LUCOEX - FINAL REPORT

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LUCOEX

(GRANT AGREEMENT: 269905)

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Final Report LUCOEX

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EURATOM

Publishable Summary

Four advanced waste management programmes in Europe have as part of their step-vice development of repository concepts for long-lived radioactive waste come together in the LUCOEX project with the common objective to demonstrate the technical feasibility of certain vital deposition sequences for a safe and reliable disposal of radioactive waste in geological formations.

This demonstration has been done by executing four parallel experiments at different underground research laboratories ; all designed for the specific purpose of developing these kind of underground facilities. Each experiment has focused on different concepts and different geological and technical/legal pre-conditions and all experiments have been executed with a focus on openness and willingness to share the knowledge gained to support the development of safe and reliable repositories throughout Europe.

At the Bure underground research laboratory in France Andra has demonstrated the construction feasibility of a complete HLW cell in Callovo-Oxfordian clay with a concept optimized for a possible future retrieval of the waste. As a secondary objective Andra has developed a better understanding for the cell and its mechanical behaviour under thermal loading as well as the thermo-hydro-mechanical (THM) behaviour of the surrounding rock, mainly in terms of the overpressure caused by the heating phase.

Andra's counterpart in Switzerland, Nagra, has performed the FE-experiment at the Mont Terri underground research laboratory, which is a full-scale, multiple heater test in Opalinus Clay. The experiment includes a) the verification of the technical feasibility of constructing a repository tunnel using standard industrial equipment, b) the optimization of the bentonite buffer material production, and c) the investigation of (horizontal) canister and buffer emplacement procedures at underground conditions including the development of key machinery. A secondary goal (not part of LUCOEX) was to investigate the coupled THM effects onto the host rock to validate existing THM models.

The excavations of horizontal disposal tunnels with vertical disposal positions in crystalline rock, KBS-3V, are planned to be constructed using conventional technology.The sealing is studied in the EU-project DOPAS. In LUCOEX Posiva has at the Onkalo underground rock characterization facility (URCF) in Finland focused on disposal issues for this concept including a) development of the final prototype machinery necessary for the transportation and installation of buffer components, b) method and tools for filling the gap between the bentonite blocks and the host rock with bentonite pellets, and c) methods and strategies for quality assurance and problem handling. The work in Finland was finalized with a successful full-scale installation using the developed machinery and concepts.

An alternative strategy developed for the disposal in crystalline rock is to place the canisters horizontally in drifts, KBS-3H. The process is newer and it has the potential to become more robust from deposition point of view and more cost efficient than "vertical disposal", but it isn't as mature as the KBS-3V concept and requires more development work. In this project SKB has shown at the AEspoe Hard Rock Laboratory (HRL) that it is technically feasible to a) drill straight enough pilot holes for horizontal disposal drifts; b) manufacture the necessary buffer components; c) assemble all components including the Supercontainer; d) deposit bentonite components and the Supercontainer and finally e) seal and monitor the activities within the drift. The secondary goal for SKB is to investigate the early buffer evolution in the drift to update existing material models.

The final component of the LUCOEX project has been the dissemination of our findings. This has been done through a) making it possible to visit the experiments at the underground research laboratories, b) presenting our results and findings through scientific articles and presentations at conferences, c) producing movies from the different experiments, d) hosting conferences and workshops, and e) providing a scholarship programme to give external parties the possibility to participate both in hosted events and on site during the experiments.

Contents

1 Final publishable summary report

1.1 Context and Objectives

The European Council outlined the following objective for the research area "Management of radioactive waste":

> *"Through implementation-oriented RTD, the activities aim to establish a sound scientific and technical basis for demonstrating the technologies and safety of disposal of spent fuel and long-lived radioactive wastes in geological formations ..."*

The radioactive waste disposal implementers within the LUCOEX project (SKB, Andra, Nagra and Posiva) have addressed these objectives by implementing a joint collaboration project which meets the FP7 work programme theme of Fission-2010 1.1.1. The experiments included in the project have shown the technical suitability of the different emplacement concepts and provided increased understanding of technical feasibility and added knowledge regarding the early evolution of some of the concepts important for the long-term safety.

Important experience has also been gained regarding testing and improving of methods, equipment, technologies, processes and operability related to the construction, component manufacturing, operation and closure of repository systems.

The key technical areas addressed have been: disposal gallery construction, manufacturing and emplacement of buffer, emplacement of simulated canisters, backfilling and sealing of galleries.

1.1.1 Detailed objectives: Work Package 1

The objectives for Work Package 1 have been to continuously integrate the results of the different demonstration activities and to disseminate the obtained knowledge by:

- Providing a broad base for integrated planning, evaluation and reporting of the outcome.
- Communicating technical findings and conclusions drawn during progress.
- Support networking among scientists and engineers with focus on creating forums for presenting and discussing the LUCOEX project.
- Invite representatives working with concepts not studied, to discussions on the findings.
- Providing training opportunities by hosting activities e.g. at respective underground rock laboratory carrying through demonstration activities.
- Provide programme for exchange staff between participating organizations for information transfer on performed demonstration activities.
- Invite and support travel and lodging of students to participate at hosted events.
- Publish results in technical magazines and at specific seminars/conferences.

1.1.2 Detailed objectives: Work Package 2

The objectives for Work Package 2 and the FE-experiment at Mont Terri have been to:

- Verifying the technical feasibility of constructing a repository tunnel using standard equipment
- Optimization of the bentonite buffer material production
- Investigation of (horizontal) canister and buffer emplacement procedures in situ
- Investigation of THM coupled effects onto the host rock incl. verification of modelling

1.1.3 Detailed objectives: Work Package 3

The objectives for Work Package 3 and the ALC-experiment at Bure has been to:

- Construct a HWL-cell consistent with the 2009 benchmark concept including both cell head and the usable part.
- Verify the function of the cell head insert and its ability to absorb the thermal dilation of the cell stainless steel casing.
- Provide data on the casing behaviour under actual thermal load.
- Verify the design of the cell head and its ability to limit the thermal gradients on the drift wall.

In addition to the planned LUCOEX deliverables this work package has also provided additional deliverables:

- Initial data report after one year.
- Initial data report after two years.

1.1.4 Detailed objectives: Work Package 4

The objectives for Work Package 4 and the MPT at AEspoe has been to:

- Test the system components in full scale and in combination with each other to obtain an initial verification of design implementation and component function.
- This includes the ability to manufacture full scale components, carry out installation (according to DAWE) and monitor the initial system state of the MPT and its subsequent evolution.

In addition to the original objectives related to the MPT a drilling activity has also been added to LUCOEX with the objectives to:

- Demonstrate the ability to drill long, straight horizontal pilot holes in crystalline rock using guided core drilling technology.

1.1.5 Detailed objectives: Work Package 5

The objectives for Work Package 5, developing and demonstrating the final prototype machinery at Onkalo URCF and participating in the MPT at AEsoeö has been to:

- Design, Develop and manufacture emplacement machines.
- Design, Develop and manufacture pellet installation equipment.
- Demonstrate the full-scale emplacement of both buffer and pellet in-situ.
- Develop quality assurance processes.
- Develop problem handling during installation.

1.1.6 Detailed objectives: Work Package 6

The objectives for Work Package 6, managed by SKB, has been to:

- Set up the both physically and virtually infrastructure to coordinate the project activities
- Help organize and balance the LUCOEX work and activities.
- Facilitate and support the organization and management of the different work packages.
- Supervise the production of necessary documentation for the LUCOEX, to provide means of quality controlling them and to publish them, including open access.
- Disseminate results to the scientific and engineering communities and to the public.
- Act as an information and communication center about the activities of the LUCOEX.

1.2 Scientific and Technical Results

The Scientific and Technical results from the LUCOEX project are provided in detail within the deliverables from the project, which are published on the LUCOEX homepage http://www.lucoex.eu. In this summary we've just listed the key results from the technical work packages: WP2-WP5. Further detail regarding the both these work packages and WP1+WP6 are available in LUCOEX deliverable D1.21 (WP1+WP6), D2.6 (WP2), D3.4 (WP3), D4.4 (WP4) and D5.9 (WP5).

1.2.1 Key Results Work Package 2

Area	Status
Construction and Excavation	Excavation and reinforcement of disposal tunnels using standard machinery has been shown.
Component Manufacturing	Extensive research has shown how to produce an optimized granulated bentonite mixture and highly compacted bentonite blocks.
Installation	Pedestal design and use of highly compacted blocks have been shown viable. As a consequence of the THM objective of the experiment, the emplacement procedure was not done according to the Swiss concept.
Sealing and Closure	A backfilling machine was designed and proved useable to install the backfill material with the required density. Further developments are required to control the density and its homogeneity.

Table 1: WP2 Status of concept and Key results

The Full-Scale Emplacement (FE) Experiment at the Mont Terri underground rock laboratory (URL) is a full-scale multiple heater test in a clay-rich formation ('Opalinus Clay'). It simulates the construction, waste emplacement, backfilling and early post-closure evolution of a spent fuel (SF) / vitrified high-level waste (HLW) repository tunnel as realistically as possible.

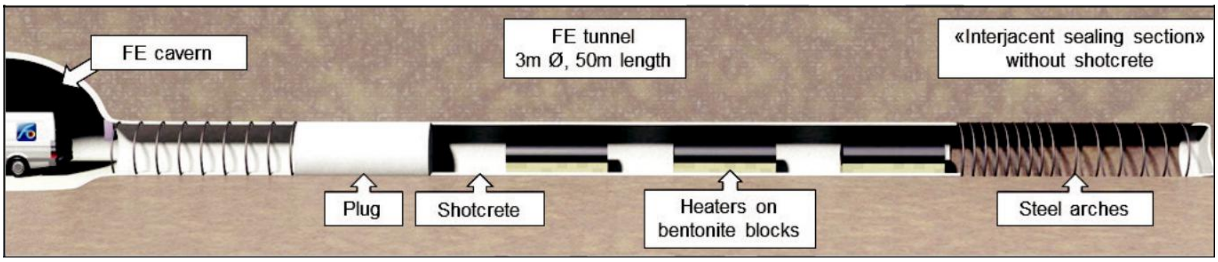


Figure 1: Visualization of the general experimental layout of the Full-Scale Emplacement (FE) experiment at the Mont Terri URL; sensors and bentonite backfill are not displayed

The overall objective of Nagra's participation in the FP7 EURATOM Project LUCOEX was to demonstrate, on a 1:1 scale, the Swiss repository concept for the disposal of SF and HLW in Opalinus Clay. This includes:

- Verifying the technical feasibility of constructing a repository tunnel using standard equipment
- Optimization of the bentonite buffer material production
- Investigation of (horizontal) canister and buffer emplacement procedures in situ
- Investigation of THM coupled effects onto the host rock incl. verification of modelling

Construction and Excavation

The FE experiment is based on the Swiss disposal concept for SF / HLW.

The rock mass in the 'far-field' was instrumented with 45 meter long boreholes drilled from the FE cavern during 2012 before the FE tunnel was built and therefore allowed a 'mine-by' observation of the later tunnel excavation.

The construction of the 50 m long experimental tunnel with a diameter of approximately 3 m was completed in September 2012 using conventional equipment. During construction the 'excavation damage zone' (EDZ) was instrumented with radial boreholes drilled from within the tunnel. Additionally the tunnel construction was surveyed with a total of ten convergence measurement sections which were installed during the excavation within the FE tunnel with an average spacing of approx. 6 meters. At the far end of the tunnel the so-called ‘interjacent sealing section‘ (ISS) was built using only steel arches for rock support whereas the rest of the tunnel was supported by shotcrete.

Component Manufacturing

After re-assessing the range of possibilities for backfilling materials only natural (non -activated) sodium bentonite from Wyoming was used for the FE experiment. The backfill in the Swiss concept is based around both highly compacted buffer blocks and a bentonite pellet mixture.

The first step of the manufacturing process was the test production with varying production parameters to optimize density and water content in order to provide mechanical stability and long-term integrity of the blocks. Only thereafter, approx. 3’000 highly compacted bentonite blocks, each block with an average weight of approx. 24.5 kg, an average dry density of approx. 1.78 t/m^3 and an average water content of approx. 18 %, were produced. After several additional parameter optimization tests approx. 350 tons of a highly compacted and granulated bentonite mixture (GBM) were produced. The average dry “pellet” density of approx. 2.18 t/m^3 and with a very broad “pellet” size distribution, a so-called Fuller-type distribution, an overall bulk dry emplacement density of at least 1.45 t/m^3 could be achieved.

Installation

The first step in the installation process was the filling of a full 2 m long section with bentonite blocks in the ISS followed by the stepwise construction of the bentonite block pedestals, emplacement of the heaters on top of the pedestals and backfilling of the remaining open volume with granulated bentonite mixture. In the FE tunnel three heaters were emplaced with dimensions similar to those of waste canisters.

The three heaters were installed following the construction of the pedestals as seen in Figure 2. Finally a large amount of additional sensors were installed for observation of the bentonite buffer. They are not part of the repository concept but are installed for the THM-experiment following the proof-of-concept installation. A high degree of redundancy was pursued by using a variety of sensor technologies. The technologies used may also hint towards a monitoring arrangement in a future pilot repository as foreseen in the Swiss concept.

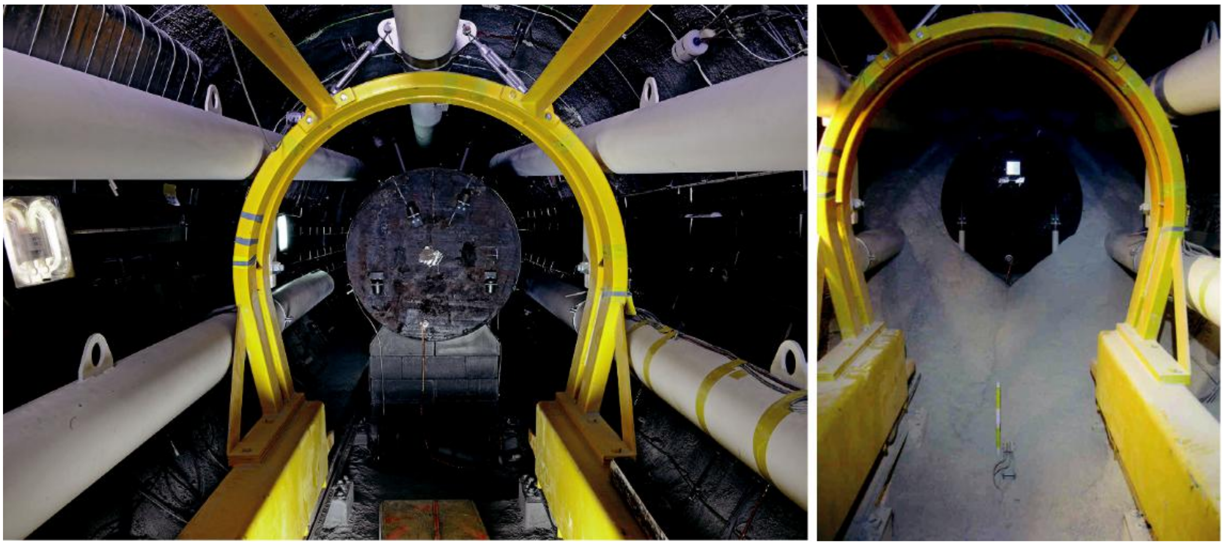


Figure 2: Backfilling machine with screw conveyors driving over the heater and its pedestal (left, photo by COMET) and during backfilling operation (right)

Backfilling and closure

The backfilling part of this project consisted of two parts: the creation of a backfilling machine (Figure 3) and the actual backfilling of the tunnel.

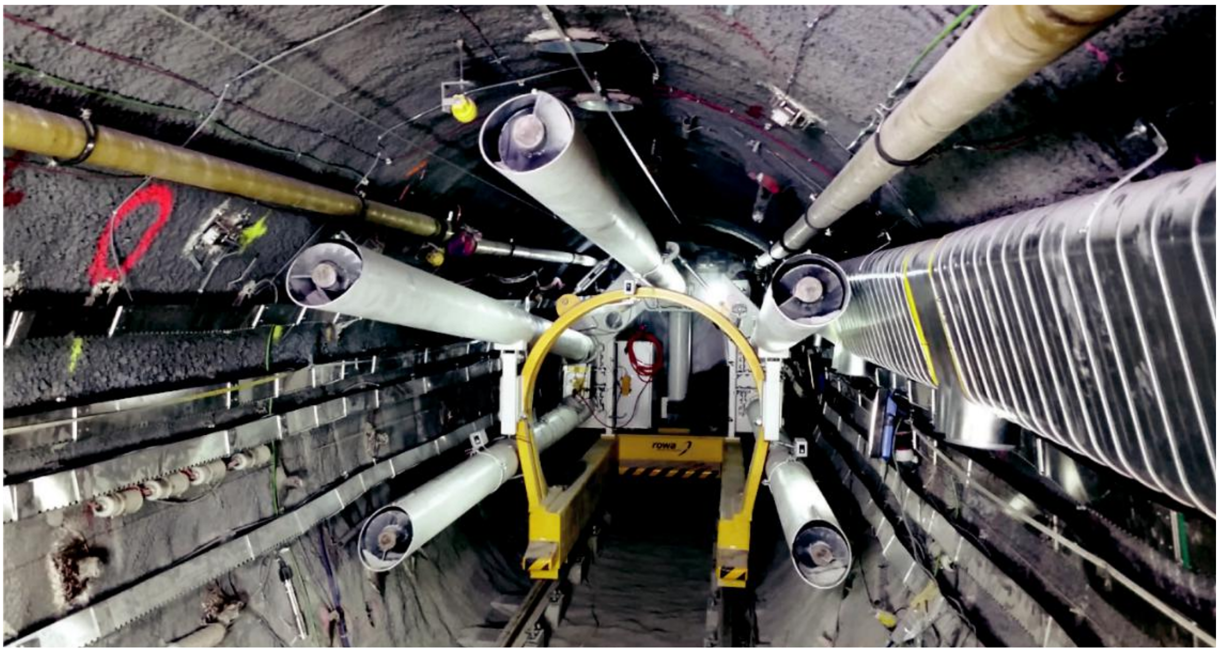


Figure 3: Five screw conveyors on the backfilling machine in the FE tunnel (photo by COMET)

The focus for the development of a prototype backfilling machine for backfilling horizontal tunnels was to achieve as dense and homogenous backfill installation as possible. The machine which was manufactured here was optimized to fit into the small diameter FE tunnel. It transports, emplaces and compresses the GBM using five auger conveyors working simultaneously. All relevant parameters such as the backfilling speed and the backfilling pressure can be controlled individually.

After an extensive design and manufacturing process; the prototype machine was successfully tested in two full-scale pre-tests in May and August 2014. Finally it was successfully used to backfill the FE tunnel with approximately 255 tons of GBM between September 2014 and January 2015. In some segments a bulk dry density of up to 1.56 t/m^3 was achieved. At the pre-tests, where the density measurement were performed with different methods and with a better spatial resolution, a 'local' bulk dry density of up to approximatel 1.70 t/m3 was measured close to some auger outlets.

Finally the experiment was sealed off towards the FE cavern with a concrete plug holding the buffer in place and reducing air and water fluxes.

Heating & monitoring

After the emplacement and the consequent backfilling of the first and deepest heater, the heating was started. With an initial heat output of 1,350 Watt per heater a temperature of approx. 130-150°C at the heater surface and around 60°C at the rock surface are expected for the FE experiment at Mont Terri after 3 years. According to current planning, the heating and monitoring phase of the FE experiment at Mont Terri is envisaged to last at least 10 to 15 years.

Work package conclusions

Lots of experience were gained during the excavation, installation and sealing of this proof-of-concept experiment where parts of the Swiss concept have been successfully demonstrated. With the continued monitoring of the thermal evolution the understanding of the THM-processes necessary for developing the safety case for the repository concept will be improved. Other key reaming tasks include the development of additional machines to increase the automation level in the repository.

1.2.2 Key Results Work Package 3

Area	Status
Construction and Excavation	Some limitations were identified in regards to secondary systems when drilling the disposal cell. It was however shown that excavation is possible with readily available technology.
Component Manufacturing	Component necessary for the creation of a steel lined HLW-cell supporting retrievability was manufactured. No clay components are, however, used in this concept.
Installation	Installation of steel liners and the operation of a the HLW cell has been demonstrated for "H0" waste (packages installed without spacing buffers).
Sealing and Closure	The sealing and closure is investigated in the DOPAS project.
Additional deliveries	The project has developed a better understanding of the THM behaviour of the cell and we are now able to compare simulations with the actual THM-processes in the host rock.

Table 2: WP3 Status of concept and Key results

The main aims of ALC full scale emplacement experiment performed within the context of WP3 were to demonstrate the construction feasibility of a High-Level Waste (HLW) cell representative of the Andra 2009 benchmark concept, perform the installation of five heaters simulating the waste packages and determine the impact of a thermal loading on the overall behaviour of the cell.

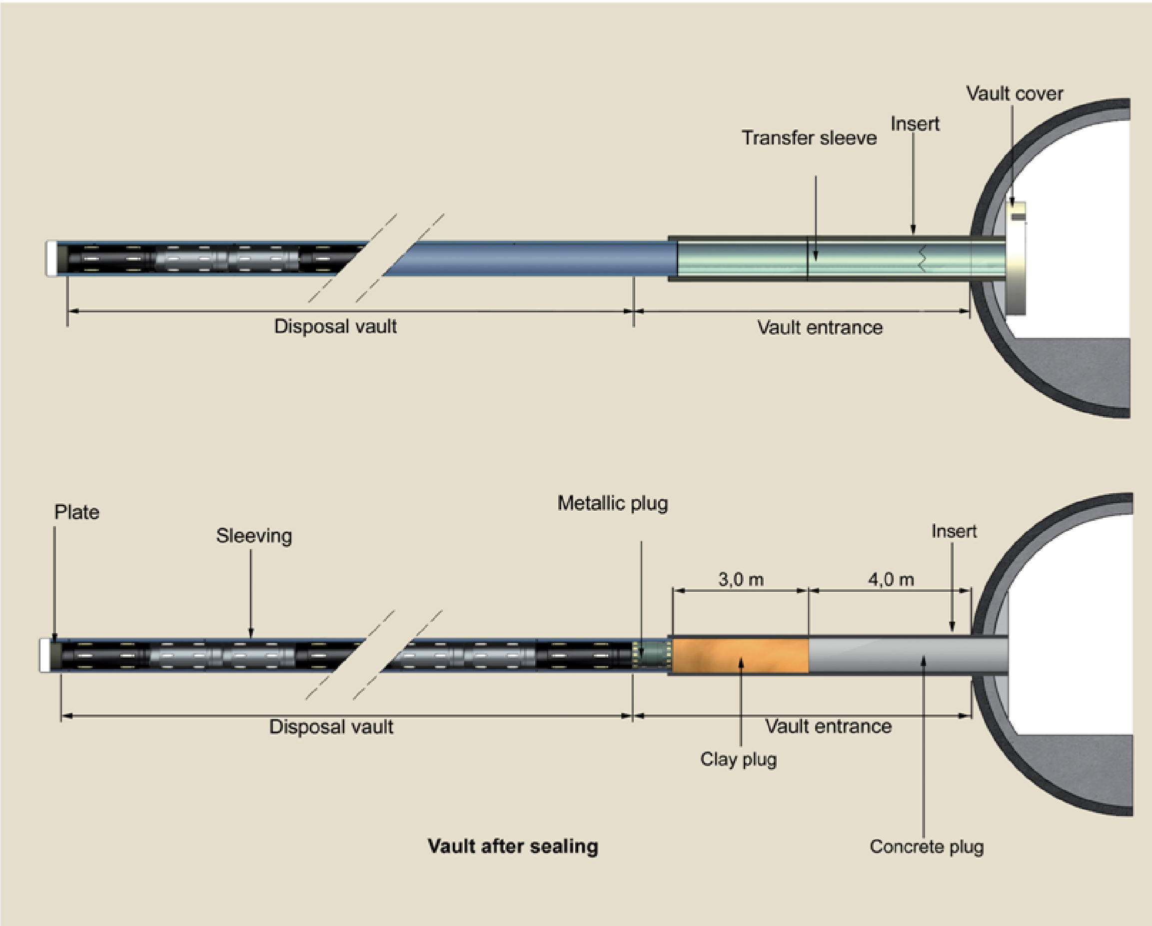


Figure 4: Schematic diagram of a HLW cell according to the 2009 French benchmark concept

Construction and Excavation

According to Andra’s 2009 benchmark concept, the HLW cell is a micro-tunnel which is approximately 40 m long and 0.7 m in diameter. It comprises a “useful part” (approx. 30 m) for package disposal and a 10-metre-long cell head. They are to be favourably aligned with respect to the natural mechanical stress field.

The useful part of the disposal cell, where the packages are placed, has asteel sleeve. The cell base is closed off by a “base plate”, also made of pure iron. A metal radiation-protection plug separates the cell head from the useful part. The cell head has a metal sleeve (called the “insert”). The insert is partly backfilled with a swelling-clay plug and then sealed with a concrete plug to provide additional safety. This final configuration corresponds to the period after cell operation and sealing.

The HLW-cell for this demonstration was excavated in two phases where a 6m long head section was first excavated with a speed of 0.35 meters per hour. This cell head is equipped with an insert 767 mm in external diameter (i.e. an annular space 12 mm wide at the radius) and 21 mm in thickness. The useful section of the cell was then excavated at a speed of 0.46 meters per hour and equipped with a sleeve 700 mm in external diameter (i.e. an annular space 12 mm wide at the radius) and 20 mm in thickness. The rig and processes for this drilling was previously developed within the national programme in France.

Even though the thrust remained low throughout the drilling we had a minor failure during the last 700 mm requiring intervention by personnel inside the cell.

Figure 5: (left) Drilling station in gallery. (right) Drill head in position

Installation

After excavation the following components have been installed :

- A base plate, a sleeve head plate and an insert head plate .
- More than 150 sensors which were installed on the casing including:
    - strain gauges sectors at the sleeve intrados,
    - rock/sleeve clearance measurements,
    - relative humidity/temperature sensors in the annular space in the useful part and in the insert,
    - convergence sensors for measuring the horizontal and vertical convergence of the sleeve and insert, and
    - two temperature profiles are measured.
- Five heater elements, each of which is three meters in length and 508 mm in diameter.

Figure 6: (left) View of a heater element when it is installed.(right) View of a heater/sleeve distance variation sensor section

The instruments peripheral to the cell including nine boreholes drilled from the GAN access drift and the NRD perpendicular drift to monitor the temperature, the pore pressure and the deformation of the surrounding rock, have been installed prior to the cell excavation.

Sealing and closure

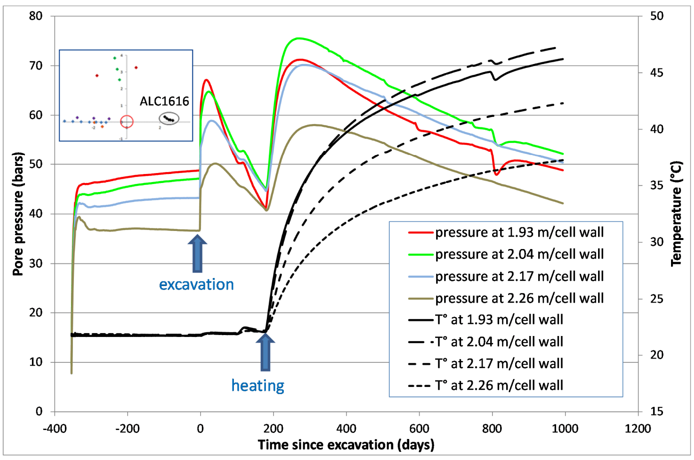
The sealing and closure of the proof-of-concept installation were simplified, as the components for this are investigated in the DOPAS project. In LUCOEX we installed a plug at the head of the useful section (representing the radiological protection plug) and a closing plate at the head of the insert. This allowed us to more efficiently handle the cabling necessary for the THM-experiment following the installation.

Additional studies

After performing the proof-of-concept installation we directly continued with the THM experiment. The heating phase began with a constant 220 W/m power supply for the 15 m occupied by the heater elements, at a depth of between 10 and 25 m into the cell. This power was calculated so that a temperature of 90°C would be reached at the sleeve wall in 2015.

After 2.5 years of measurements, the loss of sensors is less than 10%, mainly due to the thermal loading. The heating system has an acceptable reliability with only 4 minor failures in 2 years caused by the control cabinet fans failing.

The hydro-mechanical impact of the cell excavation, monitored on the peripheral boreholes, is consistent with the measurements taken during the excavation of the previous cells parallel to the major horizontal stress. Indeed, the excavation leads to pore pressure increase in the horizontal plane of the cell and to pore pressure drops in the vertical plane.



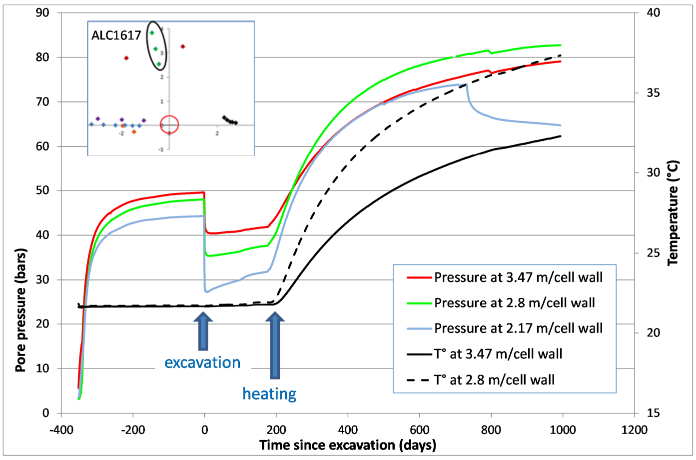


Figure 7. Pore pressure and temperature evolution in the ALC1616 borehole in the horizontal plane of the cell (left) and in the ALC1617 borehole in the vertical plane of the cell (right)

This difference in behaviour between the two directions is directly related to the anisotropy of mechanical properties of the Callovo-Oxfordian claystone.

Despite an initial annular space of 25 mm, the sleeve is subjected to a mechanical loading no later than 2 months after the drilling. This phenomenon can be explained by the partial filling of the annular space by rubble. The mechanical loading applied by the rock is localized in the horizontal direction (corresponding to the maximum extension of the fracture network around the cell) resulting in a radial bending of the sleeve. A similar loading process has already been observed on the sleeve of full scale cells as well as on reduced scale tubings having the same orientation.

The THM impact of the thermal loading on the surrounding rock mass is consistent with the results obtained in previous reduced scale heating experiments. The heating leads to overpressures related to the difference in thermal expansion coefficient between pore water and rock, both in the horizontal plane and in the vertical plane of the cell. The thermal pressurization coefficient is between 3 and 5 bar/°C. Differences in time needed to reach the pore pressure peak are observed between the 2 directions due to THM anisotropy of the rock. The first numerical simulations of the experiment exhibit a quite good qualitative reproduction of the THM behaviour of the near field rock.

In agreement with results obtained in previous reduced scale heating experiments, the temperature increase leads to an acceleration of the mechanical loading applied on the sleeve (increase of the convergence rate). Once the annular gap is completely consumed in the vertical direction, the ovalization of the sleeve is blocked before decreasing gradually, indicating a decrease in load anisotropy. The experiment also permitted validation of the correct operation of the sliding connection between insert and sleeve to absorb its thermal expansion. Measurements show that thermal expansion of the sleeve occurs both towards the end and towards the head of the cell.

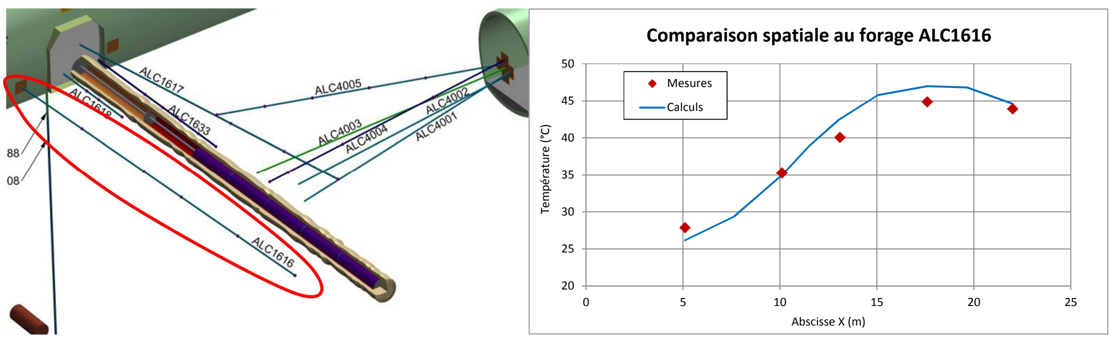


Figure 8. Comparison of the calculated (in blue) vs measured (in red) axial evolution of the near-field rock temperature in the horizontal plane after 500 days of heating (ALC1616 borehole) – simulations performed by ISL

Numerical simulations are currently being developed with the aim of helping the identification of the main mechanisms involved in the evolution of the THM behaviour of the heated cell. The calculations are performed by ISL and UPC. In both cases the THM formulation is based on a multiple-phase approach. Hydro mechanical coupling (Biot model) was used, as the thermal issue was handled separately. The initial results of the modelling of the experiment reproduce the main trends of the rock's THM behaviour.

Concerning the simulation of the thermal field, both UPC and ISL are, however, overestimating the near-field rock temperature in the heated zone and underestimate it in the cell head despite their relatively different design. However, the observed differences are not likely to hinder the overall interpretation of the experimental results. The investigations are currently continuing, with some of the main aims being to provide a better representation of the boundary conditions in drifts and to improve the description of the numerical model.

Work package conclusions

The construction feasibility of a HLW cell representative of the Andra´s 2009 benchmark concept, including a useful part and a head part, has been demonstrated. The ALC full-scale experiment contributes to increase the reliability of Andra's HLW cells design, especially in regards to the impact of a thermal loading. It will also provide valuable feedback towards implementing new full scale heating experiments consistent with the new benchmark concept.

1.2.3 Key Results Work Package 4

Area	Status
Construction and Excavation	Previous excavation has shown that excavation can be executed using a push reamer guided by a straight pre-drilled pilot hole. The project has demonstrated that it is feasible to drill the necessary pilot hole for a 100 m drift (300 m will be tested during 2015).
Component Manufacturing	The project has demonstrated that the necessary mechanical and clay components can be manufacture. A comparison between pressing techniques, uniaxial and isostatic, has also been carried out.
Installation	The project has developed the necessary machinery for performing the installation and also demonstrated that an installation can be carried out according to plan.
Sealing and Closure	The project has demonstrated that the drift can be sealed using a metal compartment plug.
Additional deliveries	In addition to the planned deliverables SKB has also delivered a first data report from the monitoring for the early stages of the drift evolution.

Table 3: WP4 Technical status of the KBS-3H concept and key results from the LUCOEX project

Background

SKB and Posiva are developing a common method for disposal of spent nuclear fuel in crystalline rock. The method selected for the final repository is the KBS-3 method which employs copper canisters surrounded by bentonite buffer and placed at depth in crystalline bedrock. The reference design is KBS-3V employing vertical disposal of the canisters, where horizontal disposal of canisters, KBS-3H, is a possible alternative. The latter is being explored and elaborated by the two organisations with the goal to assess a potentially more cost efficient and industrialized version of the KBS-3 method. KBS-3H has been developed since 2001 and the development work is based on the KBS-3V method but with focus on KBS-3H specific issues.

Work Package 4 of the LUCOEX project is the most recent part of a stepwise development of the KBS-3H concept and integrates the key disposal components, including the Supercontainer, distance blocks, compartment plug, transition block and pellets filling in a full scale proof-of-concept installation.

In addition a drilling activity has been added which demonstrates the drilling of a pilot hole, which is necessary for constructing drifts.

Construction of drifts

The construction of the disposal drifts have previously been proven trough the construction of the two deposition drifts (Ø 1.85 m) excavated at the -220 m level of the AEspoe HRL in Sweden: one 15 m long and one 95 m long. The challenge with producing these drifts is that the tolerances are very strict as a result of the very limited space between the Supercontainer/bentonite-components and the rock wall. This puts very high requirements on the straightness of the pilot hole.

Using a combination of a Devishot (Pee-Wee) and a Reflex Gyro for deviation measurements and a DeviDrill™ steering system the ability to make corrective actions down to 0.1° compared to a more normal application of 1° steering corrections have been demonstrated. Using this technology it has been demonstrated that a 100 m pilot hole fulfilling the requirements for a KBS-3H drift can be achieved. Figure 9 illustrates the drilling results in azimuth (horizontal) and inclination (vertical). When assessing the data in relation to the KBS-3H requirements, it was concluded that the inclination deviation was maximum -2.2

mm/6 m with ±10mm/6 m allowed and the azimuth deviation was maximum -3.5 mm/6 m with ±20 mm/6 m allowed.

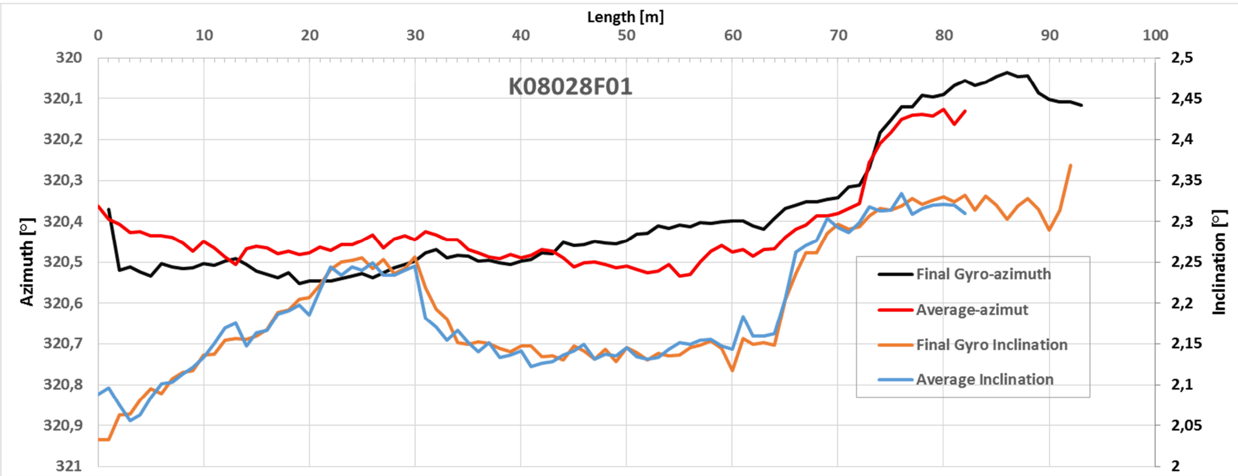


Figure 9: Final deviation measurements (azimuth and inclination) with Reflex Gyro and average calculated files in the LUCOEX borehole, K08028F01.

The results clearly demonstrates that the KBS-3H geometrical requirements can be fulfilled over a 100 m length scale. It also provides experience and a strategy going forward and testing the full 300 m, which will be done at the Onkalo URCF during 2015.

MPT design and instrumentation

The MPT integrates the key KBS-3H components including the Supercontainer, distance blocks, compartment plug, transition block and pellets filling.

The test is basically a shortened non-heated installation of the KBS-3H reference design - DAWE.

The components and the drift itself are extensively instrumented to be able to analyze the early evolution of the concept.

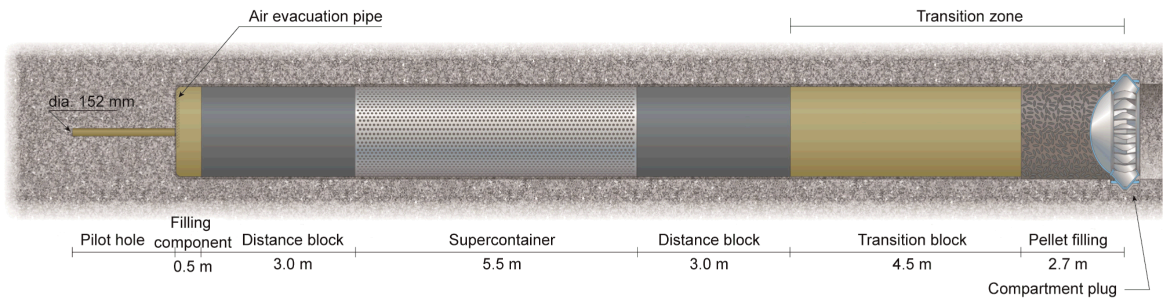


Figure 10: Schematic illustration of the MPT layout.

This proof-of-concept experiment is divided into the following main activities:

- Component manufacturing
- Machinery upgrade
- Drift preparations
- Assembly
- Installation
- Sealing and Closure

Component manufacturing

The KBS-3H bentonite blocks are larger than the KBS-3V blocks; hence a new uni-axial mould had to be manufactured. Its design is basically the same as that employed for KBS-3V earlier and both solid blocks and rings can be pressed with different adapters.

The buffer block manufacturing activities are listed in Table 4 below. The activities are listed in the order they were executed.

Activity	Description
Control of delivered bentonite	Samples from some of the delivered big-bags of bentonite are taken and investigated with laboratory tests.
Mixing of bentonite	Water is added to the bentonite to yield the right water content
Compaction of bentonite	Bentonite powder is compacted to blocks with a maximum compaction pressure of about 65 MPa.
Investigation of the compacted blocks	A visual inspection of the compacted blocks is made. The weight and the dimensions of the blocks are measured.
Machining of the blocks	The compacted blocks are machined to the stipulated shape
Investigation of the machined blocks	A visual inspection of the machined blocks is made. The weight and the dimensions of the blocks are measured.

Table 4: A list of activities included in the manufacturing of the bentonite blocks

A delivery of bentonite, approximately 150 tons was purchased by SKB for different large scale experiments at AEspoe HRL during winter 2012. The bentonite was originally from Wyoming and of type MX-80 and produced by AMCOL International Corporation USA. A delivery control of the bentonite was made, which showed that the material requirements were fulfilled.

After delivery control an Eirich mixer was used to mix the material to the required water content. Successful compaction was then done using a uni-axial press. The programme included 12 rings of one water content and 31 solid cylinders with two different water contents. Evaluation afterwards showed that there was a variation in block density (where some blocks had a slightly too high average density) but this was considered acceptable for the current test since the average density of the produced blocks used within the installed experiment were within the acceptable variation. The reason for the variations is primarily that the facilities rented for the production of these blocks are not optimized for this type of production and the productions series limited in size.

Machine upgrade

The KBS-3H deposition machine is a first prototype for demonstration of horizontal deposition in full scale. The machine was jointly designed by SKB and Posiva and manufactured by ECA in 2005–2006 within the 6th Framework programme "ESDRED" of the European Commission. The machine was first demonstrated in full scale tests at the AEspoe HRL in 2007.

It utilizes a water cushion transport principle, which works by stepwise movements inside the drift. A lifting and pushing sequence is repeated until the components being installed reaches its' destination. The water cushions and the heavy loads from the Supercontainer make the control of the machine challenging. Machine testing before the MPT has been troublesome due to limited control ability and an incomplete software application. During the MPT the machine was thoroughly instrumented in order to identify the reasons behind earlier control issues. A stepwise test- and upgrade programme using dummy components was carried out resulting in extensive re-programming of the control system as well as mechanical alterations. Additionally, the automation level of the machine was increased in order to avoid manual operation. These actions ensured that the MPT experiment could be reliably carried out and that the horizontal deposition concept could be evaluated as a whole.

Drift preparations

Since no tunnel is located nearby the MPT drift all cables had to be installed in cable notches in the rock wall. These were cut out using a standard concrete saw on rails adapted for the drifts curvature.

Core holes were drilled for rock sensors which were subsequently cast into place. A main pipe system was installed in the cable notches to limit the risk for leakages in cable bundles. Figure 11 illustrates the drift prepared for installation with pipes and sensors.

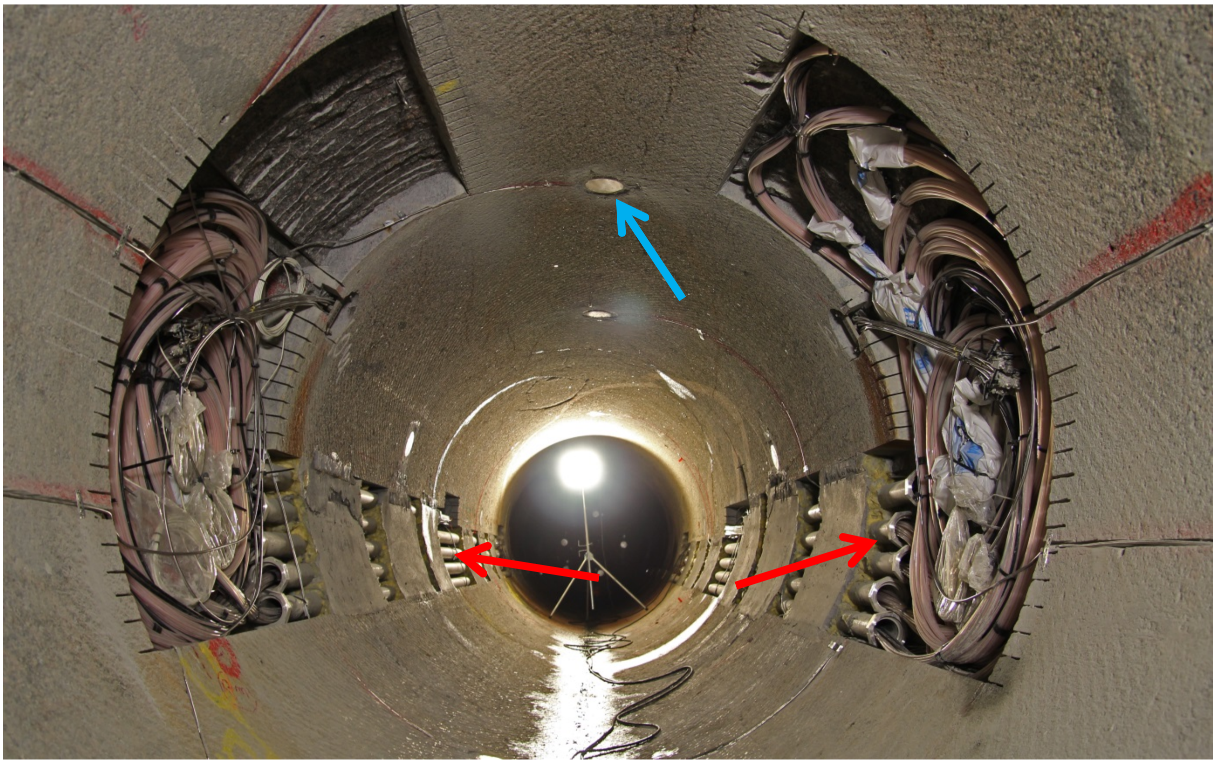


Figure 11. The MPT drift prepared for installation, red arrows points at the main pipe systems and the blue arrow points at one of the many rock sensors.

Assembly

Since the KBS-3H project had only tested the assembly of concrete dummies previously, a pre-test with a distance blocks was carried out. The pre-test integrated all steps from assembly to deposition. It was initiated in February 2013, and it quickly proved that the original intention to protect the buffer blocks with plastic foil while drilling and preparing them for assembly would be inadequate. Due to the winter season, the relative humidity (RH) was between 15-25 % at the time and the distance blocks started to develop surface cracks within an hour in conjunction with drilling. Although the surface cracks were quite small initially they were still too large and prevented the use of the vacuum hoist tools and therefore halted the work. Several actions were taken in order to address the cracking problems; all transport containers were fitted with new rubber seals, plastic bags with aluminum foil and more rigid wooden pallets were purchased. However, the installation of an industrial humidifier in the assembly facility was the real solution to the problem. It allowed for a controlled environment during assembly and the pre-test including the assembly, component transport and deposition could later be successfully carried out.

Figure 12. Test distance block being moved out from the assembly facility complemented by a specially designed sensor arrangement, or cable block, in which sensor cabling could be placed during transport and installation, marked with a red arrow

Experiences from the pre-test were later implemented in the main MPT assembly and full scale distance- and transition blocks, as well as a Supercontainer, figure below, could be assembled as planned.

Figure 13. Canister being lowered into the Supercontainer during assembly. Stiffening plates for straightening the shell can be seen on its outer periphery.

Installation

For KBS-3H, an efficient installation is a key part of the design. A preliminary assessment is that the components and the plug that make up a compartment have to be installed within 10 days to ensure that the buffer remains intact when the artificial watering is initiated. With the MPT being strongly focused on the handling and installation of the full scale components, it was decided to carry out the installation as fast as possible. At the same time, the test involve in the order of 200 sensors that needed to be taken into account. The MPT installation worked out as planned with all components placed at their intended locations and with tight connection between them. Figure 13 illustrates the installed Supercontainer.

Compared to the reference design where about 4 components are expected to be placed each 24 hours the corresponding MPT work was carried out at about a quarter of that speed. On the other hand, without the cabling, two components would have been managed in 24 hours during the MPT which would equal half the speed expected in a repository situation. At this stage of KBS-3H development this outcome is deemed acceptable as the process still contains manual tasks that would be automated in the final repository.

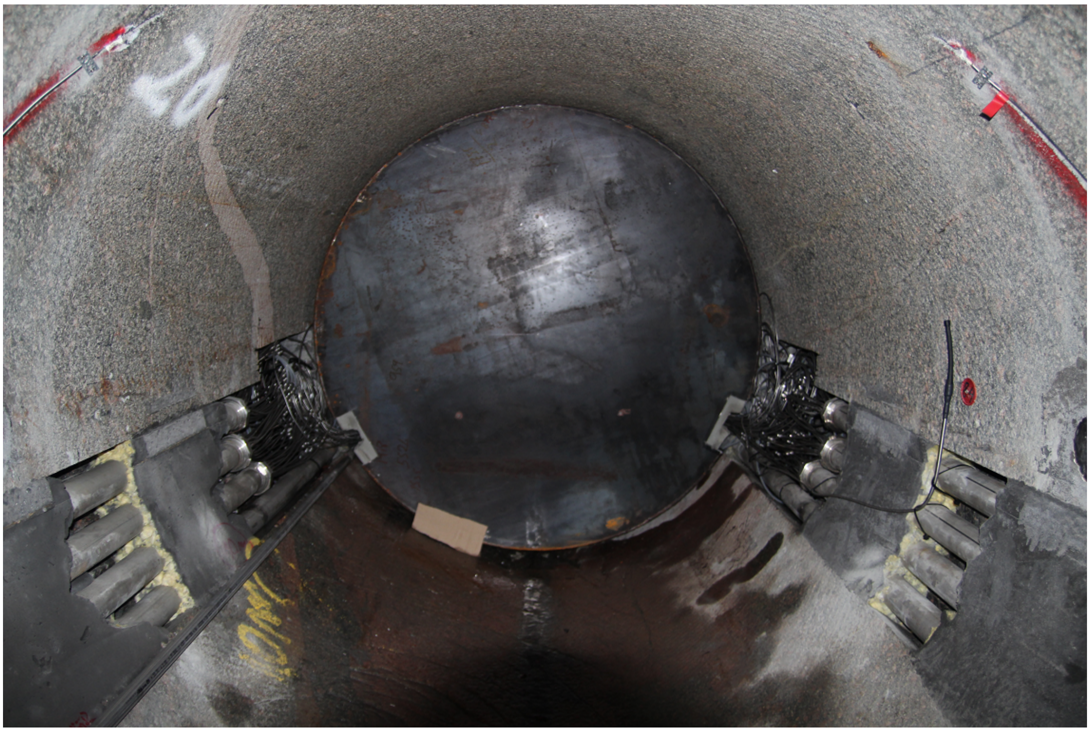


Figure 14. Supercontainer positioned in the drift with all its cables pulled. The tight fit between the Supercontainer and drift wall is clearly visible.

Sealing and Closure

The compartment plug was installed in two main steps of which the first, the fastening ring installation, was done during the drift preparation stage where a circular saw was used to cut out a slot for the plug. Once the rock was removed; the fastening ring was positioned and contact grouting tubes placed in the interfaces after which it was casted in place, Figure 14.

Once the casting of the fastening ring was done, its lower parts were filled with concrete to form a temporary bridge for the deposition machine to pass over.

After component installation, the plug installation was simply a welding activity given that the fastening ring was already cast in place. Installation was carried out as planned but it was identified that inspection was quite difficult due to limited space between the rock and the metal components as a small hole was missed in inspection of the welds and later caused leakages that had to be re-welded.

All cables were taken through the plug after which the void between it and the transition block was filled with pellets. This was followed by contact grouting of the steel-concrete and concrete-rock interfaces using silica sol. Finally the drift voids were filled with water and the air evacuated through the plug. The air and water filling pipes were subsequently removed as planned.

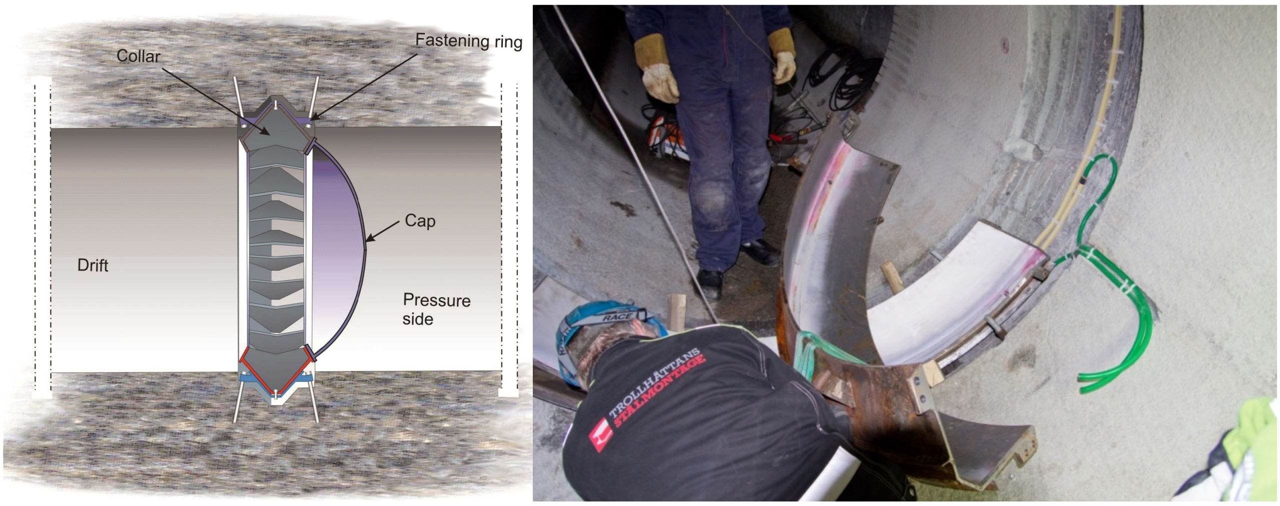


Figure 15: Left, schematic illustration of the compartment plug. Right, installation of the fastening ring

Work package conclusions

It is concluded that the MPT has demonstrated the manufacturing and installation potential of the KBS-3H design and the inherent strength of a slimmed system working with pre-assembled components. The key KBS-3H components have been tested in mutual combination and the Drainage, Artificial Watering and air Evacuation (DAWE) procedure has been carried out basically as intended. The actual function of the components will have to be assessed as more sensor data is generated and an eventual dismantling of the test.

Lots of experience were gained during the MPT and a number of areas for further optimization was identified which when addressed will make the design even more robust and cost efficient. These include:

- Harmonization of the water content of the blocks in the Supercontainer in order to simplify the handling of the clay components.
- Update of the compartment plug design to make the welding simpler and easier to inspect.
- Addition of an extra drainage pipe at the lowermost part of the plug so naturally inflowing water can be drained prior to pellets filling.
- Integration of a grouting tube in the plug design itself in order to simplify installation and improve contact grouting.
- Suggestions for further mechanical updates on the disposition machine in order to limit water splashing from its cushions and to for it to function properly with the DAWE design.

In addition to the implementation issues presented above the KBS-3H project has gained a lot of experiences for future installations. Methodologies are now available for both assembly and installation of components including advanced sensor systems.

The projects concludes that construction, component manufacturing, installation and sealing of a repository for nuclear waste based on the KBS-3H concept should be feasible and the MPT has demonstrated the key steps towards this objective.

With respect to the steered core drilling operation, the fulfilment of the strict KBS-3H requirements over a 100 m length scale provides confidence that technology is available that should be able to achieve the 300 m deposition drifts, which will be required. Methodologies and strategies towards fulfilling the requirements have also been improved.

1.2.4 Key Results Work Package 5

Area	Status
Construction and Excavation	Excavation done in parallel with the LUCOEX-project has shown that excavation of the disposal galleries can be done using conventional drill and blast technology complemented with roadheader technology for shaping the floor necessary for efficient operation of vehicles operating in the tunnels. LUCEX has developed machinery optimized for these tunnels.
Component Manufacturing	The project has demonstrated that the necessary vehicles, mechanical components and clay components can be manufacture. A comparison between pressing techniques for the clay components, uniaxial and isostatic pressing, has been carried out.
Installation	The project has developed the necessary machinery for transporting and performing the installation of the buffer and pellet components. Canister installation machinery has been developed in parallel with the LUCOEX project. Posiva has demonstrated that an installation can be carried out according to the planned process but at a slower pace.
Sealing and Closure	The Posiva plug is developed in the DOPAS project.
Additional deliveries	In addition to the disposal process Posiva has also developed processes and machinery for quality assurance and fault handling necessary in case of a mishap.

Table 5: WP5 Technical status of the KBS-3 concept and key results from the LUCOEX project

Background

SKB and Posiva are developing a common method for disposal of spent nuclear fuel in crystalline rock. The method selected for the final repository is the KBS-3 method which employs copper canisters surrounded by bentonite buffer and placed at depth in crystalline bedrock.

Work Package 5 of the LUCOEX project is a part of a stepwise development of this KBS-3 concept and includes the development, manufacturing and demonstration of key disposal components and processes including the buffer and pellet installation process equipment and the processes and equipment used for the quality assurance and fault handling.

The buffer and pellet installation sequence is shown in Figure 16.

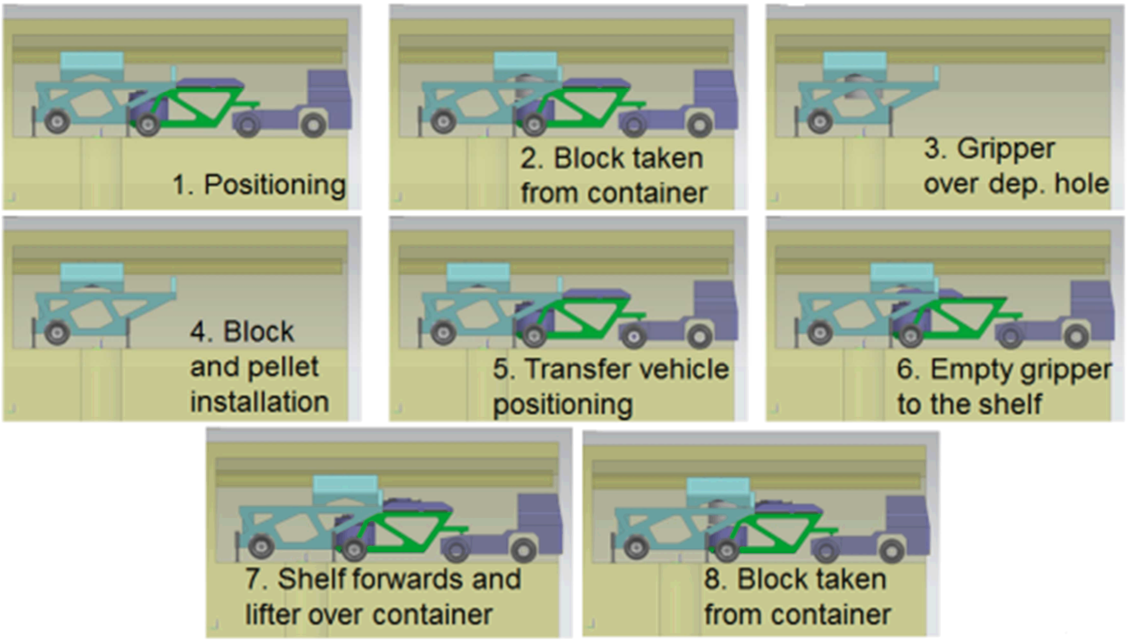


Figure 16. The installation of buffer blocks consists of eight basic steps which are shown

Bentonite container developed

The first component designed was the bentonite container, which is used for the transportation and handling of blocks and pellet. Directly after the buffer components are manufactured they are placed in individual containers after which pellet is placed in the pellet storage compartments. Then the container is ready for further transportation to storage or directly down to the disposal tunnels.

The function of the developed container, shown in Figure 17, is to simplify the handling of the buffer and for protecting the buffer from effects of the environment before moving them from the manufacturing facilities. Each bentonite block is put into a separate container under controlled conditions in the factory. The container is then sealed, thereby ensuring good protection against the outside environment.

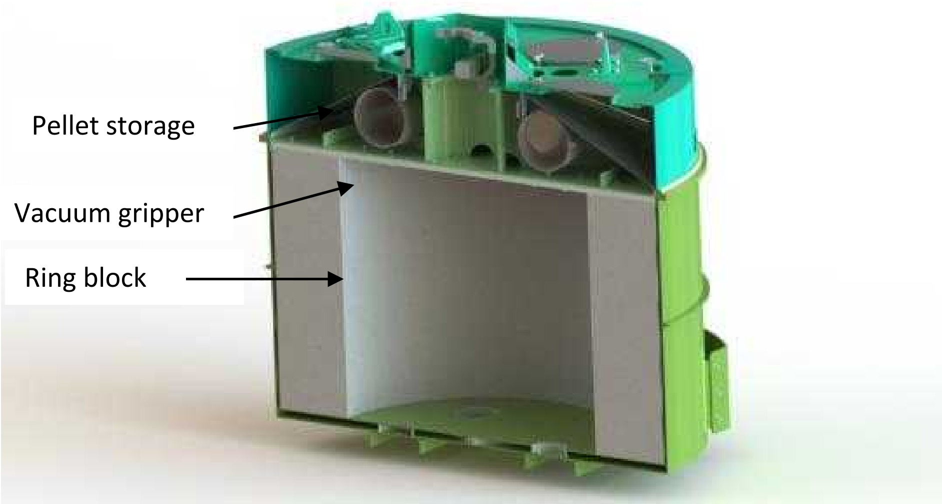


Figure 17. Split view of the bentonite container with a ring block , vacuum gripper and pellet storage

There are six pellet compartments inside the container top. Each compartment contains a pre-measured amount of bentonite pellets, so that after each bentonite block is in place, the pellets can be filled into the remaining volume. The amount of pellets loaded into each compartment is determined by calculating the gap between block and deposition hole wall.

Bentonite block installation machine developed

The bentonite installation machine (BIM) (Figure 17) was a completely novel design and required very stringent construction specifications to be followed. The BIM consists of a semi-trailer format frame on top of which a lifter unit is located.

There are five primary components on this machine:

- The frame (1): It is equipped with two wheels on a single steerable axle.
- The support leg subframe (2): The machine is levelled using four support legs moved by electromechanical actuators. It can be moved transversely (Y-direction) allowing the positioning of the machine directly on top of the deposition hole. The subframe is attached to main frame via two linear guides and moved by two electromechanical actuators.
- The pulling beam (3): This contains a king pin connection that is lifted to enable the bentonite transfer device (BTD) to pick up empty container top.
- The lifter unit (4): The lifter is movable on a pair of linear guides (X-direction) and actuated by two electric motors driving gear wheels against tooth racks. A winch with three steel ropes is providing movement (Z-direction) to a mechanical gripper to raise and lower the container top with bentonite blocks and pellets.
- The gripper (5): It has three electromechanical actuators that enable accurate radial positioning of the bentonite block during the last 100 mm downwards travel. The gripper attaches to the container top via three pneumatically actuated lock pins. The container top has a vacuum lifting surface against the top surface of bentonite block.

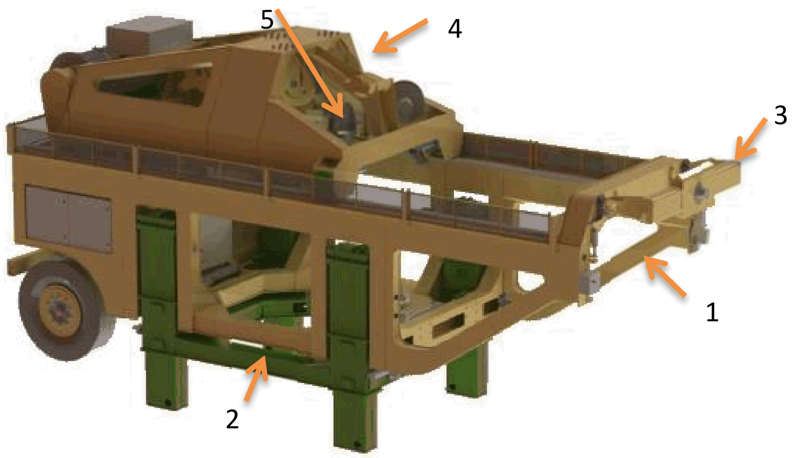


Figure 18. 3D-model of bentonite installation machine (BIM)

Bentonite block transfer device developed

As with the BIM, this component was a new design and required specialized manufacturing expertise.

The bentonite transfer device (BTD), shown in Figure 19, is a trailer moved by a terminal tractor unit. It is equipped with a single steering axle to ease the positioning near BIM and to limit the steering effort while driving in demonstration tunnel. The BTD is steered manually by the terminal tractor operator. The operator has a direct view to BTD, assisted by live feed from video cameras on BTD. The BTD gets both its hydraulic power and electric power (for controls) from the terminal tractor. All BTD movements are actuated by hydraulic cylinders controlled by proportional valves.

The BTD can carry one block in a container. This device has a longitudinally moving platform on top to store previous container top.

Figure 19. 3D-model of bentonite transfer device (BTD)

Above ground testing

The first test phase took place in a specially designed test and development facility at Posiva's Onkalo site. The focus of these tests was to verify the functionality, accuracy and reliability of the components and to fine tune the automation system controlling the machines. Most attention was given to the installation machine (Figure) and the gripper part of the buffer container (Figure 21) responsible for the vacuum lifting of the blocks and the transportation of pellet.

Figure 20. Bentonite installation machine at surface level test facility.

Figure 21. Gripper and concrete block has lowered into the bottom of test hole

Figure: 20. Releasing of pellet into the gap between buffer and test hole wall

Tests initially showed that the installation accuracy was well within requirement. Additional laser scans however showed that the space within the buffer deviated from the initial measurements with up to 4 mm. The installation time also exceeded the 2 hour requirement where the shortest installation time achieved was 3 hours 53 minutes and this was for an installation that was still short of one ring block.

Pellet filling of the gap between the buffer and test hole wall was tested. As per the planned method, after each block was in place in test hole, the pellets loaded inside the container top were released into the gap between buffer and test hole wall. This process worked as planned.

Emplacement Demonstration

On completion of the surface trials, work was moved underground to test operations in an environment more representative of a deposition tunnel for Demonstration phase 2 and 3. The test area used was at Onkalo URCF Demonstration Tunnel 1.

Due to lack of a full set of bentonite blocks demonstrations were done using a mixture of concrete blocks and bentonite blocks. This was considered an acceptable alternative as the concrete blocks are in general harder to lift and handle because of their rougher surface compared to bentonite blocks.

Measurements during the installation demonstrations once again showed that the installation accuracy was within specified requirements, while subsequent laser scans once again reviled deviations. During the debriefing three possible sources of error were identified: (1) possible measurement errors, (2) involuntary horizontal movement of the block during installation, and (3) the uneven surface of the components. Timing of the experiment also showed that the installation was slower than anticipated (3 hours 10 minutes vs allotted 2 hours). Even with these deviations we consider that we have proven our ability to install the buffer component in a safe and controlled manor.

Quality Assurance during buffer emplacement

The quality of installation is a key aspect in making sure that the multi-barrier system functions as designed. To verify the quality we have develop a sensor system integrated into the vehicles and able to transfer the information to QA-related software. The items that need to be controlled are:

- The integrity of the buffer blocks during the process.
- The position of the assembled buffer and the bentonite blocks.
- The width of the gap between assembled block and the host rock.
- The compactness in the gap between the pellets and the host rock.

Based on the studies and designs presented we are confident that all QA targets can be meet using a sensor system installed on the developed machinery.

Problem handling equipment designed

If something goes wrong either prior to, or after canister installation we need to be able to remove the buffer material and any other remaining material from the deposition hole to be able to take back the canister. We have in this project evaluated different techniques for this including:

- Lifting medium and large pieces of buffer material by attaching lifting eyelets an anchors.
- Breaking larger pieces using heavy drill-hammer and vacuum cleaner (industrial cleaning lorry).
- Combined water jet and vacuum suction rig.

Based on these tests we see that the usage of anchors to remove broken bentonite block parts is limited to specific cases, where the bentonite still retains its strength near manufacturing values. If there has been exposure to humidity or severe shocks, there is a very high risk that this method is not suitable. Breakage and vacuum cleaning is the only viable option in that case.

A combined water jet and vacuum suction rig was designed and tested. Our conclusion is that it can be used in all problem solving cases involving bentonite removal from deposition hole; manually before canister is installed, or by remote control after canister installation. Based on the test at the Onkalo URCF, the removal time for one solid block is approximately one hour, hence complete excavation of a full borehole should be able to be accomplished in an eight-hour day.

Work package conclusions

Lots of experience were gained during the development and manufacturing of these prototype machines and the work with QA and fault handling. Our conclusion is now that we have demonstrated that we can, with the knowledge from LUCOEX and DOPAS and the national programme in Finland, handle construction, component manufacturing, installation and sealing of a repository for nuclear waste based on the KBS-3V concept.

1.3 Impact

The LUCOEX project has provided a check on the suitability of the different emplacement concepts and given the stakeholders a possibility to understand and compare important parameters for the implementation and the long-term safety of the concepts. Important experience has been obtained regarding testing and improving of methods, equipment, technologies, processes and operability related to the gallery construction, manufacturing and emplacement of buffer around waste canisters, emplacement of waste packages, and backfilling and sealing of galleries.

1.3.1 Project partners

The stakeholders that have gained the most out of the project are the project participants.

They have gained a lot of information through the actual work performed within the scope of the LUCOEX project which has been a part of the stepwise development of repository technology within the individual national waste management programmes. This includes both technical know-how from excavation operations, development and operation of advanced machinery, material science investigations and backfilling and closing of the cells/drifts. All this information is vital and provides an essential milestone for the construction, operation and sealing of nuclear waste repositories in a safe and reliable manner. Without the information developed – this would not be possible. In addition Nagra, Andra and SKB are using the installations performed within the LUCOEX project for developing a better understanding of the early development of the repository in regards to THM-processes and material science where crucial information has already been gained necessary for the safety case for the different repository concepts.

Finally the project partners have received a lot of know-how through both formal interactions (like the hosted events such as conferences, workshops and site visits) and informal contacts through direct contact, e-mail and individual site visits. This has given the project participants a better understanding of alternative technologies and a base for extended cooperation beyond the scope of the LUCOEX project. An example is the ongoing discussions between Sweden and Finland regarding choosing a common technique for the production of buffer and possibly backfill components – which also could extend all the way to a common production facility for these components. This work is based on the experiences gained in Sweden, Finland and Switzerland regarding the production of highly compacted bentonite components using uniaxial and isostatic compression.

The cooperation has also given the project participants a chance to compare the information gathered both before and during the LUCOEX project. In combination with the feedback from the Expert Group, this has allowed the project partners a second opinion and feedback on the work they are performing.

In conclusion; the LUCOEX project has given the project partners necessary information in the stepwise development of final repositories for nuclear waste. The work has also paved the way for ongoing material science and THM-studies necessary for the evolution of the safety cases. The project has also increased the interconnections between the waste management organizations through networking events . All this is expected to result in more efficient designs and more accurate performance assessments of final repositories for nuclear waste in the individual countries participating in the project.

1.3.2 External stakeholders

The secondary stakeholders are the European Council, all the external project participants and the general public who have participated in the events hosted and at conferences where the project has been presented.

European Council

The European Council outlined in its decision 2006/976/EURATOM that the projects within the research area “management of radioactive waste” should:

> *“Through implementation-oriented RTD, the activities aim to establish a sound scientific and technical basis for demonstrating the technologies and safety of disposal of spent fuel and long-lived radioactive wastes in geological formations ...”*

This combined with the FP7 work programme 2010 (European Commission C(2009)5946 from 30 July 2009) where it is stated that the projects should contribute:

> *"to the progress towards the implementing of geological disposal in line with the Vision Report and initial roadmaps of IGD-TP and the 2020 objectives of the SET-Plan, together with significant advances in the treatment and/or understanding of key remaining issues. In particular, this should lead to demonstrable improvements in robustness of associated performance and safety analyses, and ultimately to increased confidence in the safety case ..."*

The project has through the work performed in the LUCOEX supported these goals by:

- Demonstrating key aspects of building, manufacturing key components, operating and closing repositories for long-lived radioactive wastes in geological formations with the current level of technology.
- Creating a foundation for future studies on material- and thermal processes linked to the operation and long term safety of final repositories for long-lived radioactive wastes in geological formations.
- Taken the next step in the stepwise implementation of geological disposals for radioactive waste where we expect that the first repository in crystalline rock will be made operational within the following decade.
- Identifying key remaining issues including primarily optimization and increasing the installation speed.

External project participants

The external project participants include representative from fourteen countries in Europe, North America and Asia who participated in the events hosted by the project. Also included are the 28 scholarship recipients who took the opportunity to participate in the hosted events and also to participate and support the work at the underground research laboratories at Bure, Mont Terri, Onkalo and AEspoe during the course of the project through the training scholarships.

The LUCOEX project considers that we have been successful in sharing the knowledge and experiences from the project to these external project participants who have been given in-depth knowledge about the work that has been performed. Some have even contributed back to the project through the scholarship training programme.

By sharing the knowledge with these, most often, experts within the field we expect to be able to support other countries in their work with national geological repositories for nuclear waste. The information shared will allow them to efficiently proceed with their national research, development and demonstration programmes by using the programmes and technical developments within Sweden, Finland, France and Switzerland as templates for their own solutions. Adaptions of the concepts to their local legislations and geological conditions will be necessary, but it will be far more time and cost efficient than having to designing everything from the ground up. By using an existing programme as a base we also expect that it will be easier for the less developed programmes to achieve public acceptance for both the repository concept as well as the safety case if best practices from LUCOEX partner organizations are used.

General public

The long lasting impact of this project is also to a large extent the legacy which has been past to all the visitors and scholarship recipients who took the opportunity to visit and participate in the experiments on-site at Bure, Mont Terri, Onkalo and AEspoe during the course of the project.

In addition we have during the LUCOEX project published numerous articles and presented the project at different conferences and workshop (listed in appendix 1).

Each of the scholarship recipients have also spread the knowledge from the project through their own words by presenting the LUCOEX project "at home" when returning back from a workshop or by writing a report on the subject studied during an training internship.

Finally we see that the LUCOEX homepage (www.lucoex.eu) has had between 100 – 1000 unique visitors each week downloading reports and deliverables from the project homepage. By keeping the homepage live during the following years and by ensuring that it is easily indexed by search engines like Google and Bing we ensure a continued spreading of the knowledge.

The LUCOEX project considers that we have been successful in sharing the knowledge and experiences from the project to the general public through the efforts listed above.

Conclusion on impact

The project has successfully shared the knowledge gained during the course of the project through the following activities:

- Underground research laboratories have been open to visitors including project partners, experts, authorities and the general public.
- Internal project meetings and workshops.
- Networking and direct contact between experts and engineers.
- Dialogue between the Expert Group and the project partners.
- Hosted 4+1 open workshops and two conferences focusing on key aspects of the construction, operation and closure of repositories for long-lived nuclear waste.
- Performing 28 scholarships resulting in either a technical report (from the training internships) or a presentation done by the scholarship recipient at "home".
- Published 36 articles relating to the work performed within the LUCOEX project.
- Produced 3 movies or video clips relating to the work performed within the LUCOEX project available at http://www.lucoex.eu/conference/.
- The LUCOEX project has hosted or participated at 33 different dissemination activities including everything from newsletters, poster sessions and conference presentations to hosting conferences.

Through these efforts we have increased the understanding of where we stand today in the stepwise development of repositories for long-lived nuclear waste. We have also openly shared the information and the experiences from the LUCOEX project which in combination with the openness of the project participants regarding their national programmes and concepts, give other member states´programmes a good technical support in developing their programmes and concepts . This is expected to both lower costs and increase the safety level as more resources are pulled towards similar and common solutions.

2 Acknowledgement

The project partners like to thank the European Union for supporting this work through the European Union's EUROATOM-research programme (FP7) under Grant Agreement 269905 – LUCOEX.

The Full-Scale Emplacement (FE) Experiment was implemented in the Mont Terri underground research laboratory, which is operated by Swisstopo, the geological survey of Switzerland.

SKB, as coordinators, would finally like to thank the LUCOEX partners Nagra (Switzerland), Andra (France), Posiva (Finland) and SKB's personnel in the WP4 (Sweden) for the continuous discussion and knowledge exchange throughout this EU project and beyond.

3 References

LUCOEX Reference	Reference document	Available on www.lucoex.eu
1.06	Minutes from PPM No.1	YES
1.07	Expert Group Report No.1	YES
1.08	Minutes from PPM No.2	YES
1.09	Compilation of presentations from Mid-term Workshop	YES
1.10	Minutes from PPM No. 3	YES
1.11	Expert Group Report No. 2	YES
1.12	Minutes from PPM No.4	YES
1.13	Proceedings from the Large Workshop	YES
1.14	Expert Group Report No.3	YES
1.15	Result of LUCOEX with possible use in other EU Member States' concepts	YES
1.16	Publishable technical report on WP2 result	YES
1.17	Publishable technical report on WP3 result	YES
1.18	Publishable technical report on WP4 result	YES
1.19	Publishable technical report on WP5 result	YES
1.20	Minutes from PPM No.5	YES
1.21	Final Report WP1	YES
1.22	Final Project Technical Report	YES
1.67	Minutes of Project Progress Meeting - PPM2	YES
2.01	Workplan	YES
2.02	Report on construction of the emplacement tunnel	YES
2.03	Requirements, manufacturing and QC of the buffer components	YES
2.04	Construction of emplacement equipment	YES
2.05	Emplacement report	YES
2.06	Final Report of WP2	YES
3.01	Report on the preliminary test of forced casing digging	YES
3.02	Test plan of the ALC experiment	YES
3.03	Report of the digging and emplacement of the cell	YES
3.04	Final Report of WP 3	YES

4.01	Working Report on manufacturing of distance blocks and blocks for the supercontainer	YES
4.02	Working Report on the upgrades done to the deposit machine	YES
4.03	Working Report on the Multi Purpose Test	YES
4.04	Final Report of WP 4	YES
4.05	Steered core drilling in crystalline rock	YES
4.06	Inital Data report: MPT-test	YES
5.01	Detailed Project Plan	YES
5.02	Buffer Emplacement test	YES
5.03	Memo on designing the gap filling tool.	YES
5.04	Memo on buffer emplacement testing	YES
5.05	Quality Assurance and Problem Handling during buffer emplacement	YES
5.06	Definition of the WP5 emplacement process phases and their quality requirements.	YES
5.07	Memo on Development of quality assurance tools.	YES
5.08	Plans for solving the emplacement problem situations.	YES
5.09	Final Report of WP 5	YES
5.10	Plan on WP5 integration and dissemination	YES
5.11	Project expert review report	YES
5.12	Interim report on the project reviews	YES
5.13	Interim report on the project reviews	YES
5.14	Interim report on the project reviews	YES
5.18	Paper for professional journal	YES
5.19	Paper for professional journal	YES
5.20	Documentary film of buffer installation demos	YES
6.03	Newsletter 1	YES
6.04	Periodic report to be submitted to the Commission	YES
6.05	Newsletter 2	YES
6.06	Newsletter 3	YES
6.07	Periodic report to be submitted to the Commission	YES
6.08	Periodic report to be submitted to the Commission	YES
6.09	Newsletter 4	YES

APPENDIX I - SCIENTIFIC PUBLICATIONS

- List of all scientific (peer reviewed) publications relating to the foreground of the project.

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
1	Liggande kopparkapslar utreds för miljoner	Monica Kleja	Ny Teknik, Oct 16th 2014 (Publisher Talentum Media AB, Sweden)							Yes
2	State-of-art, proof-of-concept installations for repository concepts based in crystalline rock	Magnus Kronberg	Mineralogical Magazine, Planed publication 2015 in the UK.							Yes
3	The excavation of a circular tunnel in a bedded argillaceous rock (Opalinus Clay): Short-term rock mass response and FDEM numerical analysis.	Lisjak A.; Garitte B.; Grasselli G.; Müller H.R.; Vietor T.	Tunnelling and Underground Space Technology, 2015, Bd. 45, S. 227–248.					22		no
4	Nagra's activities at the Grimsel Test Site and the Mont Terri Project: Update and outlook	Vomvoris S., Blechschmidt I., Vietor T., Mueller H.R.	Proceedings of the International High-Level Radioactive Waste Management Conference, April 12-16, 2015, Charleston, South Carolina.					11		no
5	The Swiss radioactive waste management program - Brief history, status and outlook	Vomvoris S., Claudel A., Blechschmidt I., Müller H.R.	Journal of Nuclear Fuel Cycle and Waste Technology 10/2013; 1(1):9-27.					19		no

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication.
[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

6	FE/LUCOEX: Design criteria for bentonite block manufacturing and emplacement in an underground facility	Garitte B., Müller H.R., Weber H.P.	Proceedings of the LUCOEX Conference and Workshop: Full-scale demonstration tests in technology development of repositories for disposal of radioactive waste. Oskarshamn, 2.-4. June 2015, 155-160.	6	www.lucoex.eu	yes
7	Backfilling a Horizontal Tunnel with Granular Bentonite – Machine Development, Pre- & Mock-up Tests and Application at the Mont Terri URL	Köhler S., Sakaki t., Weber H.P., Garitte B., Müller H.R.	Proceedings of the LUCOEX Conference and Workshop: Full-scale demonstration tests in technology development of repositories for disposal of radioactive waste. Oskarshamn, 2.-4. June 2015, 35-47.	18	www.lucoex.eu	yes
8	Excavation of the FE tunnel at the Mont Terri URL	Müller H.R., Köhler S., Vogt T.	Proceedings of the LUCOEX Conference and Workshop: Full-scale demonstration tests in technology development of repositories for disposal of radioactive waste. Oskarshamn, 2.-4. June 2015, 129-134.	6	www.lucoex.eu	yes
9	Instrumenting, monitoring and heating the Full-Scale Emplacement (FE) Experiment at the Mont Terri URL	Müller H.R., Vogt T., Garitte B., Sakaki T., Spillmann T., Hertrich M., Giroud N.	Proceedings of the LUCOEX Conference and Workshop: Full-scale demonstration tests in technology development of repositories for disposal of radioactive waste. Oskarshamn, 2.-4. June 2015, 49-53.	5	www.lucoex.eu	yes
10	LUCOEX: QA/QC during bentonite material production and emplacement in the framework of the FE Experiment.	Weber H.P.; Garitte B.; Köhler S.; Müller H.	Proceedings of the LUCOEX Conference and Workshop: Full-scale demonstration tests in technology development of repositories for disposal of radioactive waste. Oskarshamn, 2.-4. June 2015, 185-193.	9	www.lucoex.eu	yes
11	Structural geological analysis during excavations in the Mont Terri Rock Lab: Influences of pre-existing fractures on tunnel stability and EDZ characteristics.	Becker J.K.; Jaeggi D.; Lisjak A.; Madritsch H.; Müller H.R.; Schefer S.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	2	www.clayconferencebrussels2015.com	yes
12	Stability of compacted bentonite blocks and block pedestals under changing climatic conditions in tunnels and long-term loads	Garitte B., Kober F., Müller H.R., Köhler S., Weber H.P., Blechschmidt I.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
13	FE experiment / LUCOEX: Production of bentonite based backfill materials.	Garitte B.; Müller H.R.; Weber HP.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
14	FE experiment: THM modelling, predictions, observations and interpretation.	Garitte B.; Thatcher K.; Vogt T.; Müller H.R.; Vietor T.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
15	FE experiment / LUCOEX: Development of a prototype machine for backfilling horizontal emplacement tunnels with granulated bentonite.	Jenni H.; Köhler S.; Müller H.R.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
16	High resolution fiber optic monitoring	Kishida K.;	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th	**2**	www.clayconferencebrussels201	**yes**

	system for the FE experiment at the Mont Terri URL.	Vogt T.; Guzik A.; Müller H.R.; Frieg B.; Knüpfer B.	international conference, Brussels, March 23-26, 2015		5.com	
17	Swiss backfilling concept – Requirements and Approaches for Optimization of the Bentonite Barrier around SF/HLW Disposal Canisters.	Köhler S., Fries T., Müller H.R., Gaus I.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
18	The Full-Scale Emplacement Experiment – Implementation of a multiple heater experiment at the Mont Terri URL	Müller H.R.; Vogt T.; Garitte B.; Köhler S.; Sakaki T.; Weber HP.; Vietor T.:	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
19	Numerical pre- and post-construction models of the geomechanical behaviour in the FE experiment at the Mont Terri URL.	Nater P.; Garitte B.; Köhler S.; Müller H.R.:	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
20	Evaluation of gas transport phenomena in support of the Full-Scale Emplacement Experiment at the Mont Terri URL	Pappafotiou A., Senger R., Marschall P., Garitte B., Müller H.R.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
21	FE Experiment: Density measurement of granulated bentonite mixture in a 3D 1:1 scale mockup test using dielectric tools.	Sakaki T.; Köhler S.; Hertrich M.; Müller H.R.:	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
22	FE Experiment: Density measurement of granulated bentonite mixture in a 2D pre-test using a dielectric moisture profile probe.	Sakaki T.; Köhler S.; Müller H.R.:	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
23	FE Experiment: Monitoring of water content in Opalinus Clay using a moisture profile probe and a customized TDR sonde.	Sakaki T.; Vogt T.; Müller H.R.; Wörsching H.:	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
24	Geomechanical characterization of the Opalinus Clay from an analysis of the FE Tunnel excavation at the Mont Terri URL	Senger R., Marschall P., Goodarzi S., Walters D., Müller H.R., Vogt T., Garitte B.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
25	Near-field permeability distribution of FE tunnel in the Mont Terri Rock Laboratory - Influence of shotcrete lining on EDZ development	Shao H., Paul B., Wang X., Hesser J., Becker J., Garitte B.,	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**

		Müller H.R.				
26	Fiber optic sensing methods for monitoring temperature and strain implemented in the FE experiment.	Vogt T.; Müller H.; Frieg B.; Vietor T.:	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
27	Hydraulic response of Opalinus Clay during excavation and ventilation phases of the 1:1 scale FE experiment.	Vogt T.; Müller H.; Garitte B.; Sakaki T.; Giroud N.; Vietor T.:	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
28	FE experiment: The instrumentation and monitoring concept of a 1:1 scale heater experiment at the Mont Terri URL.	Vogt T.; Müller H.; Sakaki T.; Hertrich M.; Spillmann T.; Garitte B.; Giroud N.; Vietor T.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 6th international conference, Brussels, March 23-26, 2015	**2**	www.clayconferencebrussels2015.com	**yes**
29	Development of TDR probes for monitoring water content in Opalinus Clay in the FE experiment at Mont Terri Rock Laboratory. [in Japanese]	Sakaki T.; Vogt T.; Müller H.R.; Wörsching H.; Vrzba M.	Japan Society for Civil Engineers Annual Meeting 2014, 2014, S.2.	**2**	*www.jsce-int.org*	**Yes**
30	Scoping computations for the full-scale emplacement (FE) experiment at the Mont Terri underground research laboratory.	Garitte B.; Müller H.; Vogt T.; Vietor T.; Thatcher K.; Senger R.	PEBS - International conference on the Performance of Engineered Barriers: Backfill, Plugs & Seals, February 6-7, 2014, BGR, Hannover, Germany, 2014, S. 507-510.	**4**	www.pebs-eu.de	**yes**
31	Bentonite buffer material production and emplacement during the Full-Scale Emplacement (FE) Experiment at the Mont Terri URL.	Müller H.R.; Garitte B.; Weber H.P.; Köhler S.; Plötze M.	PEBS - International conference on the Performance of Engineered Barriers: Backfill, Plugs & Seals, February 6-7, 2014, BGR, Hannover, Germany, 2014, S. 75-78.	**4**	www.pebs-eu.de	**yes**
32	Monitoring water content in Opalinus Clay within the FE-Experiment: Test application of dielectric water content sensors.	Sakaki T.; Vogt T.; Komatsu M.; Müller H.	Fall Meeting American Geophysical Union AGU, 09.-13. December 2013, San Francisco, 2013	**1**	*sites.agu.org*	**yes**
33	Excavation induced hydraulic response of Opalinus Clay - Investigations of the FE-Experiment at the Mont Terri URL in Switzerland.	Vogt T.; Müller H.; Garitte B.; Sakaki T.; Vietor T.	Fall Meeting American Geophysical Union AGU, 09.-13. December 2013, San Francisco, 2013	**1**	*sites.agu.org*	**yes**
34	Monitoring THM effects in a full scale EBS/host rock system - first experiences of the FE-Experiment in the Mont Terri URL during construction and ventilation phase.	Vogt T.; Müller H.; Sakaki T.; Vietor T.	Extended Abstract.- MoDeRn Monitoring in geological disposal of radioactive waste: Objectives, strategies, technologies and public involvement, proceedings of an international conference and workshop, Luxembourg 19-21 March 2013, Deliverable D-N°: 5.4.1, 2013, S. 326-334.	**9**	www.modern-fp7.eu	**yes**

35	The Full-scale Emplacement (FE) Experiment at the Mont Terri URL.	Müller H.R.; Weber H.P.; Köhler S.; Vogt T.; Vietor T.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 5th international meeting, Montpellier, October 22-25, 2012, 2012, S. 200-201.	**2**	www.montpellier2012.com	**yes**
36	Granular bentonite production as buffer material for a full-scale emplacement ("FE") experiment.	Teodori S.P.; Weber H.P.; Köhler S.; Plötze M.; Holl M.; Müller H.R.	Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, 5th international meeting, Montpellier, October 22-25, 2012, 2012, S. 336-337.	**2**	www.montpellier2012.com	**yes**

APPENDIX II - DISSEMINATION ACTIVITIES

List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project.

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
1	*Web*	*SKB*	*www.lucoex.eu*	*2011-2020*	*online*	*Open to all*	*--*	*International*
2	*Workshop*	*SKB*	*Project Planning, Risk management and Cross reviewing of plans*	*Mar 14th -15th 2011*	*SKB's main office Stockholm*	*Project partner organizations*	*≈ 20*	*Project partner organizations*
3	*Workshop*	*Posiva*	*Excavation methods for drifts and HLW cells*	*2012 Mar 14-15*	*Olkiluoto, Finland*	*Scientific community and open for all*	*≈ 40*	*Europe*
4	*Workshop*	*Andra*	*Instrumentation of Full scale emplacement experiment*	*2012 Oct 25-26*	*Montpellier, France*	*Scientific community and open for all*	*≈ 60*	*Europe*
5	*Workshop*	*Nagra*	*Bentonite Block/Pellet manufacturing and installation*	*2013 Sep 30th-Oct 1st*	*on site in Mont Terri*	*Scientific community and open for all*	*≈ 60*	*Europe*
6	*Workshop*	*SKB*	*Installation and Sealing of drifts*	*2014 May 13th-14th*	*AEspoe, Sweden*	*Scientific community and open for all*	*≈ 60*	*Europe*
7	*Midterm Conference*	*SKB*	*Achievements within the LUCOEX project*	*Oct 25th -26th 2012*	*Montpellier, France*	*Scientific community and open for all*	*≈ 40*	*Europe*
8	*End Conference*	*SKB*	*Multiple presentations on various subjects*	*2015 June 2-4*	*Oskarshamn, Sweden*	*Scientific community and open for all*	*≈ 80*	*Europe*
9	*IGDTP – Geodisposal 2014*	*Andra, Nagra, SKB, Posiva*	*4 presentations on Full scale disposal cell demonstrators in clay formation and crystalline rock*	*2014 June 24-26th*	*Manchester, UK*	*Scientific community and open for all*	*≈ 400*	*Europe*
10	*Euradwaste '13*	*SKB/Nagra/Andra/Posiva*	*LUCOEX – Demonstrating the techniqal feasibility of disposal of*	*2013 Oct 14-16*	*Vilnius, Lithuania*	*Scientific community and open for all*	*≈ 400*	*Europe*

[3] publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.
[4] Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

			spent nuclear fuel in geological formations					
11	*Exhibition*	*SWT+Nagra*	*Mont Terri URL*	*ongoing*	*St.Ursanne, Switzerland*	*Civil Society & Scientific Comm.*		*Europe*
12	*Press release*	*Nagra*	*The FE Experiment/ LUCOEX*	*14.11.2014*	*St.Ursanne, Switzerland*	*Media*	*≈ 20*	*Switzerland*
13	*Press conf.*	*Nagra*	*The FE Experiment/ LUCOEX*	*21.11.2014*	*St.Ursanne, Switzerland*	*Media*	*≈ 20*	*Switzerland*
14	*Articles*	*various*	*Various articles about the FE*	*Nov. 2014*	*Various newspapers*	*Civil Society*		*Switzerland*
15	*Interview*	*Nagra*	*The FE Experiment/ LUCOEX*	*26.1.2015*	*SRF Swiss National TV*	*Civil Society*		*Switzerland*
16	*Video*	*Nagra*	*The FE Experiment/ LUCOEX*	*May 2015*	*youtu.be/3iuH5NyG53k*	*Civil Society & Media*	*Youtube*	*International*
17	*Conference*	*Swisstopo*	*Mont Terri Technical Meeting 30*	*8.-9.2.2012*	*St.Ursanne, Switzerland*	*Scientific Community & Industry*	*≈ 100*	*Europe*
18	*Conference*	*Andra*	*Clay Conference*	*23.-25.10.2012*	*Montpellier, France*	*Scientific Community & Industry*	*≈ 400*	*Europe*
19	*Conference*	*Swisstopo*	*Mont Terri Technical Meeting 31*	*13.-14.2.2013*	*St.Ursanne, Switzerland*	*Scientific Community & Industry*	*≈ 120*	*Europe*
20	*Conference*	*BGR*	*PEBS Bentonite Workshop*	*6.-7.2.2014*	*Hannover, Germany*	*Scientific Community & Industry*	*≈ 200*	*Europe*
21	*Conference*	*Swisstopo*	*Mont Terri Technical Meeting 32*	*12.-13.2.2014*	*St.Ursanne, Switzerland*	*Scientific Community & Industry*	*≈ 120*	*Europe*
22	*Workshop*	*Nagra*	*Backfilling Machine / Bentonite*	*19.-20.5.2014*	*Grono, Switzerland*	*Scientific Community & Industry*	*≈ 50*	*Europe*
23	*Conference*	*Swisstopo*	*Mont Terri Technical Meeting 33*	*11.-12.2.2015*	*Porrentruy, Switzerland*	*Scientific Community & Industry*	*≈ 150*	*Europe*
24	*Conference*	*ONDRAF*	*Clay Conference*	*23.-26.3.2015*	*Brussels, Belgium*	*Scientific Community & Industry*	*≈ 400*	*International*
25	*Energy and Environment – ISRM Symposium Eurock 2013*	*Andra*	*Feasibility and behavior of a full scale disposal cell in a deep clay layer*	*2013 Sept 21-26*	*Wroclaw, Poland*	*Scientific community*	*≈ 400*	*Europe*
26	*10th Euroconference on Rock Physics and Rock Mechanics*	*Andra*	*THM behavior of a full scale disposal cell demonstrator in 500 m deep clay formation*	*2014 May 12-15*	*Aussois, France*	*Scientific community*	*≈ 200*	*Europe*
27	*Clays in Natural and Engineered Barriers for Radioactive Waste, 6th International Conference*	*Andra*	*Feasibility of excavation and THM behavior of a full scale disposal cell for nuclear waste in 500 m deep clay formation*	*2015 Mar 23-26*	*Brussels, Belgium*	*Scientific community*	*≈ 400*	*Worldwide*
28	*Clays in Natural and Engineered Barriers for Radioactive Waste*	*SKB/B+Tech/Aitemin*	*Poster: KBS-3H Multi Purpose Test*	*2015 Mar 23–26*	*Brussels*	*Scientific Community and open for all*	*~400*	*Europe*

	Confinement, 6th International Conference, Brussels,							
29	*AutomaatioXX seminar*	*SKB*	*Spent nuclear fuel deposition machine lifting control and pallet adjustment*	*2013 May 22nd*	*Helsinki*	*Scientific Community and open for all*	*~100*	*Europe*
30	*Newsletter 1*	*SKB*	*LUCOEX – Newsletter*	*2012 Mar 8th*	*online*	*Open to all*	*--*	*International*
31	*Newsletter 2*	*SKB*	*LUCOEX – Newsletter*	*2013 Feb 1st*	*online*	*Open to all*	*--*	*International*
32	*Newsletter 3*	*SKB*	*LUCOEX – Newsletter*	*2014 Jan 25th*	*online*	*Open to all*	*--*	*International*
33	*Newsletter 4*	*SKB*	*LUCOEX – Newsletter*	*2015 Aug 31st*	*online*	*Open to all*	*--*	*International*

APPENDIX III – CONFIDENTIAL INFORMATION

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[5]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)

[5] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Please complete the table hereafter:

Type of Exploitable Foreground[6]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
	Ex: New superconductive Nb-Ti alloy			*MRI equipment*	*1. Medical* *2. Industrial inspection*	*2008* *2010*	*A materials patent is planned for 2006*	*Beneficiary X (owner)* *Beneficiary Y, Beneficiary Z, Poss. licensing to equipment manuf. ABC*

In addition to the table, please provide a text to explain the exploitable foreground, in particular:

- Its purpose
- How the foreground might be exploited, when and by whom
- IPR exploitable measures taken or intended
- Further research necessary, if any
- Potential/expected impact (quantify where possible)

[6] General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[7] NACE nomenclature: http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

APPENDIX IV – EC QUESTIONAR

The following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information	
Grant Agreement Number:	**269905**
Title of Project:	**LUCOEX**
Name and Title of Coordinator:	**Jan Gugala, Project Manager SKB AB**

B Ethics	
1. Did your WP undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final work package reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the periodic/final work package feports under the Section 3.2.2 *'Work Progress and Achievements'*	***0Yes 0No***
2. Please indicate whether your WP involved any of the following issues (tick box) :	***NO***
RESEARCH ON HUMANS	
• Did the work package involve children?	No
• Did the work package involve patients?	No
• Did the work package involve persons not able to give consent?	No
• Did the work package involve adult healthy volunteers?	No
• Did the work package involve Human genetic material?	No
• Did the work package involve Human biological samples?	No
• Did the work package involve Human data collection?	No
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the work package involve Human Embryos?	No
• Did the work package involve Human Foetal Tissue / Cells?	No
• Did the work package involve Human Embryonic Stem Cells (hESCs)?	No
• Did the work package on human Embryonic Stem Cells involve cells in culture?	No
• Did the work package on human Embryonic Stem Cells involve the derivation of cells from Embryos?	No
PRIVACY	
• Did the work package involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	No
• Did the work package involve tracking the location or observation of people?	No
RESEARCH ON ANIMALS	
• Did the work package involve research on animals?	No
• Were those animals transgenic small laboratory animals?	No
• Were those animals transgenic farm animals?	No
• Were those animals cloned farm animals?	No
• Were those animals non-human primates?	No
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the work package involve the use of local resources (genetic, animal, plant etc)?	No
• Was the work package of benefit to local community (capacity building, access to healthcare, education etc)?	No
DUAL USE	
• Research having direct military use	No
• Research having the potential for terrorist abuse	No

C Workforce Statistics

3. Workforce statistics for the work package: Please indicate in the table below the number of people who worked on the work package (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	1 (Monica Hammarström)	3 (Jan G, Erik T, Christer S)
Work package leaders	0	7
Experienced researchers (i.e. PhD holders)	2	26
PhD Students	5	7
Other	2	10

4. How many additional researchers (in companies and universities) were recruited specifically for this work package?	10
Of which, indicate the number of men:	10

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the work package?

○ Yes
★ No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	○	○	○	○	○
❑ Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑ Organise conferences and workshops on gender	○	○	○	○	○
❑ Actions to improve work-life balance	○	○	○	○	○

○ Other:

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

✸ No

E	Synergies with Science Education

8. Did your work package involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint work packages)?

- ✶ Yes- please specify The LUCOEX-project had a total of 28 scholarships aimed at students and experts
- ○ No

9. Did the work package generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

- ○ Yes- please specify
- ✶ No

F	Interdisciplinarity

10. Which disciplines (see list below) are involved in your work package?

- ○ Main discipline: 2.1
- ○ Associated discipline: 1.2, 1.4
- ○ Associated discipline:

CLASSIFICATION OF SCIENTIFIC DISCIPLINES ACCORDING TO THE FRASCATI MANUAL

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]

G	Engaging with Civil society and policy makers		
11a	**Did your work package engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*	○ ✸	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ○ No
- ○ Yes- in determining what research should be performed
- ○ Yes - in implementing the research
- ○ Yes, in communicating /disseminating / using the results of the work package

11c	**In doing so, did your work package involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?**	○ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ○ Yes, in communicating /disseminating / using the results of the work package

13a Will the work package generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture		Energy		Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and		Food Safety		Research and Innovation	
Monetary Affairs		Foreign and Security Policy		Space	
Education, Training, Youth		Fraud		Taxation	
Employment and Social Affairs		Humanitarian aid		Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- ○ European level
- ○ International level

H	**Use and dissemination**	
14.	**How many Articles were published/accepted for publication in peer-reviewed journals?**	**36**
	To how many of these is open access[8] provided?	**33**
	How many of these are published in open access journals?	**33**
	How many of these are published in open repositories?	
	To how many of these is open access not provided?	**3**
	Please check all applicable reasons for not providing open access:	
	✶ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[9]: ……………	
15.	**How many new patent applications ('priority filings') have been made?** *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**0**

16.	**Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).**	Trademark	**0**
		Registered design	**0**
		Other	

17.	**How many spin-off companies were created / are planned as a direct result of the work package?**	**0**
	Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your work package has a potential impact on employment, in comparison with the situation before your work package:

❑	Increase in employment, or	❑	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	✸	None of the above / not relevant to the work package
❑	Difficult to estimate / not possible to quantify		

19.	**For your work package partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:**	*Indicate figure:* ✸

[8] Open Access is defined as free of charge access for anyone via Internet.
[9] For instance: classification for security project.

Difficult to estimate / not possible to quantify	

I Media and Communication to the general public

20. As part of the work package, were any of the beneficiaries professionals in communication or media relations?

✶ Yes ○ No

21. As part of the work package, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ✶ No

22 Which of the following have been used to communicate information about your work package to the general public, or have resulted from your work package?

✶	Press Release	✶	Coverage in specialist press
✶	Media briefing	❑	Coverage in general (non-specialist) press
✶	TV coverage / report	✶	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
✶	Brochures /posters / flyers	✶	Website for the general public / internet
✶	DVD /Film /Multimedia	✶	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	✶	English
❑	Other language(s)		