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EURADWASTE '19

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DEVELOPMENT AND DEMONSTRATION OF MONITORING STRATEGIES AND TECHNOLOGIES –

MODERN2020 PROJECT

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The modern2020 Project

- Modern2020 project is a collaborative project funded by Euratom under grant agreement n°662177.

- It aims at providing a **framework for the development and possible implementation of monitoring** and associated stakeholder engagement during **operational phases** of the radioactive waste disposal process

- **EURATOM Research & Training Programme 2014-2018**
  - TOPIC: « Contribute to the development of solutions for the management of ultimate radioactive waste
- **IGD-TP Topic** : Joint Activity 7 - Monitoring
- **Project Duration**: 4 years (Start June 30th, 2015
- **Total budget :** 8,6 million € (**EC contribution** : 6 million €)
- **Website : www.modern2020.eu**

Modern2020 Structure

- **WP2 Strategy** lead by **SKB (Mansueto Morosini)**
  - Linking of monitoring objectives to the safety case and decision-making strategies.
- **WP3 Technologies** lead by **Amberg infraestucturos (José-Luis Garcia-Sineriz)**
  - Research and development on monitoring technologies
- **WP4 Demonstration and Practical Implementation** lead by **Euridice GIE (Jan**
- **Verstricht)**
  - Demonstration of monitoring technologies at full-scale and under *in situ* conditions.
- **WP5 Societal concerns and Stakeholder Involvement** lead by **the University of Antwerpen** (Anne Bergman)
  - Development and evaluation of ways for integrating public stakeholders concerns into national repository monitoring programmes

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2. WP2 : monitoring strategies
3. WP3: Monitoring technlogies
4. WP4: in situ demonstration
5. WP5: Public stakeholders
6. WP6: dissemination
7. Conclusion
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INTRODUCTION

Background

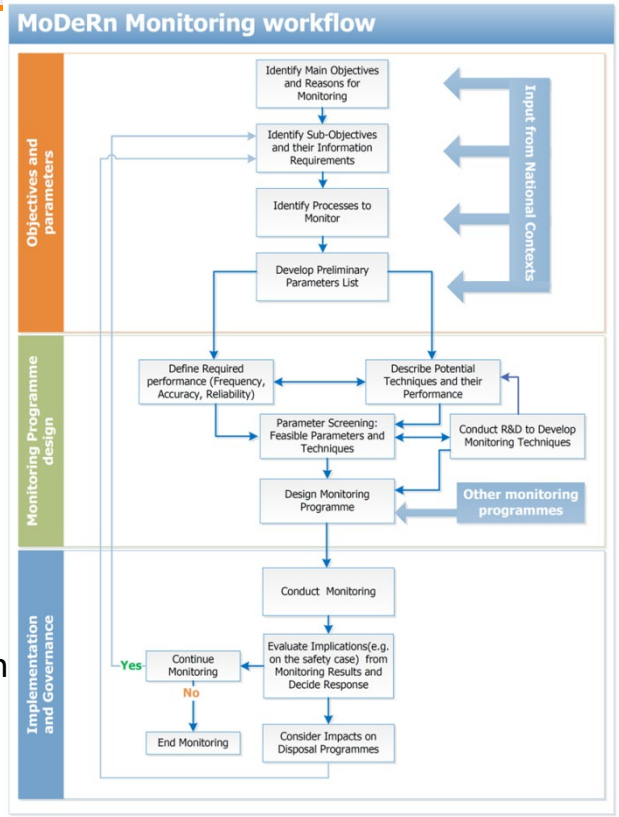
Extensive « literature » on monitoring (20 years)

- National legislation and regulatory demands
  - **STUK YVL Guide D.5**
  - **French ASN-2008 Geological Disposal Safety Guide**,
- Guiding principles from international organizations (IAEA, NEA, EU)
  - **IAEA TECDOC 1208 (2001)**
  - **IAEA Safety Requirements WS-R-4 (2006)**
  - (….see paper)
- Generic process for scoping, designing and implementing a repository monitoring programme - the MoDeRn-FP7 project (2010-2014)

Objectives & Parameters
What?

Programme-design
How?

Implementation & Governance
Use?



MoDeRn (2013a), *Monitoring During the Stages Implementation of Geological Disposal: The MoDeRn Project Synthesis*. MoDeRn Deliverable D6.1.

Approach

- All programmes agree that it is impractical to monitor all of the repository
- High-level strategies will be used to monitor specific parts of the repository during the operational period
- In Modern2020 a strategy consists of the following elements:
  - **What:** waste packages and near field; dummy packages and near field; specific EBS elements; the geological barrier; the biosphere
  - **Where:** preparation main repository, pilot repository, underground rock characterisation facility
  - **When:** during construction (baseline for operations); during emplacement; after emplacement; during closure; after closure
  - **How:** the types of technologies used, including *in situ* sensors; borehole-based sensors; surface –based technologies; air-based technologies
  - **"Whom":** operator, regulators, lay stakeholders…

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  - **"Whom":** operator, regulators, lay stakeholders…

Why to monitor?

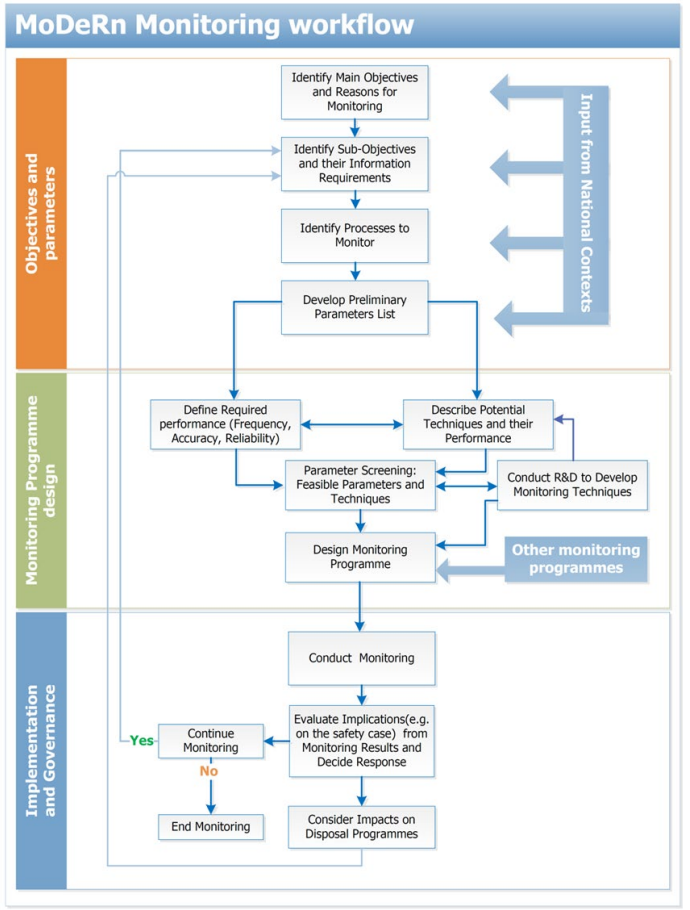
- Definition of **monitoring** (IAEA Safety Standards): "continuous or periodic observations and measurements to help evaluate the behaviour of the components of a waste disposal system and the impact of the waste disposal system on the public and the environment"

- The emphasis placed on different reasons for monitoring the near field during the operational period differ from programme one to another
  - Monitoring may provide an opportunity to demonstrate understanding of the thermal, hydraulic, mechanical and chemical processes occurring, thereby demonstrating WMO **understanding and building further confidence**
  - Monitoring programmes might focus on the short-term evolution of the repository system to show that this **evolution is consistent with the safety case**
  - Monitoring may also provide the means for **continuing to engage with stakeholders** and check the evolution of the disposal system following waste emplacement

WP2 MONITORING STRATEGIES

What to monitor?

- The MoDeRn Project formulated a reference framework and a generic workflow for developing and conducting a monitoring programme
- Further work was required to consider explicitly **how monitoring parameters could be identified**



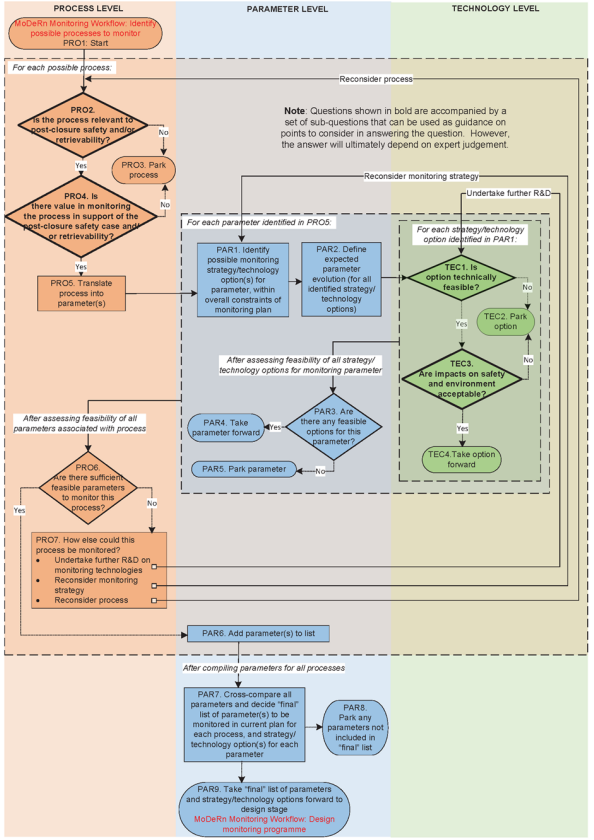
Recommendation from the Nuclear Energy Agency

Monitoring of Geological Disposal Facilities: Technical and Societal Aspects" (NEA, 2014)

- *The current, and justifiable, tendency is to measure as many parameters as possible*
- *With the transition from the repository development stage to implementation, it becomes necessary to optimise the selection of the parameters*
- *The identification of those parameters which would sufficiently demonstrate the attainment or approach to the passive safety status of the disposal system would be of substantial benefit*
- The recommendations of the NEA have been addressed in Modern2020 through the development of a generic structured approach to the selection of parameters
  - The Modern2020 Screening Methodology

The Modern2020 Screening Methodology

- The Methodology is presented as three strands: processes, parameters and technologies
- Starting point is list of processes or parameters that have been proposed for monitoring
- Basis for decisions are judgements based on existing knowledge
- The Methodology is a stepwise process to allow for **traceability and transparency**
- Judgements used as a basis for decisions may change, so processes and parameters are parked and not rejected



Decision making process (use of monitoring Data?)

- Consider how a waste management organisation might plan for responding to monitoring results
- Develop recommendations and observations on responding to monitoring results
  - General guidance and principals, rather than specific plans
- Develop a generic process for responding to monitoring results
- Terminology on performance measures and response plans
- Decision making is a complex process where monitoring is only one input

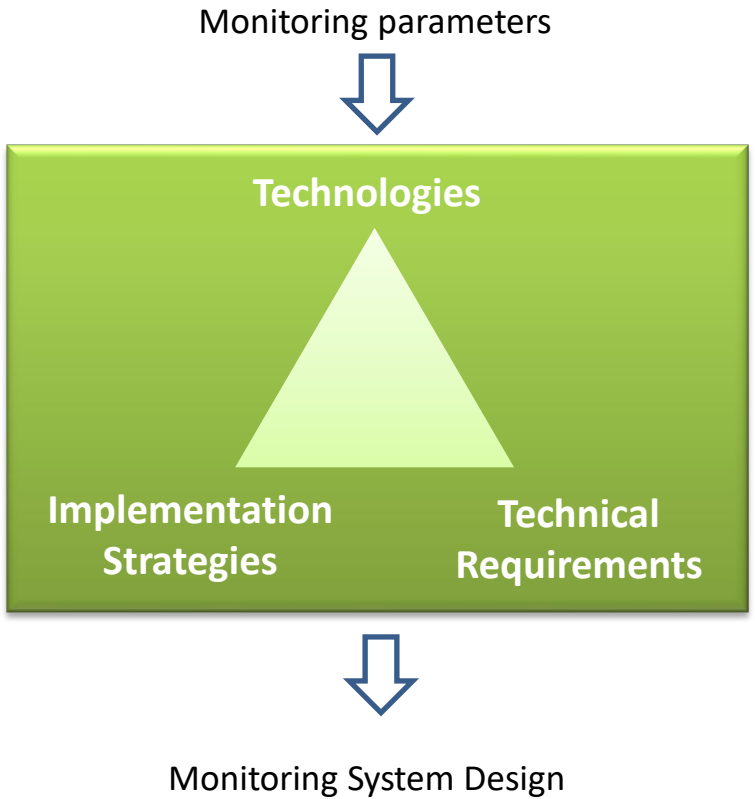
Generic Response	Explanation
Desk-based responses	
Evaluate sensor performance	Re-checking of the raw data from sensors to check that the sensor readings are valid.
Check results	Re-checking the analysis of sensor readings to check that the interpretation of the raw data is valid.
Report results	Notifying stakeholders (including regulators) of results.
Root cause analysis	Evaluating the reasons behind particular monitoring results, focused on results that are not consistent with expectations. This might include, for example, literature review.
Revise models / safety assessment	Modifying THMC and safety assessment models to incorporate new process understanding and/or parameter values.
Update monitoring plan	Revising the monitoring programme, taking into account the results from the monitoring programme to date (and any other information generated during the period since the monitoring programme was last updated).
Monitoring Programme Responses	
Continue monitoring in the same way	Continuing the operation of the monitoring programme using the same method (e.g. using the same number and type of sensors, in the same locations, and with acquisition of data at the same frequency).
Change monitoring	Changes in the monitoring programme could relate to changes in the frequency of data acquisition using the current monitoring system, monitoring the same parameter(s) with additional sensors of the same type (additional redundancy), monitoring the same parameter(s) with different sensors (increased diversity), or monitoring of different parameters.
Disposal Programme Responses	
Change operations	The emplacement of waste could be altered by, for example, placing a temporary halt on emplacement operations, or only emplacing waste of a specific type. Monitoring can also support decisions to move from one phase of repository operations to the next.
Change design	Evaluation of the results from the monitoring programme may be used to underpin decisions to change the design of the repository.
Engineering intervention	Changing the properties of the repository near field through engineering measures such as grouting, in situ vitrification and construction of new barriers.
Reversal / retrieval	Reversal is removing the waste from the disposal location by reversing the original emplacement process (the term is also used to denote the ability to reverse decisions). Retrieval is removing the waste from the disposal location by any means.

WP3 : MONITORING TECHNOLOGIES

How to monitor?

Monitoring technlogies

- Technologies exist but with evident limitation
- Actions to carry out before repository monitoring starts
  - **Adaptation** of the technologies to specific monitoring objectives, host rocks and repository concepts
  - **Innovate** of technologies for monitoring specific parameters
  - **Improvement** of the long-term performance.
- Objectives
  - Accelerate the development of suitable monitoring technologies VS needs
  - Guidance for the monitoring system qualification

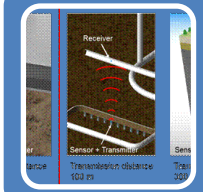


Monitoring technologies (1/3)

Wireless Data Transmission systems

Improve existing short range (tens of meters) wireless systems based on high or medium frequencies (*Arquimea, ENRESA, IRSN & VTT*)

Improve existing long range (hundreds of meters) wireless systems based on low frequencies (*Andra & RWMC*)

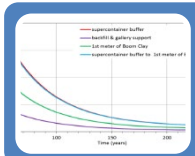


Evaluate the use of a combination of different range wireless systems to provide a complete data transmission solution (*Amberg, Andra, Arquimea, ENRESA, EURIDICE, IRSN, NRG, RWMC & VTT*

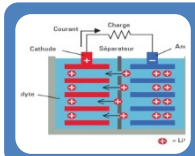
Alternative power supply sources

Nuclear batteries (Orano)

Induction (10m, VTT)



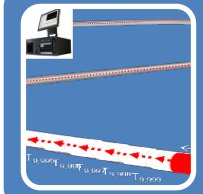
energy harvesting
from small thermal gradients (NRG)



Chemical batteries + ceramic capacitor (Arquimea)

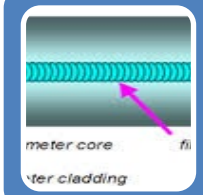
Monitoring technologies (2/3)

Optical fiber technology



Distributed CFO (Andra, EDF,Xlim/CNRS)

- Brillouin, raman, rayleigh
- For temperatute, strain, H2,



Bragg CFO (Umons)

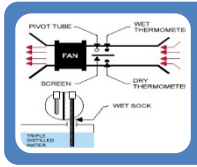
- pH, H2

Calibration method (Nagra)

Active DTS: Heatable fiber-optic cable

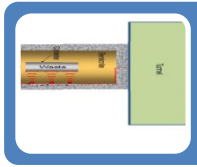
- **Distributed FO system for thermal and mechanical monitoring.**

Innovative sensors



Psychrometer (Amberg, Arquimea)

- Water content



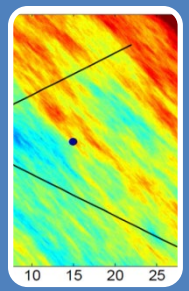
Non-contact displacement measurement (ENEA)

Chemical measurements: selection of ion electrode and prelimenary evaluation

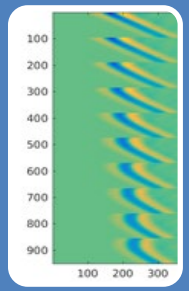
- Smart cell THMC

Monitoring technologies (3/3)

Improvement of seismic full waveform inversion technologies



Seismic waveform inversions (ETH)



Anomaly detection algorithms (TUL)

Development of a method based on combined Electrical Resistivity Tomography and Induced Polarisation Tomography, VTT & U. Strathclyde

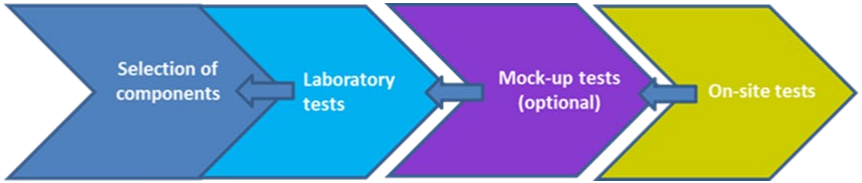
Combined (3D/4D) Electrical Resistivity and Induced polarization Tomography (ERT/IPT) techniques in order to monitor water content changes in 3D in the buffer-backfill-bedrock systems, (VTT)

Diffuse non-intrusive monitoring of the EBS based on combined Electrical Resistivity Tomography (ERT) and Induced Polarisation Tomography (IPT), (U. Strathclyde)

Guidance for the monitoring system qualification

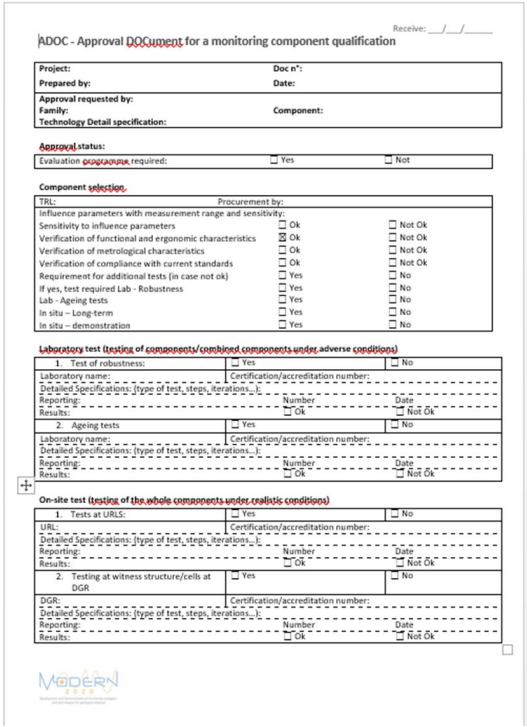
a common multi-stage qualification methodology

- Strong synergy between Energy, Space fields and DGR needs with a qualification process in 3 stages: i) Selection of components, ii) The laboratory qualification and iii) On-site qualification



Global sketch for the qualification of monitoring components in DGRs

Proposal of an Approval DOCument (ADOC) for a monitoring component qualification



ADOC - Approval DOCument for a monitoring component qualification

Receive: __/__/____

Project:	**Doc n°:**
Prepared by:	**Date:**
Approval requested by:	
Family:	**Component:**
Technology Detail specification:	

Approval status:

Evaluation programme required:	☐ Yes	☐ Not

Component selection

TRL:	Procurement by:	
Influence parameters with measurement range and sensitivity:		
Sensitivity to influence parameters	☐ Ok	☐ Not Ok
Verification of functional and ergonomic characteristics	☒ Ok	☐ Not Ok
Verification of metrological characteristics	☐ Ok	☐ Not Ok
Verification of compliance with current standards	☐ Ok	☐ Not Ok
Requirement for additional tests (in case not ok)	☐ Yes	☐ No
If yes, test required Lab - Robustness	☐ Yes	☐ No
Lab - Ageing tests	☐ Yes	☐ No
In situ – Long-term	☐ Yes	☐ No
In situ – demonstration	☐ Yes	☐ No

Laboratory test (testing of components/combined components under adverse conditions)

1. Test of robustness:	☐ Yes	☐ No
Laboratory name:	Certification/accreditation number:	
Detailed Specifications: (type of test, steps, iterations...):		
Reporting:	Number	Date
Results:	☐ Ok	☐ Not Ok
2. Ageing tests	☐ Yes	☐ No
Laboratory name:	Certification/accreditation number:	
Detailed Specifications: (type of test, steps, iterations...):		
Reporting:	Number	Date
Results:	☐ Ok	☐ Not Ok

On-site test (testing of the whole components under realistic conditions)

1. Tests at URLS:	☐ Yes	☐ No
URL:	Certification/accreditation number:	
Detailed Specifications: (type of test, steps, iterations...):		
Reporting:	Number	Date
Results:	☐ Ok	☐ Not Ok
2. Testing at witness structure/cells at DGR	☐ Yes	☐ No
DGR:	Certification/accreditation number:	
Detailed Specifications: (type of test, steps, iterations...):		
Reporting:	Number	Date
Results:	☐ Ok	☐ Not Ok

WP4 IN SITU DEMONSTRATIONS

How to monitor?

Why Demonstration ?

Implementation of monitoring set-ups at real scale, and at (geotechnical) conditions similar to a repository, offers a tangible environment to assess the topics investigated / developed in the Modern2020 project

- the monitoring strategy concepts
- the (innovative) monitoring technologies
- the (public) stakeholder engagement

In addition, it provides, in itself, also relevant input on the factors that determine the succesful performance of a monitoring system, such as:

- installation and interaction with construction
- long-term management of monitoring systems

- Evaluate monitoring system
  - Using monitoring technologies with high Technological readiness level (TRL)
  - With innovative solution

EBS monitoring plan (KBS-3V, Posiva)

AHA experiment (monitoring THMC evolution on HLW cells prototype ,Cigeo concept, Andra)

LRTBM (monitoring seals, IRSN)

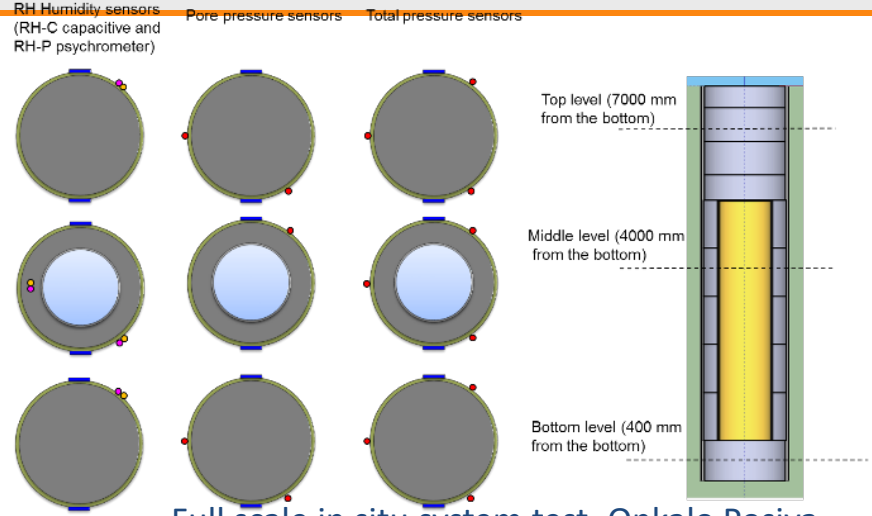
FE experiment (monitoring of the THM evolution of the EBS and the host rock, Nagra)

Evaluate possible monitoring design

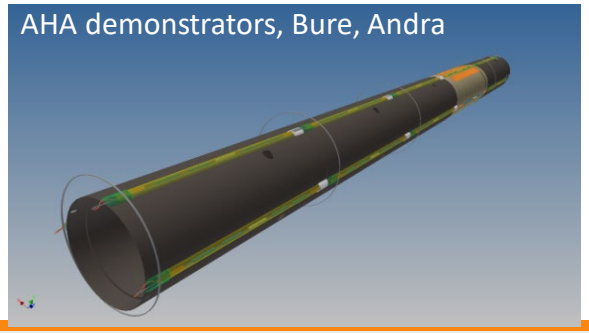
Evaluate possible monitoring design

Implement monitoring design using monitoring technologies with high Technological readiness level (TRL)

- Evaluate practical aspect (duration, implementation methods)
- Evaluate cost
- Evaluate of the monitoring on the safety



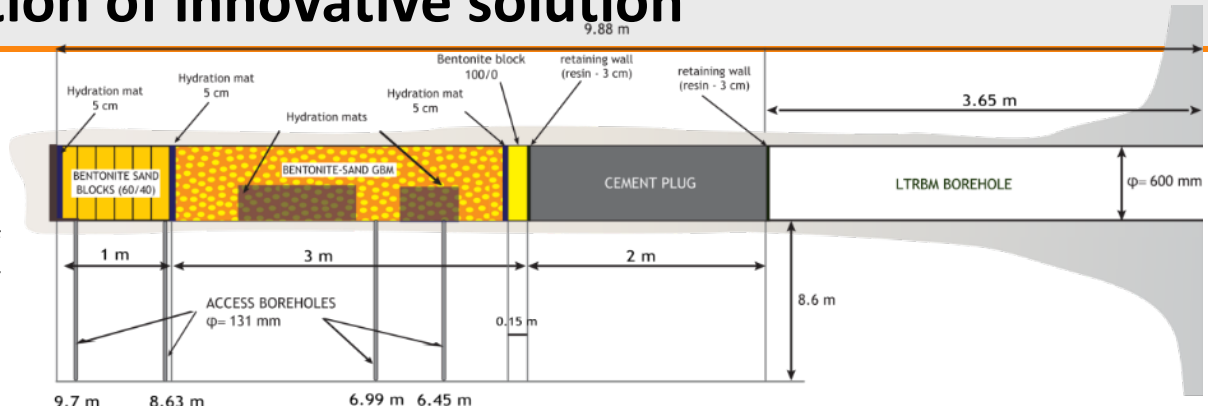
Full scale in situ system test, Onkalo Posiva

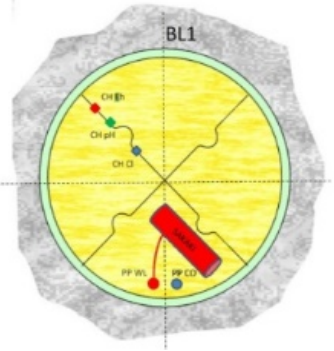


Evaluation of innovative solution

Long-Term Rock Buffer Monitoring experiment (LTRBM)

Objectives: LTRBM experiment is intended to test new monitoring solutions developed in WP3 of Modern2020 to assess their performance under real in situ conditions, e.g. inside an Engineered Barrier System (EBS), to demonstrate a full wireless data transmission from the EBS borehole to the earth's surface and to assess commercial sensors that have never been tested in a bentonite buffer

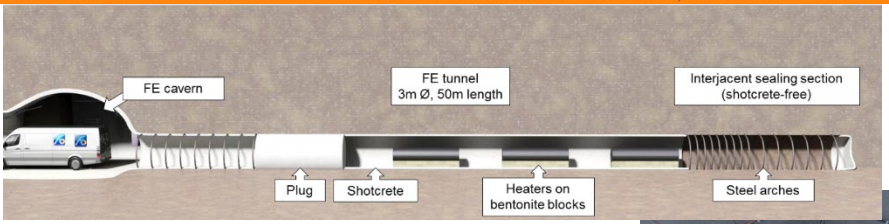




New measuring instruments from partners

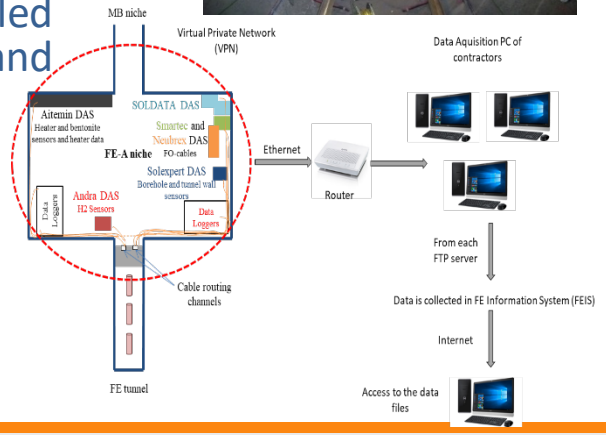
- ***Chemical sensor*** *based on measurements of potential difference between an ion-selective electrode and a reference electrode (measuring electrodes pH, Eh and Cl^-) provided by* ***VTT*****_WP3**
- ***Thermocouple Psychrometers*** *(measures suction using dew point method) attached to a wireless transmitter provided by* ***ARQUIMEA*** *(4 units)*_**WP3**
- ***THMC smart sensor*** *(measures total pressure, pore pressure, temperature and relative humidity) provided by* ***CTU*****_WP3**
- ***Total pressure*** (based on fibre optic technology) *provided by* ***Andra*** *(4 units)*
- ***Pore water sensors*** *(vibrating wire for pore pressure measurements and electrical resistivity for temperature) attached to a wireless transmitter provided by* ***Andra*** *(2 units)*

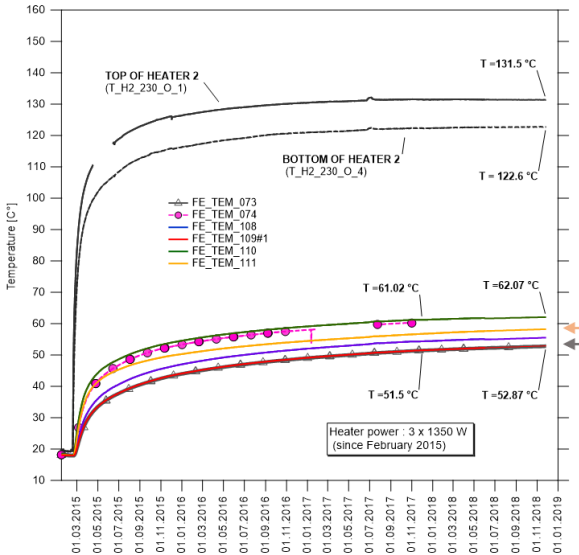
FE experiment

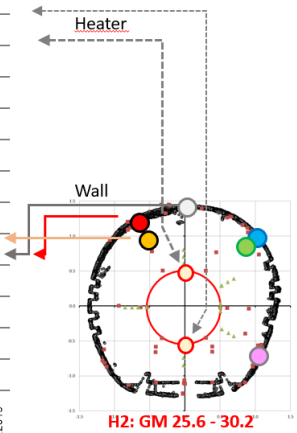


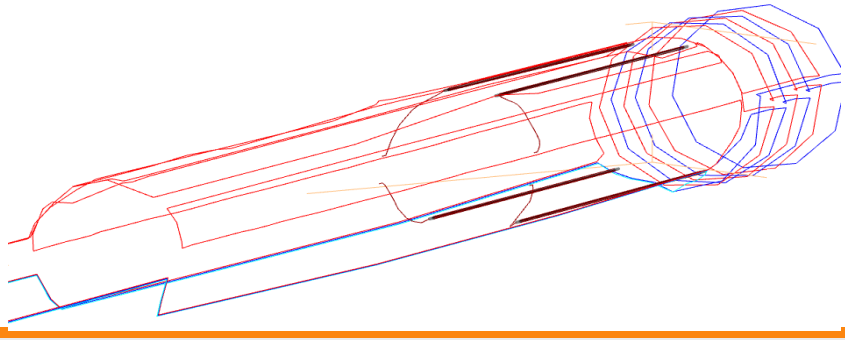
- Fibre-optic cables for distributed strain and temperature sensing (cables with single and/or multimode fibres) were installed at FE tunnel wall and in boreholes.

- Challenge on data treatment









WP5: public Stakeholders

- To **actively engage** local public stakeholders (people in concerned communities) in repository monitoring RD&D within the Modern2020 project, and to **analyse the impact** this has on both the participating stakeholders' and the project partners' understanding of, and expectations regarding, repository monitoring

- To **define** more specific **ways for integrating public stakeholder concerns and expectations** into specific repository monitoring programs

- To **develop ideas on how to ensure accessibility and transparency of monitoring data** (of the type gathered through in-situ monitoring) to public stakeholders

- To **learn lessons** on how local stakeholder groups could be engaged effectively with RD&D programs and projects **at EU level**.

Responsible research and innovation (RRI)

Responsible research and innovation (RRI)

- RRI pushed by the EU
- RRI: “societal actors work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of society” (Horizon 2020 website)
- RD&D should be anticipatory, inclusive, responsive, reflective, and sustainable
- Modern2020 has tried to adapt to RR

- ‘Home engagement activity’ (making use of existing configurations; in collaboration with respective NWMO)
  - Municipality of Eurajoki (Finland), Municipality of Östhammar (Sweden), Local partnerships in Mol and Dessel (Belgium), Clis de Bure (France)
  - Belgium and Sweden from the start; Finland and France to follow later
  - ‘Activity level’ influenced by national programme (cf. environmental court process in Sweden)

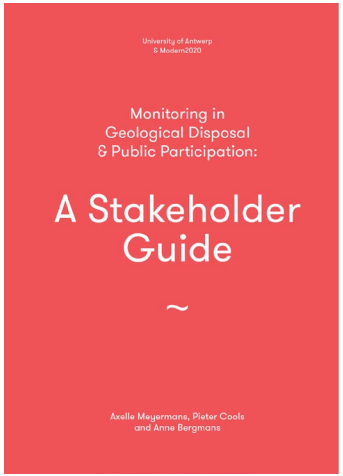
Specific outputs

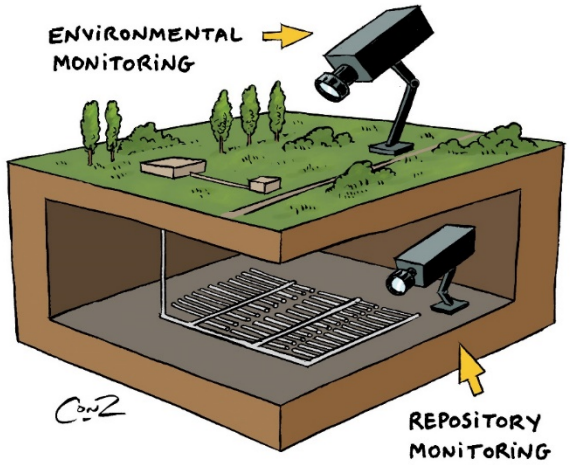
More reflective and analytical

- Monitoring the Underground: Specific Challenges for Engaging Concerned Stakeholders (D5.1)
- Lessons learned from engaging with local citizens in an international R&D project (D5.3)

More practical

The Stakeholder Guide to Repository Monitoring (D5.2)





Dissemination

2nd International Conference on Monitoring in geological disposal of radioactive waste

Strategies, technologies, decision making and public involvement

150 participants 15 countries
90 organizations 43 speakers

All presentation is available on Modern2020 website

Training school about monitoring

Learning unit 1 : Nuclear fuel cycle and geological disposal concept
Learning unit 2 : Monitoring : objectives, process and parameters
Learning unit 3 : Monitoring program design
Learning unit 4 : Implementation and governance

Conclusion

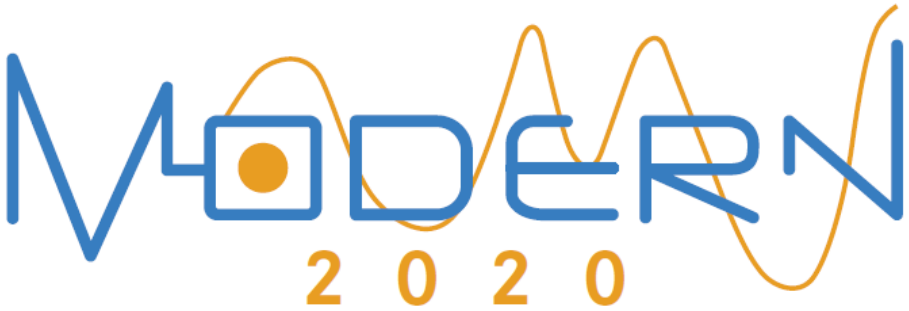
- The Modern2020 Project has enhanced our ability to implement, both strategically and technically, repository monitoring during the operational phase to build further confidence in the post-closure safety case
  - international consensus on strategies, parameter-selection methodologies and plans for responding to monitoring result
  - Identify and accelerate the R&D on monitoring technologies
  - Real test cases
  - the work on stakeholder engagement in the Modern2020 Project has been successful and has identified innovative methods for early engagement of stakeholders in the development of monitoring programmes
    - Both groups benefitted from the interaction, especially as it was a long-term interaction over the course of the four-year Project

Further Work

- The key requirement now, is for the guidance to be applied in specific programmes, and for detailed operational phase monitoring programmes to be developed.
  - Common strategy : Pilot phase, industrial pilot phase, first emplacement field, Full-Scale *In Situ* System Test….always heavy monitoring system
- the new monitoring techniques provide much more information (huge amounts of digital or analog data) that the standard data acquisition systems can not properly handle. Furthermore, the fast spreading of the BIM (Building Information Modelling) technologies to all kind of civil works will demand to integrate the monitoring data as part of the digital model of the future repository.

Acknowledgement

9th European Commission Conference on EURATOM Research and Training in Safety of Reactor Systems
Pitesti, Romania, 4-7 June 2019



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