**, for example when the issue is still being outlined? • To what extent should local citizens **continue to be involved** in the process? • Is it possible to **identify specific 'points of engagement'** in the process of technology development?
WHERE should the participation take place? At what level?	• How do we deal with the **tension** between the goal of an R&D project to develop a certain technology at **European** level and citizen stakeholders' lived experiences of **local** radioactive waste disposal projects? • How should we take into account differing **local experiences of public participation** in national nuclear waste disposal projects in a European R&D project in which local stakeholders from different countries are all participating together? • Should local stakeholders be invited to participate in project meetings at European level? Or should local citizens mainly be consulted about the projects in their local environments?

EXPLORING PUBLIC PARTICIPATION IN PRACTICE

Introduction

The questions about public engagement in R&D above were considered and debated by the local stakeholders involved in Modern2020 on several occasions. Having been involved in R&D projects as citizen participants in their own countries, our participants from Belgium, Finland, France and Sweden were able to formulate critical opinions, remarks and recommendations about how local stakeholders are engaged in techno-scientific matters such as the monitoring of geological repositories.

In what follows, we present actual statements from local stakeholder participants and invite you to reflect further on their (sometimes very diverse) opinions and thoughts about actively engaging stakeholders in R&D. But if there is one thing they agree on, it is that engagement is essential.

> "I think it is our role as a local stakeholder to confront the scientists with what we as citizens actually find efficient and effective. And to encourage them to think about how they are going to communicate their work towards the public, and implement it in such a way that citizens agree with the approach. I think this is in fact the mission (of stakeholder engagement)."
>
> Belgian stakeholder,
> WP5 Home Engagement Activity, Mol (Belgium), June 2017
> (original statement in Dutch)

This statement is an example of what a citizen might expect from being engaged in a technologically complex R&D project. This person, for example, believes it is important to **confront technical representatives** in the nuclear waste management sector with the opinions and remarks of citizens in order to challenge their approach to and implementation of the project or technology they are developing.

Naturally, not every local stakeholder shares this opinion on what constitutes the value of citizen engagement. During the Modern2020 General Assembly (June 2017), groups of citizen representatives and experts from the project discussed the 'WHY' [XXI] AND THE THREE IMPERATIVES OF STAKEHOLDER ENGAGEMENT in more detail. All citizens and scientists agreed that stakeholder engagement can and should be used to **increase trust and acceptance.** Explaining things in an understandable and transparent way could alleviate unfounded fears and suspicion, and help to ease the process. Thus, they supported the instrumental imperative, though most stakeholders and some scientists added two important conditions. Firstly, **communication should happen early,** and should be completely honest and transparent. Secondly, there should be **room for disagreement.** It is possible that even after receiving more information, people will still dislike or distrust the project or technology. In that case, they should have the opportunity to voice their arguments and raise alternatives.

When it came to the substantive imperative, we saw a mix of different opinions. Some scientists believed that the input of citizens could **improve their design** and that it was important to

WHY SHOULD CITIZEN STAKEHOLDERS BE INVOLVED: WHAT CAN BE GAINED?

Since the **participatory turn** of the mid 1990s (see box p24), there has been increasing support for the idea that citizens should be involved in large infrastructure projects and science and technology developments. More and more governments, companies and waste management organisations are proactively engaging with citizens who might be affected by such projects. But what is actually to be gained by stakeholder engagement? Why should it be done?

To answer this question, many refer to the work of social scientist and environmental activist **Andy Stirling**, who makes distinctions between the 'instrumental', 'substantive' and 'normative' reasons for citizen stakeholder engagement.

Convincing the public: instrumental imperative

This imperative states that stakeholder engagement is necessary for increasing trust and acceptance among the public. From this perspective, citizens are mainly seen as people who lack sufficient information, and stakeholder engagement focuses on communication strategies that will convince them and decrease resistance. The main goal is to make sure that governments, scientists and waste management organisations can develop and implement their project as planned.

Making better projects: substantive imperative

This imperative states that involving citizen stakeholders helps to improve the overall quality of the project because citizens can provide input that will make the technology better attuned to social requirements. From this perspective, and in contrast with the instrumental imperative, stakeholder engagement should be a two-way interaction between technical experts and citizens. Both can learn from each other.

The right thing to do: normative imperative

This imperative means that in a democratic society, citizens should be involved in discussions and decision-making about large projects and technologies that could affect their lives. Such processes should not be purely 'technocratic', but also democratic. From this perspective, citizen stakeholder engagement is a way to make these processes more democratic. The normative imperative is sometimes referred to as the 'procedural justice' argument, as it states that engaging citizens is important not because it leads to acceptance or better technologies, but because it would be unjust if the people who may be affected by these projects had no say in them.

consider their views, whereas others did not believe this would make a difference. Most citizens did think there was something to gain from a more interactive exchange, but some emphasised that they **could not contribute to all topics.** The conclusion was that citizens and scientific experts should decide together what should and should not be discussed. Lastly, with regard to the democratic imperative, we found little consensus in our discussion groups.

While most participants agreed in general that it was important to have public discussions about important projects, **many were not convinced** that the practices of citizen stakeholder engagement make the process more or less democratic. There was some confusion about the exact meaning of this 'democratic imperative' and participants had different views about who should be involved (elected officials, ordinary citizens, experts) and at what policy level (local, regional, national).

Who should be included?

> "I think people who don't know anything about it (the topic of nuclear waste management) should not decide. They can give advice or say "I have doubts or am not in favor" but you should not say too much (...). You can agree or disagree, but you cannot say that something is bad when you don't know anything about it."
>
> Belgian stakeholder,
> WP5 Home Engagement Activity, Mol (Belgium), June 2017
> (original statement in Dutch)

Should citizens have a relevant educational or professional background in order to be able to contribute to research and technology development? Should local stakeholder participants have some **prior knowledge** about the technological and scientific challenges connected to the issue, or should everyone (even those with no techno-scientific expertise) be given the chance to participate? Should the **importance of their input be weighted equally** or should there be a hierarchy in terms of more or less important input from citizen stakeholders? **Who decides what input is important** and which remarks deserve less attention?

Our local stakeholders had very different opinions about these issues, which shows that there are **no easy answers** to these questions. A very slight majority of the local stakeholder participants in our online survey (56%) supported the view that citizen participants should have a basic level of techno- scientific knowledge in order to be able to contribute substantially to an R&D project, but the other half (44%) disagreed with this proposition. This divide was found among local stakeholders from all of the countries included in the project: Sweden, Finland and Belgium [5].

It became even more complicated when we asked the participants how they would **define this 'basic level of techno-scientific knowledge'**. We got very different answers. What do you think?

- Finishing secondary school
- Having a degree in technology or science
- Understanding 'scientific language' (for example in reports)
- Having been involved in nuclear waste management for several years
- ...

We might also ask ourselves whether it is necessary for the stakeholders invited to participate in an R&D project to be a **representative sample** of the community they come from. The local stakeholders consulted during Modern2020 were once again divided on this issue, but the majority tended to agree that they should be.

In general, they thought it was important for local stakeholders to be able to represent the members of their local community. This also goes for the representation of people with rather **controversial or unpopular views** on nuclear waste management.

An even greater majority of the local stakeholders believed it was necessary for them to be included in the discussion, though within certain limits. Some said that if their opinions were too far removed from the general ideas of the public, they should not be allowed to dominate the discussion.

In short, even if we acknowledge the democratic right of everyone concerned to be able to participate, there are practical and ethical issues to consider that are riddled with tensions. If only a select group of people can participate (e.g. in an R&D project meeting or workshop) and those people are expected to be a representative sample of their local community, how can we also guarantee that they all possess a basic level of techno-scientific knowledge? What do we do when certain people, especially those who hold controversial opinions, threaten to monopolise the discussion? Do we have the right to exclude them from the debate or not? But what is participation worth if it is not meant to assess the project or technology under development critically?

5 ~ The invited French stakeholders unfortunately did not participate to this online survey. This is why this country is not mentioned here.

What should be the role of citizen stakeholders within an R&D project?

> "I think that everyone should be allowed to have a say and participate in the process, but I do not think that everyone should be involved in the decision making. I do not believe that it is a good idea to allow single individuals, small NGOs etc. to be part of the decision. I believe that in a democracy the elected persons should make decisions with the help of experts in the area. It should not be the loudest ones that decide."
>
> Swedish stakeholder,
> Delphi questionnaire Round 1, October 2018

Most of the local stakeholders involved in Modern2020 agreed that citizens should have **the right to participate** in an R&D project **but should not be included in formal decisions.** Local stakeholder involvement in R&D is then defined as local participants having the option of being kept informed of developments within the project as well as having the right to question and challenge the information they receive from the experts, without having the responsibility of making decisions.

However, some of our participants did believe that elected individuals – including citizen representatives – should have the ability to get involved in a decision when appropriate or requested by experts.

When it comes to decisions about **specific technical elements** of the project, in particular, most local stakeholders (and technical experts) were of the opinion that we should **leave this up to the nuclear waste management representatives and other experts.** It is then the main responsibility of civil stakeholders to remind these technical representatives to take other matters into account as well, such as the concerns of a local community. Our local stakeholders also emphasised that when, after having been questioned thoroughly, the experts are able to present nothing but good arguments, the local citizens should put their trust in these experts to do a good job. This brings us to the topic of (dis)trust, which is crucial to local stakeholder engagement in R&D.

> “In nuclear waste management, trust arrives on foot but leaves on horseback.”
>
> Belgian stakeholder,
> Local Stakeholders Workshop, Antwerp (Belgium), September 2018

> “In Finland, trust has been created for decades. It takes time. We have never been disappointed! During all those years, we have only had good experiences. Posiva (nuclear power company in Finland) has made a “design with” (the local stakeholders) and they have not imposed something on us.”
>
> Finnish stakeholder,
> Local Stakeholders Workshop, Antwerp (Belgium), September 2018

In democratic societies, sufficient public trust in politicians and engineers is needed to realise geological disposal. As the safety of a geological repository for nuclear waste can never be guaranteed completely (because of uncertainties that may arise in the distant future), the public must trust that the nuclear waste management organisation has done the best job it can.

However, questions then arise as to how much trust the public should have in the institutions responsible. And can ‘healthy distrust’ also be a good thing? In the Modern2020 project, it became clear that the **amount of (dis)trust** people have in the nuclear waste management institutions **varies considerably from one country to another.**

The **Finnish local stakeholder participants** emphasised their **‘culture of trust in the nuclear expert’**. As the power company Posiva had established active and transparent communication from the very beginning as well as a veto right for the municipal community, a rather unique situation of mutual trust had emerged.

As one participant put it:

> "The culture of trust is so strong right now that people really don't think or talk about it (the geological repository) regularly."

Because of this generally high level of trust among Finnish local stakeholders, they see active participation in the R&D of monitoring systems as rather unnecessary, since they trust the expert to do a good job. Still, the Finnish participants wanted to be kept up-to-date about the latest developments.

A very different story was told by the French participants in Modern2020. They were of the opinion that, in their case, trust had been broken throughout the French decision-making process on the geological disposal site in Bure. This had resulted in a general lack of confidence in the nuclear waste management organisation and other actors in the nuclear field.

> "How to rebuild trust remains a huge question",

as one French stakeholder participant put it. Paradoxically, this generally low level of trust among the French citizen stakeholders had resulted in the same lack of interest in R&D matters as we saw among Finnish participants.

The French local stakeholders were more concerned with following up on the nuclear waste disposal process in general than with what they could contribute to the rather specific aspect of monitoring in geological disposal:

> "It is not our role to influence the design, but rather to inform people of the development of this design."

Right now, the local French community is focusing more on receiving adequate and accessible information about the French disposal project so that they can review it and confront experts with their concerns, remarks or counter-expertise when necessary.

As for the Belgian and Swedish local stakeholders, we can conclude that their levels of trust fall somewhere in between. In the case of Belgium, a site for the surface disposal of low- and intermediate-level radioactive waste had been selected near Dessel and Mol in agreement with the local municipalities. As local stakeholder participation was an essential feature throughout this decision-making process, a certain level of mutual trust had developed between the local communities and NIRAS/ONDRAF (the Belgian nuclear waste manager). However, this trust had a rather conditional nature, as local stakeholders indicated that they could easily withdraw their trust depending on the behaviour of the authorities.

As for Sweden, in addition to the general context of trust in state institutions, it was significant that SKB, the Swedish nuclear waste management organisation, had managed to win **the vital trust of the local authorities** through negotiations in which the municipalities had been able to act on a relatively equal footing with the company (also partly enabled by the establishment of a veto right for the local community) [XXII] .

Participating in a European context as a local stakeholder

> "It might be a provocative statement, but I don't think that the EU level is the most relevant one to discuss nuclear waste management programs and issues. That is not their business."
>
> French stakeholder,
> Local Stakeholders Workshop, Antwerp (Belgium), September 2018

> "I also wanted to add that I really enjoy to share knowledge with other countries. That is really appreciated."
>
> Finnish stakeholder,
> Local Stakeholders Workshop, Antwerp (Belgium), September 2018

At **what policy level(s)** should local stakeholders participate: local, national or European? Is it relevant for local stakeholders to follow up on European technology development projects and if so, how can they transfer this knowledge to their local experiences of radioactive waste management? And more practically speaking: Should we, in the context of a European project, organise interaction sessions at national level or stick to inviting the stakeholders to attend project meetings at European level?

For now, a mix of the two seems to work best. However, some local stakeholders involved in Modern2020 reported that they would have liked to have had more meetings at the local level throughout the project. This tension also influences the extent to which local stakeholders feel they have been able to contribute to the Modern2020 project.

If the technical project partners do not receive or establish a clear framework for incorporating local experiences and remarks into their project work, they often fail to **include the local stakeholders as true partners** in the project. This shortcoming was voiced by a Belgian local stakeholder:

> "We sometimes feel a bit like the 'fifth wheel'. It feels that the project partners see it as a nice extra and legitimation that we are there, but we are not really involved. For the time being there is no really 'equal' involvement of stakeholders in terms of presenting something from our perspective as well."

WP2 Workshop, Paris, March 2017

This feeling of not quite belonging to the overall project might also be connected to certain **practical issues.** For some local stakeholders, the language barrier might be difficult to overcome (the common language used in our project was English). The involvement of local stakeholders should also be planned carefully and sufficient resources should be made available to include them.

Finally, it is important to make sure that informational project documents are provided to the citizen participants in good time. However, in spite of such worries, our local stakeholders still **remained motivated to participate,** as they considered it valuable to learn from geological disposal projects and local stakeholders' experiences in other countries. They also felt it was necessary to gain insights into the different aspects of a geological disposal project, even though this involved the highly specialised techno-scientific development of a monitoring system. A Swedish participant worded his justification for taking part in the discussion as follows:

> "The final disposal of spent nuclear fuel is a very complex issue that requires protecting humans and the environment for 100 000 years. Trying to deal with uncertainties for these periods is a challenge. I have a moral responsibility to my children, grandchildren and future generations. Helping people see further than the end of their noses is enough."

Delphi questionnaire – Round 1, October 2018

It is clear that participation in general, but in technical R&D projects on controversial issues such as nuclear waste disposal in particular, poses huge challenges both to public stakeholders and to project organisers.

Now that you have seen how other local stakeholders experienced their participation in an R&D project related to nuclear waste management, HOW DO YOU REFLECT ON YOUR OWN POTENTIAL ENGAGEMENT? [XXIII]

HOW TO REFLECT ON YOUR OWN EXPERIENCES WITH STAKEHOLDER ENGAGEMENT

How is citizen stakeholder engagement organised in your country or municipality? Can it be improved?

This section presents some **useful and critical concepts** for thinking about engagement initiatives in your region and for developing arguments to help improve them if necessary.

When are we involved? Is everything already decided? Upstream or downstream involvement?

Using a river as a metaphor for the development of a large project, it is important to consider if you are **involved upstream (early) or downstream (late).** When stakeholder engagement is 'downstream', this means most important issues have already been decided and citizen involvement mainly serves to convince people and perhaps negotiate how and when to implement the project. Earlier, 'upstream' involvement probably presents more opportunities to influence decisions that will determine the course of the project. Citizen stakeholders who wish to influence fundamental aspects of a project should demand upstream involvement.

QUESTIONS FOR YOU

Which issues can still be negotiated and which have already been decided? Which issues are important to you? When do you just want to be kept informed and when do you want to be able to give input?

Where are we on the ladder of participation? Who has the power to make decisions?

The **ladder of participation** (originally developed by Arnstein, 1969) is a tool for thinking about the quality of participation in terms of how much influence citizens have. An adapted version of this ladder (Pröpper and Steenbeek 1999) has five steps that differ in terms of both the intensity of participation and the level of influence the participants have over the issue.

- The first step on the ladder is '**information**'. In general, this needs relatively little investment from the participants, but neither does it offer them much influence.
- The second step is '**consultation**'. Here, engagement is primarily organised to show that people can have their say, but their direct influence remains limited. For example, in a consultation process, people are asked to give their opinions, but there is no obligation for the initiator to actually take these opinions into account.
- Even in an '**advisory role**' – the third step – there is no guarantee.

Nevertheless, with this form of participation, initiators generally issue a response (whether because of a legal obligation or not) to particular pieces of advice.

- The fourth step is **'co- production'**, in which stakeholders are invited to participate actively in developing solutions and designing plans, projects or technologies. Final decisions are still taken elsewhere (e.g. by local government, project initiators, etc.).
- The highest step on the ladder of participation is **'co-design'**, in which citizens or their representatives are effectively given the power to take decisions or act as partners in a project.

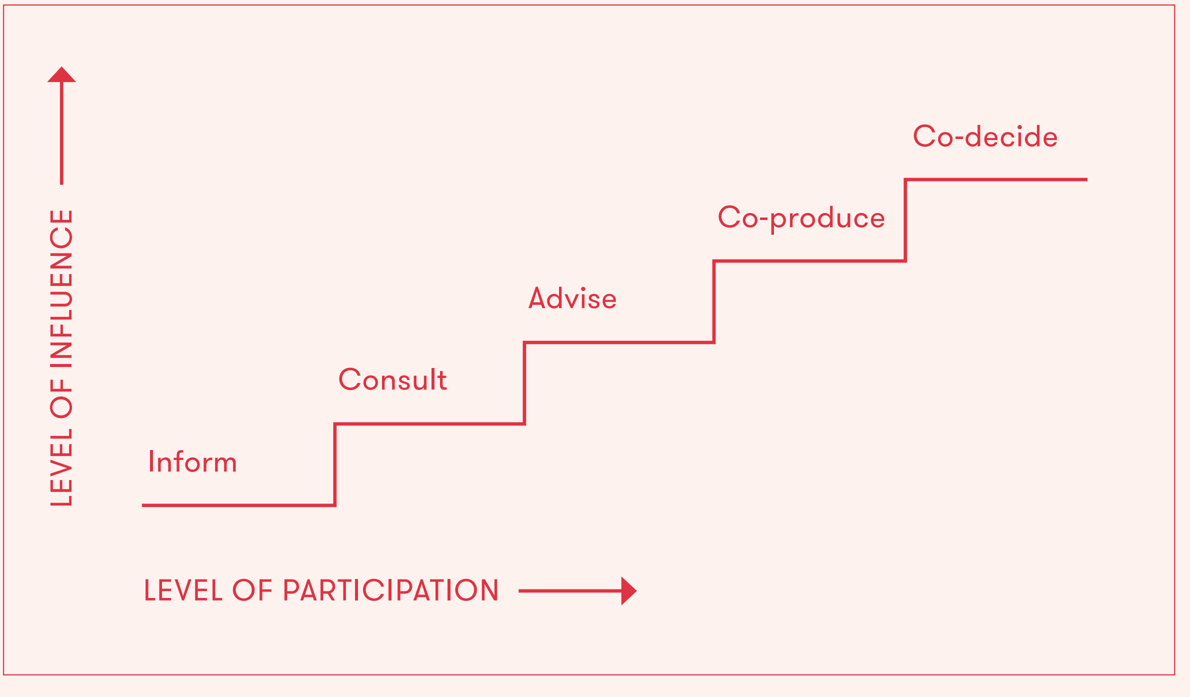
Obviously these higher levels of influence are far more demanding in terms of investment (in time and resources) for the citizens concerned.

QUESTIONS FOR YOU

Which ladder of participation step are you on in your municipality or project? Do you like or dislike this position? Are you on the same step for all issues all the time or does it differ? Which step would you like to be on? Why? Why do you think this is possible or not?

MORE QUESTIONS

Which issues can be negotiated on and which ones cannot? Is it a one-way process or a dialogue? Who is responsible for what? And do you trust them with that?



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VII However, constructing a common repository for waste from several EU countries is considered a possibility. See e.g.: European Commission: Nuclear Waste Directive, retrieved 16.10.17 from http://europa.eu/rapid/press-release_IP-11-906_en.htm

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X Representation of the phases developed by the authors, following OECD NEA (2017). The Geological Disposal Strategy of Nuclear Waste. Retrieved 05/10/17, from https://www.oecd- nea.org/rwm/reports/1995/geodisp/geological-disposal.html

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XIX Apart from the Modern2020 results, this table is also based on the outcomes of the prior MoDeRn project. For more information on these outcomes, see (amongst others): Bergmans, A., Elam, M., Simmons, P., & Sundqvist, G. (2012). Perspectives on Radioactive Waste Repository Monitoring. Confirmation, Compliance, Confidence Building, and Societal Vigilance. Technikfolgenabschatzung - Theorie und Praxis/Technology Assessment - Theory and Practice, 21(3), 22-28.

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Welcome to the stakeholder guide* to monitoring in geological disposal and public participation. Informed by both scientific work and experiences of local stakeholders in the Modern2020 project, this guide presents the state of the art of monitoring technologies and strategies for high-level nuclear waste repositories and reflects on how citizens can engage with this topic through public participation. It hopes to provide the reader with helpful tools and insights for reflecting on, and discussing nuclear waste management, geological disposal, monitoring and the engagement of the public with these topics.

To this end, various key questions are explored and answered throughout the guide:

- How can geological disposal offer a good solution for the long term management of high level radioactive waste?
- Why, where, when and what should we monitor in a geological repository?
- Who are the key actors in nuclear waste management?
- What are the various ways in which citizen stakeholders can engage with these topics?

The stakeholder guide might of be interest to citizens who already have some notion of nuclear power and the management of radioactive waste and wish to engage further with this issue, as well as to journalists, NGOs and policy-makers in the field of nuclear waste management.

* This guide was written by social science researchers from the University of Antwerp in the framework of the Modern2020 project and in close collaboration with an international group of researchers and local stakeholders.