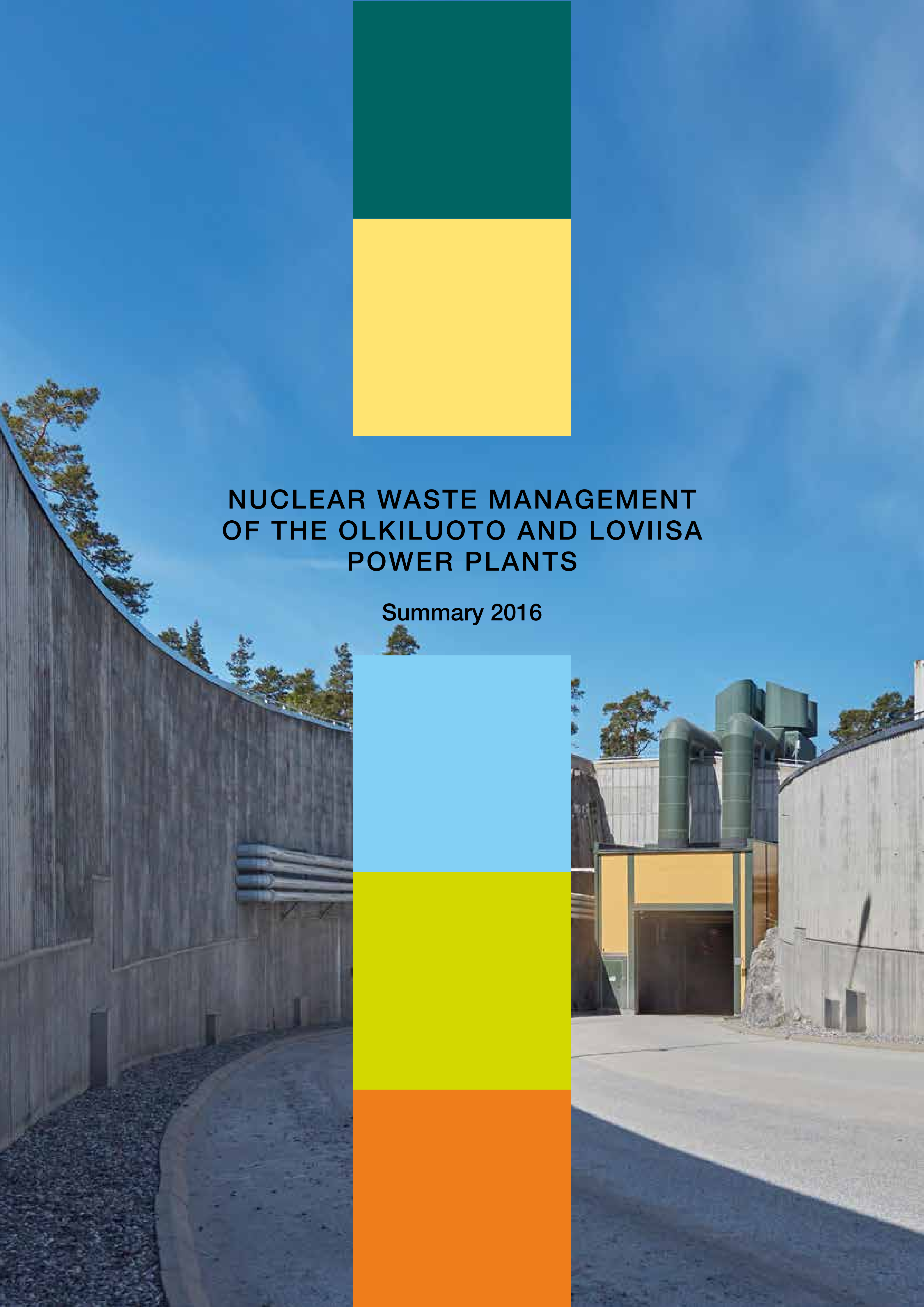
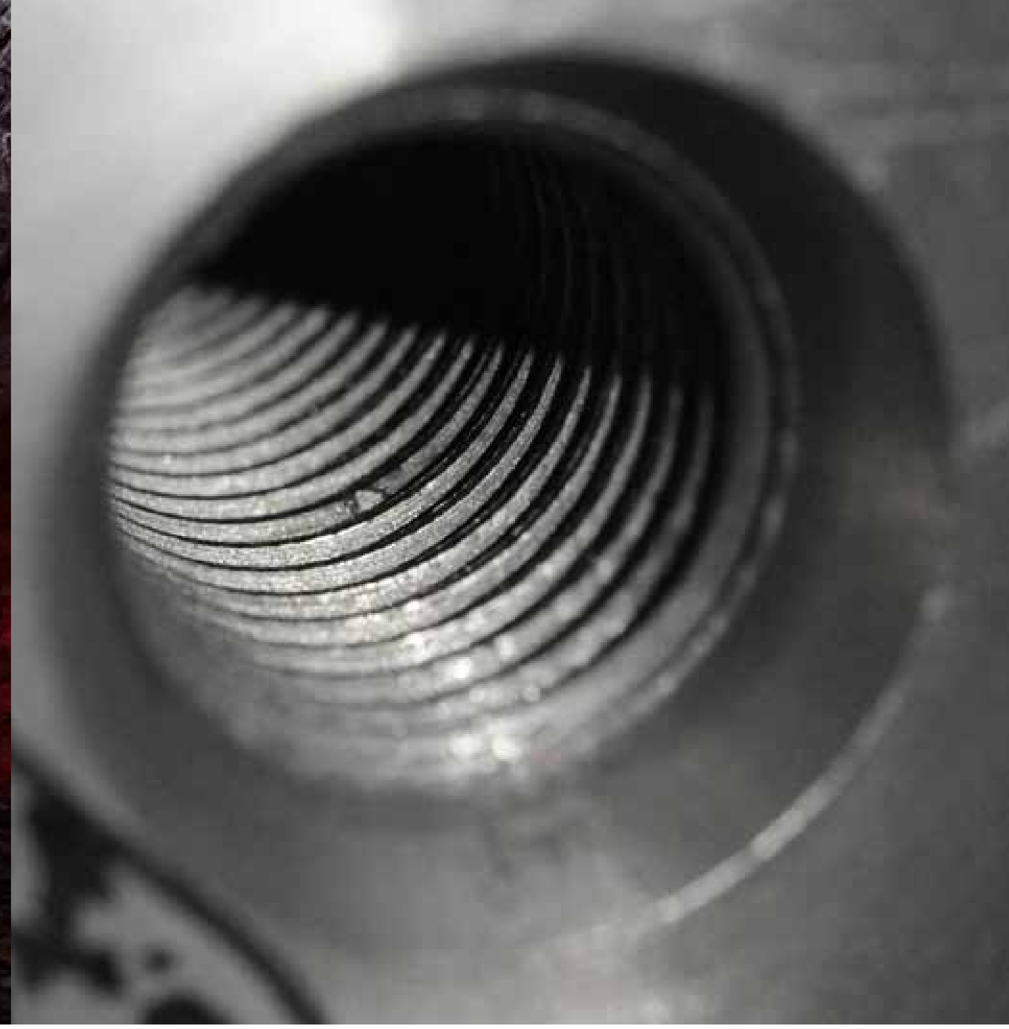


NUCLEAR WASTE MANAGEMENT OF THE OLKILUOTO AND LOVIISA POWER PLANTS

Summary 2016

Photo: Bernhard Ludewig



SUMMARY

This report is the report referred to in the Nuclear Energy Decree presenting the activities that Teollisuuden Voima Oyj (TVO) and Fortum Power and Heat Oy (Fortum) as parties with the nuclear waste management obligation have carried out with respect to nuclear waste management in 2016. The final disposal of operating waste has been implemented on the Olkiluoto site in Eurajoki and on the Hästholmen site in Loviisa since the 1990s. The activities carried out by the companies to fulfil their nuclear waste management obligation focus on the final disposal of spent nuclear fuel in Olkiluoto and the operation of Posiva Oy (Posiva) which is jointly owned by the two companies. Nuclear waste management programme YJH-2015 published in the autumn of 2015 described the then-current status of research, development and planning work related to the decommissioning of the power plants, as well as plans for the years 2016–2018 and preliminary plans for the years 2019–2021. The preparations for final disposal chiefly progressed in 2016 according to the YJH-2015 programme.

The Finnish Government granted Posiva in November 2015 the construction licence for the final disposal facility of spent nuclear fuel. The licence was granted on the condition that construction starts within two years of the granting of the licence. In 2016, the Radiation and Nuclear Safety Authority of Finland (STUK) conducted a series of inspections at Posiva to establish and verify Posiva's capabilities to start the construction of a nuclear facility. At the end of November 2016, STUK concluded in its statement to the Ministry of Employment and the Economy that Posiva has the capability to start the construction of the final disposal facility. The Ministry of Employment and the Economy reviewed the condition laid down in the construction licence and the information received about the start of the construction by Posiva, and concluded that the condition would be fulfilled. The objective is to start the final disposal of spent nuclear fuel in the early 2020s.

The events that took place in 2016 in relation to the nuclear waste management efforts of TVO and Fortum are described in the following paragraphs.

Operating waste management and decommissioning at Olkiluoto power plant

The operating licences of the OL1 and OL2 plant units, the interim storage facility for low level waste (MAJ storage), the interim storage facility for intermediate level waste (KAJ storage), and the interim storage facility for spent fuel are valid until the end of the year 2018. Applications were prepared in 2016 for the extension of the operating licences of OL1 and OL2 until the year 2038, including the aforementioned interim storage facilities. The documentation to STUK related to the application was submitted in 2016, but the actual application for the operating licence was filed in January 2017. The operating licence of the final disposal repository of operating waste (VLJ repository) in Olkiluoto runs until the end of 2051.

The majority of the objectives defined in the YJH-2015 programme for the year 2016 with regard to waste management at the Olkiluoto power plant were accomplished by the end of the year. The monitoring programme for the VLJ operating waste repository has been executed according to the plan with a more restricted sampling scheme after the extensive sampling programme of 2015. The monitoring results for bedrock, hydrology, groundwater chemistry and air quality in the VLJ repository were reported for the year 2015 in 2016 like in previous years. The monitoring results for the year 2016 are to be reported in 2017. In 2016, VTT Technical Research Centre, assisted by TVO, designed and built a test setup in the VLJ repository for studying the microbiological corrosion of demolition waste. The setup will allow long-term evaluation of the microbiological corrosion of demolition waste in bedrock water conditions.

State-owned small-user wastes surrendered to STUK are under a specific agreement placed for interim storage in the VLJ repository in Olkiluoto. In the autumn of 2016, STUK approved the updated revision of the Final Safety Analysis Report (FSAR) of the Olkiluoto VLJ repository, making it possible to start the final disposal of small-user waste. The final disposal of small-user waste in the VLJ repository started at the end of 2016.

Operating waste management and decommissioning at Loviisa power plant

The validity of the operating licences of the LO1 and LO2 plant units and the facilities related to their nuclear fuel and nuclear waste management covers the operation of LO1 until the end of 2027 and the operation of LO2 until the end of 2030. As concerns the final disposal facility for operating waste from the Loviisa power plant, the operating licence is valid until the end of the year 2055.

The solidification plant for liquid waste which utilises a cementing technique was granted permission to start full operation in February 2016. During the year 2016, a total of 39 solidification processes were completed, 37 of them for resin waste. This equals the total volume of resin waste produced in 2016. The Cesium separation system which suffered from some problems related to process engineering was restarted during the third quarter of 2016. The amount of maintenance waste produced at Loviisa power plant in 2016 totalled 366 barrels, and 43% of this amount is to be placed in the final disposal facility. A total of 1.5 tons of maintenance waste and ca. 13.7 tons of waste metal was released from control in 2016. The efforts to reduce the amount of both waste generated and dry waste for final disposal have produced good results in the recent years.

The in-service studies carried out in the final disposal repository were continued in 2016 in line with the mo-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nitoring programmes. In 2016, a project was launched focusing on producing a significantly more highly detailed model than ever before of the evolution of the above-ground environment over the next millennia. The updating of the activity inventory continued during 2016. The activity inventory provides an assessment of the activity and amount of all waste awaiting final disposal. Attention has been focused in the assessments, more than before, on e.g. assessing the uncertainties of waste expected to be accumulated in the future. The inventory also covers a larger-than-before amount of various small waste batches, and the consistency of the inventory with respect to in-service and decommissioning waste has been increased.

During the year, the assessment of the amount of gas generated in the final disposal facility was updated based on updated waste amounts, updated corrosion rate and the decomposition rate of organic materials. Gas migration modelling continued in 2016 and the results support previous assumptions that the gas generated will migrate fairly easily out of the final disposal facility through the rock.

As specified in the project plan for the updating of the decommissioning plan, work in 2016 included the refinement of decommissioning costs, the licensing plan and the decommissioning strategy. The development of the plan for the preparatory stage of decommissioning continued. The simulation project of the decommissioning of the pressure vessel was started in 2016, and aims at producing a simulation of the RPV's decommissioning stages in accordance with the plans that have been prepared.

Status of preparations for final disposal of spent nuclear fuel

Posiva has grouped the works required for the application for the operating licence into a project scheduled to allow the submission of the application for the operating licence in 2020 and achievement of operational readiness in 2023. The preliminary design stage of the operating licence project ran for the duration of the year 2016, and in 2017 the project will move on to the design stage. Posiva carried out in 2016 a self-assessment of the effectiveness and coverage of the management system, and the safety culture. Based on the self-assessment, Posiva's management system fulfils the criteria specified for it and for its part ensures the implementation of nuclear safety in the project. Experience previously gained in the TVO Group is utilised in applicable parts as far as possible when moving towards the construction and manufacturing stage in Posiva's nuclear facility project. The most important actions specified in the plan for 2016 included an independent assessment of Posiva's organisational capability and a self-assessment of leadership and safety culture. A longer-term action plan for safety culture for the years 2017–2020 was drawn up based on the recommendation issued in the external assessment. The Group-level goal of striving for IAEA safety level 3 and achieving it by the year 2020 is taken into consideration in the plan.

Quality control has at Posiva become an integral part of Posiva's operation. Procedures used in quality control related to rock construction have been further improved to establish a smoother and more effective process ensuring that the contractors' quality control documentation fulfils the requirements. The level of cooperation with STUK has been increased during the weekly visits of STUK's local inspector. Posiva's Quality Control has continued together with STUK the commissioning inspections referred to in YVL Guide D.5.

Environmental management activities at Posiva were in 2016 implemented in cooperation with TVO as Group-level activities. The principle of continuous improvement is complied with in operational planning by looking for means to reduce the potential environmental impact of the operation of the Company. In 2016, appropriate procedures were specified for the placement of the excavation sludge as well as for the crushing and storage of the excavated rock. In order to prevent oil spills, preventive and in-service activities related to the actions of the personnel and the maintenance of the equipment were secured, including their compliance with guidelines as well as their coverage, and associated training practices. Posiva did not in 2016 meet the zero accident objective for occupational health and safety. During the year, the subcontractors of Posiva reported five accidents resulting in absence from work and three work injuries that did not cause absence from work.

Posiva supplemented during 2016 the radiation safety design of the structures as part of the design documentation on the encapsulation plant. Modifications in the radiation shielding labyrinths and penetrations as well as wall thickness were approved based on analyses. Design related to radiation protection was continued by preparing a description of operational radiation protection at the encapsulation plant and the final disposal facility. The probabilistic risk analysis for the design stage was updated in 2016 based on updated design data on the encapsulation plant and the final disposal facility.

Development programme for final disposal concept

The development programme for the final disposal concept is one of the operations planning programmes of Posiva, providing more specific information on and schedules for the plans presented in the YJH-2015 programme. In February of 2016, Posiva submitted to STUK a revision of the development plan that had been updated in terms of structure and content. The development programme provides a presentation, structured according to the requirements made in STUK's decision, of the R&D activities that in Posiva's view are necessary to fulfil each of the requirements. The programme also describes the project in which the R&D activities to be carried out are included or the line organisation that is responsible for them.

Posiva has continued during 2016 the planning of the full-scale in situ system test to be implemented in ONKALO and has set up a project for the execution of the tasks. The objective is to test the components of the final disposal system as a whole with respect to their installation on full scale in compliance with the specified criteria. The test will also serve as a pre-test for the underground commissioning test providing feedback on the duration, costs and production-scale functionality of the different phases.

Posiva continued the fuel database project in 2016 with preparations related to the definition and description of the database. The level of detail of the plan regarding radiochemical isotope measurements was also increased, and documentation was prepared for the decision-making process related to work procurement. Work aiming at the qualification of the final disposal canisters was started in early 2016. With a friction stir welding (FSW) method chosen for the sealing of the canister, studies were carried out as to the necessity of the gasket on the canister insert from the viewpoint of both the friction stir welding method and long-term safety. The conclusion drawn based on the studies was that the gasket is not needed, and the canister design was modified accordingly. The creep analysis made on the friction-stir welded canister indicated an adequate creep strength, but a further analysis is needed regarding loads acting on the bottom edge of the canister in ice age conditions. Posiva has studied the residual stresses of a friction stir welded canister by welding a full-diameter canister lid onto a 900 mm long copper overpack in the canister laboratory of SKB. The assessment of the different forms of corrosion and their significance to long-term safety has continued.

One copper overpack was manufactured in 2016 with an integrated bottom using the pierce-and-draw method. Development work focused on the optimisation of the forming of the overpack bottom to achieve uniform quality and small grain size. Two copper overpacks were also manufactured for use in the full-scale in situ system test. A cooperation project was carried out with SKB to compare the material properties of two BWR inserts produced in different foundries using different casting techniques. The project also provided information about the possible differences between laboratories as concerns the non-destructive testing methods used. Ultrasonic and eddy current inspections were carried out on the canister components manufactured in 2016. The objective of the inspections

was to provide more information about the quality of the manufacturing process and any defects in the components, and this objective was accomplished. Test measurements of the copper overpack and copper lid were also started by third-party testing organisations, designed to find the best possible solution for the qualification of inspections and for subsequent inspections during production.

The technical design activities related to the buffer concentrated on the compatibility of the deposition hole and the buffer, particularly the effect that deposition holes with properties deviating from design values will have on the design of the buffer. The experience gained from the installation tests of the final disposal canister was integrated into the technical design of the buffer and resulted in the gap between the buffer blocks and the canister being increased to improve the certainty of canister installation. Plans were defined in 2016 for further clarifications regarding the stabilising of density differences between the bentonite buffer and the tunnel backfill. The development of a method for assessing the reducing effect of dilute water on clay density was started by task planning in cooperation with SKB. The development of swelling pressure in the buffer has been continued by tests carried out on different scales. A new, half-scale buffer test that will continue for about one year was started towards the end of 2016. Laboratory tests were also commenced to allow the assessment of the potential threat caused by the use of cement to the performance of engineered barriers.

Trial manufacturing of the main backfill components were also performed using four different materials during 2016 for purposes of material selection. The optimisation and development of the reference design presented for backfill in the application for the construction licence continued with the updating of backfill requirements. The reporting of works defined in the development and testing plans related to the management of leakage water during backfill installation was also started during the year, as was also the development of backfill qualification documentation. The component-specific backfill installation tests proceeded with floor levelling installation tests carried out in the above-ground test facility.

In 2016, the deposition tunnel end plug test project POPLU continued with two tests in which water pressure behind the plug was increased to test the performance of the plug. The experience gained and the results of the POPLU tunnel end plug test were compared with the results of SKB's and Posiva's joint DOMPLU end plug test. The aim of the comparison was to enable Posiva to choose the reference end plug type during the first quarter of 2017. The selected plug type will be implemented in connection with the full-scale in situ system test. The heating system for the test canisters to be used in the system test was designed in 2016, including the modifications needed in the EBS components due to the heating system. In addition, the design of the test monitoring system was started in collaboration with SKB.

The methodology development for the closure of the investigation drillholes proceeded with a project launched to close two deep investigation drillholes in the Olkiluoto research area. Work related to the closure of drillholes within the extension area of Fingrid's switchyard in Olkiluoto started in November. The main material used in the sealing of the holes is concrete, using a mix specifically developed for this purpose. Bentonite was also installed in the holes to prevent the formation of ground water flow routes in the direction of the hole. The need for further development activities will be planned on the basis of field work.

Characteristics of final disposal site

Utilisation rate assessment of the updated layout plan of the final disposal facility was prepared in 2016, and preliminary rock suitability classification was carried out regarding both the area of the commissioning test tunnels and the repository for low and intermediate level operating waste. A plan for the drilling of a pilot hole in the profile of the central tunnel was also formulated for the area where commissioning test is to be carried out.

Deep drillhole OL-KR58 was drilled on the Kuusisenmaa Island in Olkiluoto in the spring of 2016 for the purpose to study the bedrock below the sea. The studies are designed to provide more information on the evolution of groundwater, for example. Groundwater gas samples were taken from the drillhole as part of hydrogeochemical sampling.

Geological mapping of ONKALO was carried out in the new excavated rock facilities. The development project for the verification of the compliance of the deposition holes with requirements, started in 2014, continued in demonstration tunnel 2. The purpose of the project is to determine the measuring method of the deposition holes which is the most suitable for the production stage, and to monitor any changes occurring in the test deposition holes over a period of at least one year.

Hydrogeological data was collected in ONKALO through flow measurements conducted in probe holes as excavations proceeded. Leakage water mapping and leakage water measurements were carried out regularly once a month. Characterisation drillhole ONK-KR17 was sampled for gas several times during 2016. Work related to the interpretation of the results and associated modelling started at the end of the year. In situ tests were started at groundwater station ONK-PVA6 where microbial strains inherent to Olkiluoto were collected at in situ pressure and conditions on surfaces of iron minerals separated from the Olkiluoto rock. The Olkiluoto Rock Matrix Retention Properties (REPRO) test programme focused in 2016 on the monitoring of the last phase of the test programme, the Through Diffusion Experiment (TDE).

A report titled Geology of Olkiluoto was published in 2016; it presents a description of the petrological and deformation history of Olkiluoto bedrock as well as the associated deterministic modelling. The implementation of the Discrete Fracture Network (DFN v3) scale model of the future final disposal site was planned and started in 2016. It is part of the application for the operating licence and the analyses used for long-term safety assessment. The updating process of the hydrogeological structural model was completed in early 2016, and the model specimens and other documentation were released for use in required applications in June 2016. In 2016, groundwater modelling included the finalising of the surface hydrology model for the needs of the end-users, and reporting was started. Work related to the hydrogeochemical model focused on questions pertaining to the buffering capacity of the bedrock and the sulphide content of groundwater.

Research and modelling activities for the rock-mechanical site description of Olkiluoto focused in 2016 on the reporting and analysis of work carried out in previous years. A decision was made in 2016 to end the POST project. It was concluded on the basis of the prognosis calculations that the execution of the in situ shear test in the tunnel conditions of ONKALO, which was defined as the objective of the POST project, is not possible and the test involves too many uncertainties related to implementation. The mechanical properties of the rock joints were defined based on geological mapping data for use in the rock-mechanical site description of Olkiluoto. The methodology for the quantitative imaging of the rock joint properties was completed.

In addition to the monitoring of the surface environment, biosphere research campaigns related to the surface environment were carried out in 2016 as part of Posiva's safety case work. The majority of these were located outside Olkiluoto.

Any changes caused by the construction of ONKALO and the final disposal facility are monitored by means of the Olkiluoto monitoring programme (OMO) specifically set up for this purpose. Rock-mechanical monitoring continued as in previous years and the number of observations correlated with the excavation works started. Total leakage of water in ONKALO was abt. 32 l/min on average in 2016. A visual leakage water survey was carried out during the year over the full length of the tunnel to identify leaking fractures and zones and to monitor any changes at leakage points. Groundwater samples were ta-

ken in ONKALO according to the programme primarily at the groundwater stations, but also in e.g. the characterisation drillholes. A total of ten groundwater stations were under regular monitoring in 2016. Both chemical and microbiological analyses of groundwater have been carried out at them, and with a few exceptions, the results have been consistent with the natural state of groundwater. The monitoring of the surface environment in Olkiluoto area continued according to the research plan presented in the monitoring programme, and data were produced both for the monitoring of environmental impact and for use as input data in biosphere modelling. A continuously operating measuring dam was installed in the drainage ditch of the ONKALO area in 2016. In the autumn of 2016, a momentary release of runoff water with a high pH was observed from the construction site of the encapsulation plant to the ditch running to the nature conservation area. Pumping of water was transferred to another ditch as a corrective action. The monitoring of foreign materials as part of the monitoring programme was ended during 2016. The term ”foreign materials” has been replaced with ”safety-classified materials” (TLT materials) and the management of foreign materials at Posiva has been combined with the management of materials at TVO into a Group-level management function. The design of a monitoring programme of the engineered barrier system (EBS) has started.

Safety case and research to support it

The plan for the structure and content of the TURVA-2020 safety case for the operating licence application was submitted to STUK for comments in 2016. The requirements for long-term safety have been updated and the intention is to freeze them in early 2017 for the safety case. Almost all of the designs for release barriers used as input data for the safety case were approved in 2016 and input data were collected on the various barriers, the fuel and the rock facilities. The methodology to be utilised in the assessment of safety, particularly the methodology for scenario forming, has been designed and tested in 2016. Design activities related to the modelling strategy for analysing the scenarios of radionuclide releases were carried out in 2016. In keeping with the original goal, the failure mode and effect analyses (FMEA) pertaining to the various engineered barriers (canister, buffer, backfill, closure) and to the bedrock facilities were produced by the end of the first half of the year.

The GAP project (Greenland Analogue Project) has been completed and the final report of the project has been published. The Saimaa project is designed to study the penetration of glacier meltwater into groundwater circulation within the area known to have been hydrologically active at the waning phase of the last glacial period. The drilling programme comprising three drillholes was completed during the year 2016. Sorption studies based on electromigration were continued in 2016 with strontium. The influence of ionic strength on the sorption of silver in light protected conditions was also studied in 2016. Sampling carried out as part of the studies mapping the current status of the surface environment in the reference area focused on agricultural products in Southwest Finland. Remote mapping activities were continued in Olkiluoto and the reference area utilising documentation consisting of aerial images which have proven better suited for the monitoring of reference biotopes than satellite images.

Horizontal emplacement solution KBS-3H

In 2011, a project was launched in cooperation with SKB for the further development of the horizontal emplacement solution. The project will be completed during the first half of 2017. The main goal of the joint project is to develop the technical design of the 3H alternative and the understanding about the systems to a level allowing a preliminary safety assessment to be produced for the 3H alternative. As a rule, work has progressed in compliance with the YJH-2015 programme. However, as a deviation from the programme, a decision was made to postpone to the next possible project stage the reaming of the pilot hole in the Äspö rock laboratory to the full 1.85-metre diameter size of the horizontal hole and the subsequent post-injection in the horizontal hole, which were scheduled to take place in 2016. Correspondingly, the further clarifications regarding occupational and operational safety that were planned for the year 2016 have been transferred to a later date.

Posiva made in 2016 a strategic decision on the continuation of the KBS-3H development work. The decision was not to continue the further development of horizontal emplacement immediately upon conclusion of the joint project with SKB; instead, development work will focus on closing the open issues related to the KBS-3V concept.

Design of encapsulation plant and final disposal facility, and preparations for production

The project plan for the final disposal facility project was updated in early 2016 according to the model based on the practices adopted in the reorganisation of the project. The unrealised scope of the ONKALO project was incorporated within the scope of the final disposal facility project. The last excavation phase of the ONKALO scope, the TU6 contract work, was started in March 2016 and completed in December 2016. Work included in the first tunnel work contract of the final disposal facility, the LTU1 contract, was started in December 2016.

Progress was made during 2016 in testing the prototype of the remote controlled mover designed for the transfer of the disposal canister. Testing included various tests measuring the performance and conformity of the remote controlled mover. The testing of the prototype of the canister transfer and installation device and buffer installation device continued in the demonstration tunnels of ONKALO under conditions similar to those prevailing in the final disposal facility. Development areas were defined for the devices on the basis of the tests to ensure that installation work for the full-scale in situ system test can be carried out in early 2018. These modifications have been implemented during 2016.

A project for the optimisation of canister production was set up in 2016 to carry out tasks related to the determination of the canister production chains, the performance of calculations for comparing the cost efficiency of in-house production versus outsourcing, and the consideration of alternative suppliers of the different canister components. The first work package comprising the identification of the costs of the various canister components and the current suppliers was executed in 2016.

In development work related to the isostatic manufacturing technique of the buffer blocks, blocks were produced for one whole full-scale buffer. In 2016, a procurement method analysis regarding the backfill blocks was started, designed to identify suppliers capable of delivering precompressed backfill blocks complying with the manufacturing specification. Based on the procurement method analysis, three more materials from different raw material suppliers were chosen, in addition to the original four bentonite materials, for the productions tests carried out using the uniaxial compression method.

Tender invitation documents for a dry transport cask for fuel transports from Loviisa were finalised in 2016. The possibility of using the wet cask that TVO uses also to transfer fuel from the spent fuel storage in Olkiluoto to the encapsulation plant is still being investigated. An analysis was made in 2016 of the options for fuel transports from Loviisa, including possible routes. The decision on the transport mode will be made at the same time as the decision on the procurement of the transport cask.

A report was produced in 2016 of the use of the arrangements currently in place at TVO for the processing and final disposal of the low and intermediate level waste generated at the encapsulation plant during the first decades of the operation of Posiva’s facilities. A reservation for a final disposal repository for low and intermediate level waste will be maintained in Posiva’s final disposal facility also in the future, and the existence of such a repository will be taken into consideration in the long-term safety assessments to be prepared for the final disposal facility.