Finnish Research Programme on Nuclear Waste Management KYT2018

Framework Programme for the Research Period 2015–2018

Publications of the Ministry of Employment and the Economy
Energy and the climate
51/2014

TYÖ- JA ELINKEINOMINISTERIÖ
ARBETS- OCH NÄRINGSMINISTERIET
MINISTRY OF EMPLOYMENT AND THE ECONOMY

Finnish Research Programme on Nuclear Waste Management KYT2018

Framework Programme for the Research Period 2015–2018

Publications of the Ministry of Employment and the Economy
Energy and the climate
51/2014

Työ- ja elinkeinoministeriön julkaisuja Energia ja ilmasto 51/2014
Arbets- och näringsministeriets publikationer Energi och klimat 51/2014
MEE Publications Energy and the climate 51/2014

Tekijät | Författare | Authors

Planning Group of the Finnish Research Programme on Nuclear Waste Management
Chair Jarkko Kyllönen
Secretary Kari Rasilainen

Julkaisuaika | Publiceringstid | Date
November 2014

Toimeksiantaja(t) | Uppdragsgivare | Commissioned by
Työ- ja elinkeinoministeriö
Arbets- och näringsministeriet
Ministry of Employment and the Economy

Toimielimen asettamispäivä | Organets tillsättningsdatum | Date of appointment
26 September 2013

Julkaisun nimi | Titel | Title

Finnish Research Programme on Nuclear Waste Management KYT2018
Framework Programme for the Research Period 2015–2018

Tiivistelmä | Referat | Abstract

The objective of KYT2018 (Finnish Research Programme on Nuclear Waste Management), run by the Ministry of Employment and the Economy, is to ensure the sufficient and comprehensive availability of the nuclear technological expertise and other capabilities required by the authorities when comparing different nuclear waste management ways and implementation methods. Research required for the supervision of nuclear waste management falls under other public authority programmes, whereas that related to the planning, implementation and development of nuclear waste management falls under research programmes conducted by licensees as part of their nuclear waste management obligation.

The Framework Programme for 2015–2018 was prepared by a working group appointed by the Ministry of Employment and the Economy.

The contents of the KYT2018 Research Programme comprise key research subjects in terms of national expertise. These include nuclear waste management technologies, research into the long-term safety of nuclear waste management and sociological research related to the issue. The aim is to assemble extensive, coordinated safety research wholes. Traditional projects, whether lasting one or several years, are also suitable for the Research Programme.

The KYT2018 Research Programme serves as a discussion and communication forum between authorities, organisations engaged in the nuclear waste management and research institutions, creating the preconditions for utilising limited research resources. It also strives to ensure a diverse and interdisciplinary research team for research projects. Another aim is to help secure the continuous availability of essential national expertise, while promoting scientific and high-level competence, and enhancing general knowledge in the field of nuclear waste management.

Contact persons within the Ministry of Employment and the Economy: Energy Department /Jaana Avolahti, tel +358 29 506 4836

Asiasanat | Nyckelord | Key words
Nuclear waste management, research

Painettu julkaisu | Inbunden publikation | Printed publication
ISSN **ISBN**

Verkkojulkaisu | Nätpublikation | Web publication
ISSN 1797-3562 **ISBN** 978-952-227-908-8

Kokonaissivumäärä | Sidoantal | Pages
43

Kieli | Språk | Language
englanti, engelska, English

Julkaisija | Utgivare | Published by
Työ- ja elinkeinoministeriö
Arbets- och näringsministeriet
Ministry of Employment and the Economy

Vain sähköinen julkaisu
Endast som elektronisk publikation
Published in electronic format only

Foreword

KYT2018 is the Finnish Research Programme on Nuclear Waste Management for 2015–2018, run by the Ministry of Employment and the Economy (TEM). The KYT2018 Framework Programme contains a description of the programme's actors and organisation. It also includes policy definitions related to the targets and research-related contents of the programme period, with particular attention to information needs of the authorities. The research programme steering group can specify research focus areas on an annual basis.

The framework programme has been prepared by a planning group appointed by the Ministry of Employment and the Economy on 26 September 2013. Planning group members included the following: Jarkko Kyllönen (Radiation and Nuclear Safety Authority STUK), Mikko Paunio (Ministry of Social Affairs and Health, STM), Miliza Malmelin (Ministry of the Environment, YM), Jaana Avolahti (TEM), Jari Tuunanen (Fortum Power and Heat Oy), Liisa Heikinheimo (Teollisuuden Voima Oyj, TVO) and Marjut Vähänen (Posiva Oy) in addition with Mia Ylä-Mella (Fennovoima Oy) as an expert member. Kaisa-Leena Hutri (STUK), Sirkku Saarikoski (STM), Magnus Nyström (YM), Jorma Aurela (TEM), Harriet Kallio (Fortum Power and Heat Oy), Pekka Viitanen (TVO), Lasse Koskinen (Posiva Oy) and Hanna Virlander (Fennovoima Oy) were deputy members. Kari Rasilainen (VTT Technical Research Centre of Finland) was secretary to the planning group. The English version of the framework programme was prepared at VTT by Merja Tanhua-Tyrkkö and Aku Itälä.

Helsinki, September 2014

Ministry of Employment and the Economy
Energy Department

Contents

1 Introduction

Finnish legislation requires that those responsible for nuclear waste management assume responsibility for the planning, implementation and costs – including those related to research and development – of managing any waste they produce. Posiva Oy, jointly owned by Teollisuuden Voima Oyj and Fortum Power and Heat Oy, runs Finland's most extensive programme for nuclear waste management research and development.

The Ministry of Employment and the Economy (TEM) has the Finnish Research Programme on Nuclear Waste Management (KYT). The long term purpose of this program is to ensure the know-how in the nuclear waste management field, as required in the Nuclear Energy Act (Section 53b). The purpose of this research program is also to encourage the co-operation between authorities, those responsible for nuclear waste management and researchers. An essential part in the maintenance of knowledge is to educate new experts in the field. As described herein, the objectives and contents of the KYT programme are based on the views of the working group appointed by the ministry.

1.1 Operating environment of nuclear waste management

Both in Finland and abroad, the operating environment for nuclear waste management will change considerably during the research programme period 2015–2018.

National operating environment

Several decision making processes directly and indirectly related to nuclear waste management, are due to take place during the research programme period.

At the end of 2012 Posiva Oy submitted an application to the Government, for a construction licence of an encapsulation plant and a nuclear waste disposal facility to be built in Olkiluoto Eurajoki. The construction of these facilities is planned to begin in 2015 and operating licence will be applied so that the actual disposing can begin in around 2020. The schedule of the project will be updated during construction licence process.

Olkiluoto 3, the nuclear power plant unit currently under construction, is due for commissioning during the programme period. In addition, applications will be handled for construction licences for new nuclear power plants (Olkiluoto 4, Hanhikivi 1). The Government granted the Decisions-in-Principle in 2010.

The operating licences of Loviisa nuclear power units are valid until the end of 2020s. Those for the power plant units 1 and 2 in Olkiluoto are valid until the end of 2018. The operating licences will be applied for the next 20 years period before the

current licences expire. In the beginning of 2020s the licencing of decommissioning and disposal of decommissioning waste from Loviisa power plant is planned to begin. Before that the research reactor of VTT in Otaniemi will be under decommissioning. The environmental impact assessment of the decommissioning of the research reactor is under way.

VTT has started to construct new facilities in the beginning of 2014 for nuclear research and the related equipment in Otaniemi (Centre for Nuclear Safety). The research centre is planned to be built by the end of 2016. These new facilities will contribute to research on hot cell activities, where activated reactor materials, but not spent nuclear fuel, can be handled. Spent nuclear fuel can't be handled in the facilities. Facilities for nuclear waste research as well as radiochemistry and dosimetry laboratories will be constructed.

International operating environment

In the field of nuclear waste management, the international development is expected to be vivid during the research programme period. For example in the EU the radioactive waste and spent fuel management directive will affect practises and plans in the field. In Sweden, the authorities will complete handling of a construction licence application for an encapsulation facility of spent nuclear fuel and for the disposal facility (which was started in 2011). In France, the handling of the construction licence of high level nuclear waste facility will begin in 2015 and the disposal is planned to begin in 2025. In the United States, the so-called Blue Ribbon Commissions have examined alternative options for the geological final disposal planned at Yucca Mountain, which was abandoned for political reasons in 2010.

Several European nuclear waste management actors are developing solutions for the disposal of operating waste because the amount of waste is accumulating and thus also the pressure to begin the final disposal. In Finland and in Sweden the facilities for the disposal of operating waste are already in operation.

The financing from the European Union to nuclear waste research is carried out via Euratom´s research and education programs as framework programmes. At the moment, the 7th Framework Programme has come to an end. The new framework programme, Horizon 2020, for years 2014–2020 has been accepted and the first project call for years 2014–2015 has been opened in spring 2014. In 2009 a technology platform IGD-TP (Implementing Geological Disposal – Technology Platform) was established, with the purpose to coordinate nuclear waste management research. For now, the most active Finnish participant in IGD-TP is Posiva. In addition to Posiva some other Finnish organizations working in nuclear waste management field are participating the platform. Research activities on decommissioning and handling of operating waste is done also in research program of SNE TP-NUGENIA[1], which

1 Sustainable Nuclear Energy Technology Platform (http://www.snetp.eu/), NUclear GENeration II & III Association (http://www.nugenia.org/).

complements the objectives of the research needs in nuclear waste management at IGD-TP.

In the EU the commission is presently trying to achieve a joint program planning (European Joint Programme), with one aim being to link the national research programs and scattered projects to wider European research programs. In Finland this would concern KYT2018 and SAFIR2018 programs.

The Radioactive Waste Management Committee (RWMC) in OECD's Nuclear Energy Agency (NEA) handles especially the management of long-lived waste and spent nuclear fuel, the long-term safety of final disposal, and the decommissioning of nuclear facilities. RWMC has three working groups. Forum on Stakeholder Confidence (FSC) concentrates on the social acceptability of radioactive waste management. Integration Group for the Safety Case (IGSC) focuses on the safety of final disposal and its different points of view and on the development of safety cases of final disposal. Working Party on Decommissioning and Dismantling (WPDD) is concentrated on the strategies and dismantling techniques, regulation, decommissioning waste, financing and costs. Radioactive Waste Management Committee meets once a year. The working parties arrange thematic seminars, workshops and annual meetings, on annual basis. In addition the committee publishes topical reports and brochures. There is representation from Finland in the RWMC, and also from KYT-program.

The Finnish actors in the nuclear waste management field participate actively in the preparation of international recommendations and in the preparation of the safety criteria in Europe. STUK contributes on the criteria work of the nuclear waste management in IAEA, especially via Waste Safety Standards Committee (WASSC) by participating in the preparation of drafts of regulations and guidelines and by working in IAEA's projects (for example in International Intercomparison and Harmonisation Project On Demonstrating the Safety of Geological Disposal, GEOSAF). In addition to the guideline work STUK is working as a contact organization in the Online Information Resource for Radioactive Waste Management (NEWMDB), which is maintained by IAEA. The experts from STUK are also participating in peer reviews as members of IAEA review teams. The co-operation with IAEA gives an overall picture to nuclear waste matters even though it is not directly dealing with the research. STUK is also participating in the work of Western European Nuclear Regulators Association (WENRA) and in Working Group on Waste and Decommissioning (WGWD). The aim in WGWD is to harmonize the regulatory requirements considering the nuclear waste and decommissioning. For their part, the license holders (Fortum and TVO) participate via ENISS-group (working under Foratom) to the follow-up and commenting of the guidelines and regulation work of WENRA, IAEA and European commission.

The Nordic Nuclear Safety Research (NKS) is a Nordic cooperation network, funded by Nordic ministries and power companies, which supports research concerning nuclear safety, radiation protection and emergency preparedness activities and arranges seminars. In recent years, in the field of nuclear waste management, NKS

has studied e.g. the measuring of hard-to-detect radionuclides from decommissioning waste and arranged three decommissioning seminars. The first of the seminars was held in Risø, Denmark in year 2005, the second in Studsvik, Sweden in year 2010, and third in Halden, Norway at the end of 2013.

1.2 Former public research into nuclear waste management

Publicly financed nuclear waste management research was launched in Finland in the early 1970s, on the initiative of the Atomic Energy Advisory Board. Public coordinated research programmes on nuclear waste management have been conducted since 1989 (see Table 1).

Table 1. Public administration's coordinated research programmes.

Period	Research programme
1989–1993	Publicly financed nuclear waste management research programme JYT [1)]
1994–1996	Publicly administrated nuclear waste management research programme JYT2[2)]
1997–2001	Public sector´s research programme on nuclear waste management JYT2001[3)]
2002–2005	Finnish Research Programme on Nuclear Waste Management KYT[4)]
2006–2010	Finnish Research Programme on Nuclear Waste Management KYT2010[5)]
2011-2014	Finnish Research Programme on Nuclear Waste Management KYT2014[6)]

1) Vuori 1990, 1991, 1993.
2) Vuori 1997.
3) Vuori 2000, Rasilainen 2002.
4) Rasilainen 2006.
5) KYT-johtoryhmä 2005.
6) TEM 2010.

An international evaluation of the KYT2014 Research Programme was conducted in 2012. According to the evaluation team, the main goals of research program have been achieved. The research program has enhanced the education of new experts and maintained general expertise in the field of nuclear waste management. The evaluation team set forth recommendations e.g. for research topics, general nuclear waste management education, centres of expertise and co-operation with other research programmes (Apted et al. 2013). Account was taken of evaluation team proposals when preparing the KYT2018 framework programme, regarding e.g. in research topics.

1.3 Education

A key aim of the KYT programme is to ensure the continuous availability of relevant national expertise, while promoting scientific and high-level competence, and enhancing general knowledge in the field of nuclear waste management. The key principle in national knowledge and strategy groups in nuclear area is that the

critical research acquirements and expertise are maintained and developed further in the key fields (TEM 2012, 2014). This can be achieved e.g. by promoting the training of a new generation of experts. This goal is particularly topical, since the most experienced Finnish experts in nuclear waste management are approaching retirement. At the same time the generation of nuclear energy is expanding, in addition to the licencing processes of decommissioning of old plants, which further increases the need of new experts.

In the year 2010 a national pilot course in nuclear waste management was planned within KYT research program. The course is intended to provide a general picture of the nuclear management field and the laws and regulations guiding it for newcomers and experts already in the field. In addition one aim of the course is to maintain and strengthen the knowledge in the nuclear waste management field. The course of six days, is arranged yearly and there will be about 20-25 participants. The demand has been greater but the maximum limit for participants is limited due to the excursions made during the course. The course is arranged in co-operation with different actors in the field.

KYT2018 research programme supports the development of national nuclear waste management education. The research program also emphasises education effect as one criterion when evaluating project proposals after a project call. The research programme can offer co-financing in support of thesis work, the thesis fulfilling the content-related objectives of the framework programme (see Chapter 3).

1.4 Long term strategy of nuclear waste research in Finland

In Finland, the long term strategy in nuclear waste management research has been outlined as one part in the Nuclear Energy Research Strategy Group (YES). The group has been set up by the Ministry of Employment and the Economy (TEM 2014). In the group the national research strategy of nuclear energy field has been outlined until year 2030. The work was done in six divisions.

1. Nuclear safety
2. Nuclear waste management
3. Researcher training in the nuclear field
4. Future nuclear energy technologies and basic physics
5. Nuclear energy research in the social sciences
6. From research to business in the nuclear energy field.

In terms of nuclear waste research it is essential that the time scales in nuclear waste management are long and that the nuclear waste management should be carried out responsibly irrespective of the overall trend of nuclear energy field. Thus the maintenance and development of relevant know-how is the main challenge.

In the long term strategy of nuclear waste research (done by the aforementioned YES-division) the current know-how of nuclear waste research was outlined (see Attachment 1) and it was used as a basis while evaluating the critical know-hows. This means the know-hows whose maintaining needs support from the whole nuclear waste management community see Attachment 2. The list of critical know-hows, made by the Nuclear Waste Management Division of the YES group was utilized while making this framework programme.

During the planning of this framework programme, also the results from the seminar of interface between SAFIR-(http://safir2014.vtt.fi/) and KYT-program[2] have been utilized. The seminar outlined possible collaboration between the public research programmes on nuclear safety and nuclear waste management, respectively.

2 KYT and SAFIR-programs are funded by the State Nuclear Waste Management Fund where, according to the Nuclear Energy Act, two separate research funds are established; one for KYT and another for SAFIR.

2 Organisation of the research programme

2.1 Premises and targets

The premises of the KYT2018 Research Programme are based on the Nuclear Energy Act (990/1987), according to which the aim of research activity is *'ensuring that the authorities have such sufficient and comprehensive nuclear engineering expertise and other facilities at their disposal that are needed for comparisons of the various ways and methods of carrying out nuclear waste management'* (Section 53 b).

Research programme contents comprise research topics which are considered as essential in terms of national expertise. Coordinated projects covering the entire programme period are planned for the topics considered most crucial.

According to the Nuclear Energy Act, those responsible for nuclear waste management must assume responsibility for the planning, implementation and costs, including those related to research and development, of managing any waste they produce. Projects falling within the direct responsibilities of nuclear waste producers are therefore excluded from the KYT programme. In addition, research conducted in direct support of STUK's supervisory duties is also excluded. However, different actors can offer e.g. their equipment and experimental research data for researchers of KYT-programme to use, in which case the equipment and data are more widely utilised e.g. in theses.

Universities are responsible for their own strategy of the education of their undergraduate and postgraduate students and research. Research organizations e.g. VTT are responsible for the development of their own know-how based on their own strategy and outside research demand. For its own part KYT programme fulfils the financial options of these organizations.

The KYT2018 research programme serves as a discussion and communication forum between authorities, organisations engaged in nuclear waste management and research organisations. The aim of this forum is to facilitate efficient utilisation of limited research resources, while striving to ensure sufficiently versatile and interdisciplinary research teams for individual research projects and also experienced support groups for the research projects. Efficient information exchange can also help in avoiding research overlaps, as well as in coordinating participation in international projects, for instance.

On the basis of proposals by the Ministry of Employment and the Economy, the State Nuclear Waste Management Fund (VYR) makes financing decisions for nuclear waste management research projects on an annual basis. The ministry's proposal is based on the financing recommendation by the KYT steering group. The annual amount of funding is based on the liabilities of waste producers. During the research period 2015–2018 the annual funding is about 1.8M€.

KYT2018 research programme supports and encourages participation in international nuclear waste research. For example EU projects can also have joint funding by the VYR and other national or international financiers. Jointly funded projects are subject to the same financing terms and requirements as those financed by VYR alone. Those financing terms and requirements are available on webpage of KYT-research programme (http://kyt2014.vtt.fi/)[3].

2.2 Administration of the research programme

Research programme activities are based on mutual cooperation and the distribution of responsibilities between TEM, the programme steering group, one or several support groups, the coordinator, and research projects. The division of responsibilities between research programme actors is presented briefly in the following. Details of the administrative practices related to the programme are available, in the operating instructions posted on the research programme website (http://kyt2014.vtt.fi/).

Steering group

The Ministry of Employment and the Economy appoints the members of the programme steering group. The chairman of the steering group is from the Radiation and Nuclear Safety Authority STUK. The steering group includes representatives from the Ministry of Employment and the Economy, the Radiation and Nuclear Safety Authority STUK, the Ministry of Social Affairs and Health, the Ministry of the Environment, Fortum Power and Heat Oy, Posiva Oy and Teollisuuden Voima Oyj and Fennovoima Oy as an expert member. The secretary is the research programme coordinator.

The steering group is responsible for the research programme's strategic guidelines. Complementing the general guidelines in the framework programme, the group can propose annual focus areas of research to the Ministry of Employment and the Economy, in the project call or in separate instructions by the steering group. The steering group prepares the annual financing recommendation for the project proposals submitted.

Support groups

The steering group appoints the necessary number of support groups. These act as technical specialist bodies in support of the steering group, which appoints their chairpersons and members. Support groups are responsible for annually evaluating the proposed research projects, and for the following up and guiding of projects receiving funding.

Ad hoc working groups can be nominated if necessary.

---

3 When writing this framework programme the website available is for KYT2014. as KYT2018 programme will officially start in the beginning of 2015 the website will be for KYT2018.

Coordinator

The research programme coordinator is responsible for programme administration. The coordinator is selected on the basis of competitive bidding. The selection criteria are experience in nuclear waste management area, and knowledge of national and international research programmes. In addition it is required that coordinator's home organization provides support for the coordinator, e.g. in IT and financial administration and in human resources.

Website

The material concerning the research programme is mainly published on the research programme's website, described in more detail in Chapter 4.

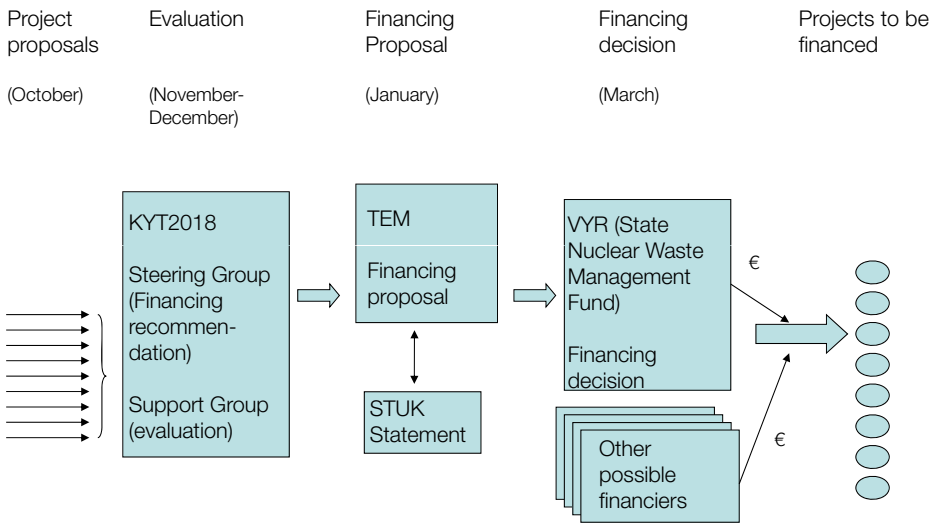
Progress of the research programme

Research projects are implemented in accordance with the VYR financing decision and an annual plan approved by the steering group. The steering group supervises the progress of the research programme as a whole, while support groups follow up and guide the progress of individual projects.

2.3 Project call and financing decision

Participants in the KYT programme are selected via a public project call process, Figure 1. The beginning of project call is announced in a letter of invitation from Ministry of Employment and the Economy. The letter of invitation is also available at the webpage of KYT programme (http://kyt2014.vtt.fi/).

Figure 1. Decision-making on research projects under the KYT2018 programme. The other potential financiers are usually research institutions that channel their own financing into their projects.



Research project proposals, entered by the due date given in the application process, are evaluated by the steering group, which prepares a financing recommendation. The support groups work as a technical expert body for the steering group. Based on the evaluation of the supporting groups, the steering group writes a feedback of the content of the project proposal. The party submitting a project proposal will be informed of the financing recommendation and the feedback.

In turn, TEM submits an official financing proposal about the annual research project entity to the State Nuclear Waste Management Fund (VYR). Before submitting the financing proposal, TEM requests that STUK issue a statement (Figure 1).

KYT2018 research programme will begin with a public project call in September 2014. Before that, TEM appointed the programme steering group. With the help of the support groups it has appointed, the steering group will evaluate project proposals submitted in the autumn. The actual research programme period begins in the beginning of 2015.

2.3.1 Project types within the research programme

Projects proposed for the KYT programme may include individual research projects or larger coordinated research entities. In practice, three types of projects are approved:

- **One-year research projects**, in which the project manager is responsible for project implementation and contacts with the research programme
- **Research projects covering a period of several years**, in which the first project proposal outlines the entire research plan and detailed plans for the first year. Plans must be updated in the following years, taking account of e.g. annual instructions issued by the steering group and the support group's evaluations of project progress. These projects need to apply for funding in each year.
- **Coordinated projects**, which is a project type introduced in the previous KYT2014 program. The aim of coordinated projects is to integrate wider research proposals in the most relevant research topics. Several research institutions participate in a typical coordinated project, which may cover the entire KYT2018 research period. In essence, a coordinated project is a small-scale research programme, where the project coordinator[4] is responsible for building a research team and for preparing a project proposal. Project coordinator is also responsible for the internal coordination and administration of the project, e.g. the project plan and reporting. The aim is to have at least four coordinated projects for this programme period, cf. Chapter 3.2. Coordinated projects can be proposed also on other topics than those mentioned in Chapter 3.2. In coordinated projects it is essential that the proposed project meets some relevant research need. It is easier to plan a co-ordinated project if a common work plan is built up on the research topic at hand. The prerequisites of coordinated projects are presented in more detail in KYT2018 operating instructions.

Having evaluated the project proposals, the steering group and support groups may require changes to them. Complying with these is a precondition for financing by the VYR.

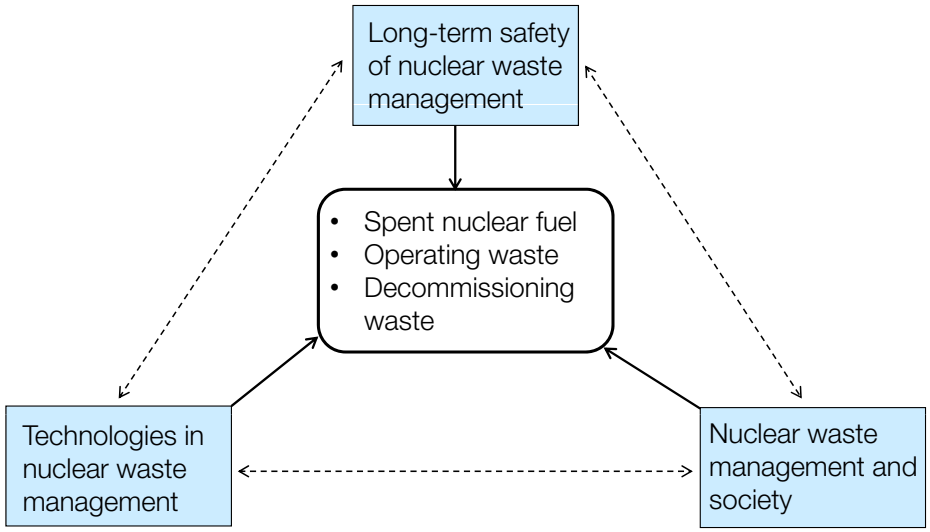
The State Nuclear Waste Management Fund (VYR) grants financing for KYT projects, one year at a time (see Figure 1). In the case of projects lasting several years, the steering group strives to ensure project continuity, provided that the project progresses according to plan. If the project fails to do so, the steering group may propose that financing should be funding cut or interrupted.

4 The coordinated project consists of subprojects and the project coordinator is the project leader of the subproject which coordinates the research.

3 Detailed objectives of the research programme

Research within KYT2018 is divided into topics, interacting with each other, (1) technologies in nuclear waste management, (2) long-term safety of nuclear waste management and (3) nuclear waste management and society (Figure 2). The public acceptability of nuclear waste disposal is dependent on its long-term safety, which is assessed in a safety case. On the other hand in a safety case the performance of technologies in nuclear waste management are assessed with long-term safety in mind. The research programme steering group can specify the emphases, between and within topics, on an annual basis.

Figure 2. Research topics of the KYT2018 research programme.



Projects included in these topics may last one or several years and they can be reviews, research or broad coordinated projects. The aim with the different projects is to ensure expertise in nuclear waste management from a multidisciplinary perspective.

The research topics are largely a continuation from the previous KYT2014 research program. When appropriate, the critical expertise areas and future know-how needs in nuclear waste management, presented in the appendices, have been taken into account. The aim of KYT2018 is to strengthen expertise in nuclear waste management.

3.1 Technologies in nuclear waste management

The authorities must have access to up-to-date information and expertise on alternative forms of geological final disposal under research and development. They must also have access to expertise required for comparisons between various ways and methods of carrying out nuclear waste management in Finland. The alternatives presented for the management of various types of nuclear waste are usually reviewed from time to time. In such a context, the possibility or need may arise to study new technical solutions.

Research into[5] new and alternative technologies enhances implementing nuclear waste management in Finland, if the current primary option, geological final disposal, is not realised as planned or if new methods are developed e.g. to reduce the amount of waste generated, or to handle the waste more efficiently and safely. This type of research can be best implemented through participation in international cooperation. However, concrete national input and expertise are prerequisites for the participation of Finnish research teams in international research programmes. In this research topic the research can be of review type and several topics can be combined.

Research topics suitable for the KYT programme may e.g. be the following, or a combination of these.

- Nuclear waste management solutions based on the reprocessing of spent fuel, nuclide partitioning and transmutation
- Retrievability of geological disposal and alternatives in geological final disposal, e.g. deep bore holes
- Storage options, e.g. dry storage of spent fuel, or other long-term storage
- Potential new solutions for the management of operating waste e.g. disposal of very low-level waste in shallow land, or disposability of new kinds of waste, and research topics on diminishing of waste amount
- New solutions for implementing decommissioning, e.g. characterization and waste treatment methods of metal and concrete waste
- Development of alternative barrier materials (e.g. canister materials)
- Further development methods for assessing nuclear waste management costs.

In Finland, the final disposal of spent nuclear fuel by those responsible for nuclear waste management is based on the fuel being used only once, in accordance with the current legislation on nuclear energy. Many large nuclear energy countries, such as France and Britain, study more advanced fuel cycles, which fundamentally involve the recycling of spent fuel in a variety of ways. Reprocessing is among the

5 In this context, no position is taken to the nature of the research. In some cases the research need of authorities demand continuous long-term research while in other cases periodically done literature survey of the state of art of the topic is enough.

alternatives to be studied. In this context, research topics include factors limiting the number of times spent fuel can be recycled in pressurised and boiling water reactors, and final disposal of spent MOX fuel. Technically speaking, P&T, partitioning and transmutation, is a more advanced form of reprocessing. Research in that field is conducted e.g. in EU research programs. The development of calculation methods is needed in P&T studies. This creates a link to SAFIR2018 research program. The partition of nuclides has been studied experimentally in previous KYT programs. In many discussions of P&T, little attention is paid to the fact that this alternative does not remove all nuclear waste and that P&T, too, requires geological final disposal.

In Finland, the final disposal programme for spent nuclear fuel, based on the KBS-3 concept is progressing towards the implementation stage. In many other countries the progress of disposal plans has been slower and for example in the USA the disposal program has been restarted. Retrievability, i.e. the possibility of retrieving nuclear waste placed in underground repository (in Finland, mainly spent fuel) to ground level has been coupled to geological disposal in some countries. One of the alternatives for final disposal solutions is based on bore holes several kilometres deep, which has been studied e.g. in Sweden. In Finland it is justified to follow the discussion about the progress and development of alternatives in geological disposal, and the discussion about retrievability.

Finland and many other countries use interim storage in water pools, but a number of different dry storage options exist. In fact, dry storage has gained ground abroad and is becoming the primary option for new facilities. As part of advanced fuel cycles France, for instance, is considering long-term storage of short-lived radionuclides, separated from the fuel cycle. The storage could last hundreds of years. The safety of storage should be verified especially if the time of storage time gets longer, due to e.g. extension of service life-time of nuclear facility (like power plant), or slow progress of disposal projects.

Geological disposal is in use also for operating waste, in Finland and in other countries. On the other hand, for some of the waste, also alternative techniques for final disposal can be used. For now, no nuclear facility has been decommissioned in Finland, while in other countries there already exist experience of decommissioning. The evaluation of potential nuclear waste management solutions may lead to the emergence of alternatives studied and used by other countries, but remaining unutilised and unstudied so far in Finland. An example in the management of operating waste lies in the final disposal of very low-level waste in shallow land or in new technical methods in decommissioning. The new technologies in nuclear power plants have also an effect on the type of the waste to be disposed. Handling of wastes in such a way that the volume of waste diminishes and waste is in insoluble form, is internationally an interesting research topic. The dismantling of nuclear facility will produce large blocks metal and concrete waste. For this waste one should find fast and reliable characterization methods to help evaluate the distribution of radionuclides.

In Finland and Sweden, the copper canister with cast iron insert has been the most studied canister option (reference canister of Posiva and SKB). In other countries other canister materials like stainless steel or compound materials have been studied. The development of new and alternative technical solutions could be studied via e.g. literature reviews.

The costs of nuclear waste management are evaluated regularly in Finland. For instance comparison of methods in decommissioning technology yields information with which one can better evaluate and justify costs and cost ranges estimated for different technical alternatives. The cost comparison requires knowledge on different methods and techniques. The development in cost evaluation skills benefits mainly authorities but also other actors in nuclear waste management field.

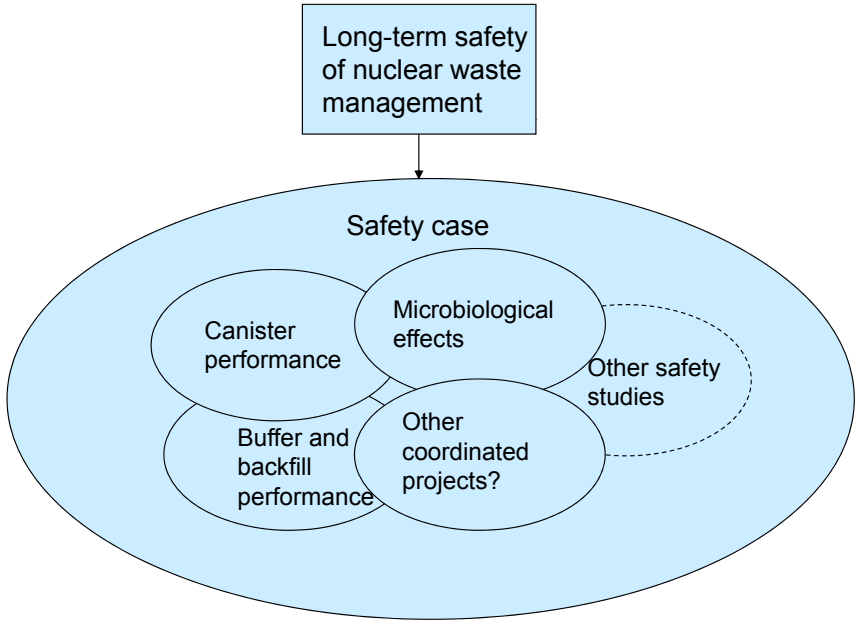
3.2 Long-term safety of nuclear waste management

Long-term safety is one of the most important things to justify in the planning and implementation of nuclear waste management. In addition, in terms of supervision, it is a challenging entity due to its interdisciplinary nature. To verify the long term safety; a high-level expertise on the safety of disposal, independent of the licence applicant, must be available to the authorities.

Safety research within the KYT2018 programme is described on the level of headlines in Figure 3. When planning a research project for long term safety, the aim should be the applicability of the results in the safety case of disposal. The development of expertise in this field is also supported by the systematic survey of critical research topics (i.e. expertise areas) done in the YES group (Attachment 2).

In this research programme, the long term safety studies of nuclear waste management can be focused on spent fuel, operating waste or decommissioning. The planning of nuclear waste management concerning all these wastes in Finland is based on geological disposal.

Figure 3. The research topics of long term safety in KYT2018 research programme. Coordinated project proposals are sought for those marked with solid line ellipses. Also other topics than those shown in the figure can be proposed for coordinated projects.. Ellipses with dashed line represent single safety studies.



In nuclear waste management long term safety studies include broad and intercoupled research entities. These are for example: (1) the safety case, including its computational analyses (2) the performance of buffer and backfill, (3) the performance of the canister, and (4) microbiological effects. A coordinated project proposal is sought for each research area. Knowledge of safety case is needed in all nuclear waste disposal but especially the performance of canister and buffer and backfill is related to spent nuclear fuel. Microbiological effects are implicitly demanded in the performance assessment of safety case. Other safety studies, of more limited studies, may last one or several years.

3.2.1 Safety case

The authorities are responsible for assessing the licence applicant's safety case. To facilitate this, a sufficient amount of high quality information, independent of the applicant, must be available to the authorities. Such information must refer to the safety case's underlying principles, philosophy and restrictions.

Safety case research is most complex, multifaceted and demanding entity where different scientific disciplines are combined. This is why the safety case proposal is suitable to be carried out e.g. as coordinated project.

Safety case methodology, e.g. a scenario analysis, can be applied not only to the final disposal of spent fuel, but also to that of operating waste and decommissioning. In principle, since a safety case methodology should be universally valid, applying it should facilitate the quantitative assessment of alternative final disposal concepts to KBS-3. In the research projects the aim should be to enhance expertise in the field of e.g. computational safety analysis methodology. Based on this know-how one can later examine the feasibility of disposal plans.

In a project plan, the applicant must present and justify the areas in which its safety case work will focus during the 2015–2018 programme period. It must present how the project stepwise progress towards an understanding that covers the entire safety case. However, when preparing the work, repeating and copying previously compiled safety cases must be avoided. Instead, new ways of analysis and new assessment models must be preferred. Among others things, attention should be paid to the following:

- The recognition of safety functions and the way in which scenarios are formed
- Alternative conceptual models and interpretations
- Development of methods for uncertainty management
- New sources of information (work conducted outside nuclear waste management research and tangential to the safety analysis methodology), e.g. the ways in which the scenarios are formed, and the work concerning safety case done in SAFIR 2018 (The Finnish Research Programme on Nuclear Power Plant Safety)
- Development of presentation methods and structure for safety case, so as to make it as digestible as possible for a wider audience (safety case principles, methods and restrictions)
- The analysis of the evolution of the repository right after the disposal facility has been closed.

Assessing the safety of the final disposal of spent fuel is largely based on scenarios, i.e. the assumed evolutions of the final disposal system, and calculating the impacts of such evolutions. The scenario formulation method must record the grounds for selecting the scenarios in question, other scenarios considered during the selection process, and the reasons for excluding some of them from the computational study. In this work it is also beneficial to familiarize oneself with scenario literature outside the nuclear waste management field.

Because a mathematical model is always constructed on the basis of a conceptual model[6], the computational study of a feature, event or process begins with the formulation of the conceptual model. Due to the complexity of the final disposal system, alternative conceptual models should be examined in order to gain a clear insight into the potential performance of the system.

The complex nature of the final disposal system and the long periods of time studied generate uncertainties that must also be quantitatively studied in a safety analysis. Part of an uncertainty analysis involves utilising the aforementioned scenarios and conceptual models. Another part involves the verification and quality assurance of calculation models. Under this topic, there is a possibility of methodological cooperation with the SAFIR programme, since the validity of calculation models is also crucial in the field of reactor safety.

In a safety analysis of final disposal, safety assessment methodologies developed in fields outside nuclear technology can be utilised. Such a use of methodological analogies facilitates the independent testing and further development of safety analysis methodology. Another possible methodological analogy can perhaps be found from nuclear safety research in SAFIR program because there also is a need to demonstrate the safety of the whole nuclear power plant and its subsystems.

Clear presentation of the key contents of the safety case to non-professional audience forms another prerequisite for the wider acceptance of the final disposal project. In this respect, KYT has an excellent opportunity to disseminate reliable information independent of licence applicants. This can contribute to enhancing the transparency of decision-making.

After the closure of the final disposal facility, the physical and chemical differences between the repository and the rock volume around will gradually even out. In Finnish safety cases the phenomena during this time period have been examined mainly through the chosen scenarios. It is essential to develop an understanding of the levelling off of these differences on the level of phenomena and by making performance studies of the whole disposal system.

3.2.2 Buffer and backfill performance

Under the KBS-3 concept, reliable assessment of the performance of buffer and backfill materials goes a long way towards determining the reliability of the entire safety case. Sufficient high-level expertise must therefore be available to authorities on the performance of these materials and the impact of such a performance on long-term safety.

Also to this topic, a coordinated project would be appropriate, because due to the broad technical and scientific challenges a research group with representatives from

6 Here the conceptual model means the symbolic description of the system under study, where the limits of the system, the initial and boundary conditions applied in calculation, materials and processes under study and, also, the quantity which is to be modelled. Technically the conceptual model is preceded by mathematical and numerical model and it helps to describe the modelling exercise to non-professionals.

several disciplines has the best opportunity to reach relevant results in respect of long term safety.

Under the KBS-3 disposal concept, bentonite buffer forms a key part of the engineered barrier system (EBS). This is because, if the buffer fails to perform as assumed, the long service life of the final disposal canister inside can be endangered, due to e.g. increased corrosion. Bentonite[7] involves a number of key topics that require clarification vis-à-vis final disposal safety. Bentonite or other clay materials are also likely to be utilised in the backfill and closure of tunnels.

The basis of the buffer and backfill research is that in safety case the performance of the buffer and backfill should be assessed. Scientifically justified conceptualizations and the mathematical and computational models derived from those can be used to assess the experiments needed in quantitative studies[8]. The development of competence in quantitative modelling needs experimental research, because in the end, the computational models should be based on experimental findings.

The understanding of the phenomena in the final disposal creates a scientifically justified base to study the behaviour of the buffer and backfill. The processes prevailing in the near-field environment of the final repository are typically interdependent. Immediately after the closure of a spent fuel repository, several gradients prevail simultaneously in the conditions of the near-field environment, e.g. thermal (T), hydrological (H), chemical (C) and mechanical (M). With time, these begin to even out[9].

The coupled behaviour of bentonite is most commonly analysed either using the THC or THM model. However, the integration of these on a certain level is necessary, since the impacts of thermal, hydrological, chemical and mechanical processes can otherwise be difficult to disengage from one another. For instance, swelling, the key chemical characteristic of bentonite, is caused by montmorillonite clay, whose chemical dissolution, cementation or mineralogical transformation will influence the swelling pressure of the buffer and backfill materials. THC and THM modelling lines require a uniform conceptual view on the structure and behavioural mechanisms of bentonite so as the respective results can be viably transferred from one modelling line to another[10].

The knowledge of microstructure of bentonite creates a basis to assess the performance of the engineering barrier system in relevant final disposal conditions. In KYT2014 a systematic microstructure research was started. The knowledge from microstructure studies is used when constructing a microstructure model of bentonite which explains the experimental findings with highest accuracy.

---

7 In this context, bentonite refers to swelling clay as a general term.
8 These studies cover for example changes in mass flows, swelling pressure and in heat transport.
9 Especially, right after the closure of final disposal repository the levelling off of gradients sets special demands on quantitative studies. During this time period irreversible changes can be caused to the bentonite buffer. This may have an effect on the long-term safety.
10 Particularly detailed analyses of coupled processes often refer to THCMBGR processes (thermal-hydrologic-chemical-mechanical-biological-gas-radiation) as a sign of the intense interlinking of near-field environment processes. Microbes, for instance, cause biological processes.

Successful research into the process and structural issues outlined above requires a combination of experimental and theoretical research. The KYT2018 programme will therefore seek to cooperate with other research organisations in the field, in order to achieve an efficient connection between experimental and theoretical work.

With the use of justified models more detailed research topics can be studied e.g. erosion phenomena (mechanic and chemical), long-term stability (mineralogic changes due to e.g. high pH, interaction with iron, impact of high salinity) and impacts of freezing. One research need is also the monitoring of changes in bentonite for example with sensor technics, which gives continuous data of the development of the buffer and in that way enhances the development of quantitative analyses. Another research need is the assessment of the significance of microbes as a possible threat to bentonite's performance.

3.2.3 Canister performance

Under the KBS-3 concept the final disposal canister is considered the most important individual barrier. Thus formation of a coordinated project to this topic can be justified. A sufficient amount of high-level expertise must be available to the authorities concerning the performance of the final disposal canister, the key factors affecting this and the methods applied in assessing the performance. The basic assumptions, principles and restrictions of assessment methods must also be understood.

In the KBS-3 concept, the canister is planned to be a copper canister with cast-iron insert, where copper has been chosen because of its resistance to corrosion and cast iron insert because of mechanical durability. When assessing the life time of a copper-cast iron canister the impact of different manufacturing techniques and faults on the durability of the canister, tensions forming within it, and the service load must be taken into account. Both pure basic material and welded copper must be studied as canister material. The welding method and the related heat supply will influence the canister, and thus the material properties and durability of the copper casing. This year (2014) Posiva has decided to use friction stir welding (FSW) as a reference method. SKB in Sweden has made the same decision earlier.

The features of canister material and manufacturing methods have an effect on the operational properties of canister. In final disposal conditions, the canister's service life primarily depends on the canister's long-term corrosion resistance, the canister's long-term mechanical durability, and the combined effect of these two.

Canister corrosion mechanisms and the propagation of corrosion are influenced by temperature, ground water composition and the transport of the dissolved substances through the bentonite buffer. On the basis of the research conducted so far, the factors affecting canister's corrosion resistance are fairly well-known. Nevertheless debate is still going on and further research needs are related to

corrosion of copper in environment with low oxygen level, and to mechanisms of stress corrosion. The most important international copper corrosion studies are also followed up and verified in Finland, in cooperation with international partners. This work is related to the topics of the KYT2018 programme.

Corrosion research is still needed because of the changing conditions (due to the groundwater flow and interaction with bentonite) and the study of possible local corrosion forms. For example knowledge of mass flows is crucial to assessing corrosion resistance. Groundwater flow can also transport microbes on the surface of the canister. Microbes have also an effect on the corrosion of copper canister. One aim in KYT2018 is to create understanding of the corrosion mechanisms caused by microbes.

As regards the canister's mechanical long-term integrity, the mechanical features of materials and structures (both the copper canister and the cast-iron insert) and their estimated changes in operation conditions must be understood. Mechanical durability is determined on the basis of tensile strength and creep strength, which are markedly influenced by the material's features (e.g. microstructure) and by changes caused by manufacturing. In creep studies of copper (especially in case of FSW weld) the microstructural relaxation of stresses and possible mechanism changes in creep with different stresses has been observed. These both have a significant effect on the behaviour of copper. The determination of strength of FSW weld should also be done with lower tensions, because for now studies have only been conducted in higher tension experiments. The data from creep studies is for now modelled with the creep model developed by VTT. At the moment, in Finland and in Sweden slightly different conceptual creep models are used in copper research. This may lead to slightly different interpretations. In addition, the joint impacts of creep and corrosion must be understood so that the long-term integrity can be assessed reliably. In practice this means that determining the couplings between material characteristics of copper metal, deformation mechanisms (creep), and corrosion requires more research. Especially research is needed of the impacts of various manufacturing and welding techniques on mechanical characteristics.

In order to control possible failure and the related risks within canister structures the potential deformation, due to external loads on the copper canister, must also be understood. In addition, the impacts of extreme loads should be studied, in order to identify any risks of failure.

The mechanical integrity of final disposal canister is based on the cast iron insert's strength, so also the mechanical characterization of cast iron structure is essential. One crucial aim is to assess the possible brittleness caused by radiation and its effect on the whole canister structure.

When studying the long-term integrity of the canister (and other barriers) it should be kept in mind that a canister exposed, for instance, to glacial impacts, has already been subjected to other loads e.g. isostatic load, prior to the glacial period. When assessing canister integrity in potential post-glacial rock displacements, an

analysis must take into account the change of characteristics due to the ageing of materials and earlier external loads.

In terms of safety analysis, essential information on the canister include the time of damage (when the release of radionuclides starts) and its type (the value of radionuclide release rates which should be applied, or to what extent does the undamaged part of the canister restrict release).

3.2.4 Microbiological effects

Microbiological activity may have an effect on the performance of the engineered barrier system (EBS) (canister, buffer, backfill, closure) of a disposal system. The microbiological effects on the long term safety of final disposal can be various (for example microbial corrosion, mineralogical transformation of barriers, and microbe-enhanced transport of radionuclides). For this reason the authorities should have enough high-level knowledge of the effects of microbiological activity on the performance of engineered barriers.

Also this topic could be a coordinated project with the aim to serve the long term safety related research needs in microbiology. In the planning of the project it is necessary to recognize the special needs in the safety case, bentonite, and canister research.

Microbes are studied by analysing water, clay, or rock samples. In KYT2018 research the already existing deep bore holes and final disposal sites, e.g. samplings from TVO's operating waste repository in Olkiluoto, can be utilised. Possible research topics can be e.g. assessment of the representativeness of sampling, the assessment of the microbial activity in disposal conditions, or the assessment of the effects of microbes on the performance of the barriers.

For all sample material, the reliability of sampling technique is the prerequisite for the usability of data. Due to the prerequisite, there should be extensive water chemical analysis from the sampling place, and the bore hole or other sampling place should be mapped geologically in a detailed manner. In KYT2014 the computational method development of bioinformatics, was started to help the interpretation of analysis results.

The role of microbes in corrosion of metals has been studied during KYT2014 research programme, especially in interaction with copper. The continuation of that work is justified provided the research is in co-operation with the studies focusing on the performance of the canister and buffer and backfill. The experimental conditions should be representative for the disposal conditions and the aims of the experiments in line with long-term safety research.

The activity of microbes has an essential role also in the degradation of low and intermediate level waste (LILW) and thus in the safety assessment of the disposal. In KYT2014 program analysis work was started on microbiological samples from a

long-term gas generation experiment[11] in an operational waste repository by using modern techniques. The experiment has lasted 15 years. Continuation of that work is justified because the experiment is coming to an end during this program period.

In terms of long-term safety, it is also essential to understand the microbial activity in the interface between geosphere and biosphere because the microbial activity may have a direct effect on the biosphere studies.

3.2.5 Other safety studies

When assessing the safety of nuclear waste management in general, and the safety of geological final disposal in particular, information is needed from several scientific disciplines.

Other safety-related research topics within the KYT2018 programme can include

- Long-term behaviour of concrete structures in final disposal conditions
- Studies related to the conclusion of tests simulating the final disposal conditions of operating waste
- The impact of spent fuel properties on the safety of final disposal, in particular the impacts of an increase in the burnup level and the final disposal of new fuel types
- The behaviour of C-14 in final disposal (spent fuel, operating waste, decommissioning waste)
- Bedrock research as regards the safety of final disposal, and the research to ensure the quality of the bedrock into which the waste is to be disposed
- Biosphere research as regards the safety of final disposal
- The modelling of the closure of repository (e.g. tunnels) and the assessment of their performance.

In the final disposal of spent fuel, operating waste and decommissioning waste the long-term behaviour of concrete structures in final disposal conditions is an essential research topic, since concrete structures must be used in any case when tunnels and repository are to be closed. In particular, the chemical interaction of concrete with the environment and increasing groundwater pH are important, because the chemical impact of concrete on the acidity-alkalinity conditions of groundwater will last for a long time, even after the concrete structure itself has disintegrated. To control ground water leakage, low pH concrete masses have been developed for injection into rock, but these, too, while eroding can change the chemical composition of groundwater. As regards the final disposal of spent fuel, the interaction of concrete

11 TVO has an ongoing gas generation experiment in operating waste repository in Olkiluoto. The decision to end the experiment should be done before 2017 or a new licence for the experiment should be applied. In the experiment, the gas generation in repository is studied in conditions which simulate the repository after closure. TVO takes samples continually of both gas and water.

with bentonite is a key research subject, since bentonite is a crucial substance in the barrier system of the final disposal repository.

Other parties, too, primarily nuclear power companies, are conducting research into the behaviour of operating waste in final disposal conditions and the durability of structures constructed for final disposal (the final disposal of operating waste is already underway). These studies either constitute large-scale experiments simulating final disposal conditions, or measurements made on actual final disposal structures. Conducting these studies, and their results, generate additional information and significant national competence. Such tests include e.g. TVO's gas generation experiment in the underground repository for operating waste at Olkiluoto, Fortum's experiment on the durability of the final disposal container, and the power companies' joint research programme on the long-term integrity of concrete in underground repository for operating waste at Olkiluoto. A scientifically adequate analysis of the results of these experiments and the conclusion of the programmes in due course require significant, systematic research input. In addition to experiments simulating repository conditions, the actual conditions within final disposal structures for operating waste are continuously monitored. This generates new rock mechanical and hydrogeochemical information of the behaviour of the repository's near field when the repository is still open.

Of all types of nuclear waste, spent fuel is the most active and long-lived and therefore understanding its characteristics is particularly important. Like in other countries, also in Finland it has been possible to licence higher discharge burn-ups due to the more advanced nuclear fuel, the experimental fuel research, and accumulated experience. The discharge burnup is a specific measure of the amount of energy generated in the reactor (per fuel mass unit). With respect to nuclear waste management, on the other hand, a high burnup of fuel leads to a longer cooling time before it can be disposed. As burnup increases, the spectrum of radionuclides in spent fuel changes including changes in nuclide distributions. Sufficiently accurate knowledge is therefore required of long term fuel development, gained both computationally and through verifying measurements. The potential use of MOX fuel in Finland requires knowledge of new type fuel and analysis of its performance in terms of nuclear waste management. This topic creates an opportunity for cooperation with the SAFIR programme.

Final disposal safety analyses have shown that C-14, the radioactive isotope of carbon, is a significant radionuclide in operating waste, spent fuel, and decommissioning waste, as regards radiological impacts. There are still uncertainties about its speciation, i.e. the chemical form in which C-14 appears. These are correspondingly reflected as conservative assumptions in safety assessments regarding its chemical behaviour. Studying the behaviour of C-14 in greater detail is therefore justified.

Concerning geological final disposal, bedrock is the natural environment into which waste is embedded. Understanding bedrock phenomena therefore forms

the basis of safety assessment. Topics requiring further clarification include groundwater flow, groundwater chemistry and the transport of radionuclides. In this context the knowledge of transport properties in fractures is essential. Moreover, mechanical issues in rock construction can also be considered research topics. These include the EDZ (excavation damaged zone), various methods of characterising it and comparisons between such methods. Spalling is another rock construction phenomenon that appears immediately e.g. as final disposal holes are drilled, while, later on, the heat generated by waste causes thermal spalling on top of the aforementioned initial spalling. Within this topic area, scientific cooperation should be sought with other research programmes. With regard to safety assessment, it is important to understand how these phenomena can be taken into account in a justified manner.

Studying the transport of radionuclides in the biosphere is necessary, since humans and other life forms will be exposed to the radionuclides there. Assessing various exposure routes over several millennia also requires an assessment of biosphere evolution. In particular, it would be vital to quantify the impacts of post-glacial land uplift in coastal regions of Finland, climate change, and the modelling of future ice ages. The need to study several consecutive ecosystem types (due to the aforementioned evolution in environment) is related to this. Understanding biosphere evolution process is important.

Before the final closure of a disposal facility, different sealing structure will be gradually constructed to prevent the swelling of backfill materials too early and to prevent the tunnel system to become a prominent flow route. Assessment of the behaviour of the sealing structures and different plugs is an essential research topic. Input data from the plug tests done in Onkalo is available to the development of the assessment methods. This is partly done also in EU project DOPAS.

3.3 Nuclear waste management and society

The purpose of social science studies within the KYT programme, related to nuclear waste management, is to support decision-making and the related preparations. The impacts of waste management decisions extend far into the future. To be realized, the nuclear waste management needs not only technical know-how but also political and wider social approval. In Finland, the licensing of nuclear waste management is done in stages. The licencing begins with the decision in principle in which nuclear waste management is evaluated against the overall good of society. The decisions made by the Government are affected by the values and expectations of the whole society.

Social science studies related to nuclear waste management have been conducted in several public research programmes since 1990's. In the previous research programme KYT2014 Finnish socio-technical challenges were studied against current international situation.

The views of various actors, stakeholders, and interested groups about nuclear waste management, and the final disposal of spent nuclear fuel in particular, remain important topics. This theme can be approached as a separate entity, for instance from the perspectives of various actors' independence. The following viewpoints are also involved:

- Ethical and public debate
- Issues related to long time scales e.g. the closed repository and the long-term preservation of the knowledge
- Generation of nuclear energy.

The volume of the public debate of nuclear waste management depends on time and place. The debate has an effect on the acceptability of the nuclear energy and nuclear waste management. Due to the long time scale involved, the question about justice between generations; i.e. what kind of burden in form of nuclear waste is left to future generations, and who will be responsible of the long-term costs. Also the reliability and preservation of knowledge and information is related to the long time scale. The question is how to ensure that the information of the final disposal is technically preserved far into the future and how to ensure that the information is understandable in terms of its contents.

Social science research of nuclear waste management should be seen in a wider context including the generation of nuclear energy, the nuclear waste management and society. With a wider perspective, there is also a better opportunity for cooperation with SAFIR-program.

3.4 Other activities to be financed

In addition to the aforementioned actual research topics, KYT2018 will cover the costs from coordinating the entire research programme on an annual basis.

The international evaluation of the KYT2014 programme noted the need for internal training and education under the research programme (Apted et al. 2012). However, according to the prevailing interpretation of Nuclear Energy Act the KYT-program is not allowed to directly finance educational projects. Nevertheless, it is possible to finance theses in research projects via KYT-program.

4 Reporting and communication of the research programme

Within the research program, an annual plan and an annual report will be published. The annual reports are written in Finnish. The research programme's annual plan presents the research projects approved for financing, alongside their key content and planned objectives. The summary form by every project will be in the attachment of the annual plan. On the other hand, the annual report presents the actual results obtained in the projects, and how research objectives were met. The summary form, by every project, will be in the attachment of the annual review.

After the end of the research programme period, a final report will be published presenting the results of the entire programme period. The final report will be published in Finnish and it will be translated into English. Research project results obtained within KYT programme must be publishable (Nuclear Energy Act, Section 53d).

Research programme results related to various topics will be discussed at thematic seminars which are arranged when considered necessary. Each thematic seminar focuses on one topic at a time.

If necessary, joint seminars are arranged in co-operation with SAFIR programme. Possible joint topics could be e.g. safety case, concrete studies, questions of spent fuel, and questions concerning the society.

At the end of the research program period the research programme results are presented and discussed at a final seminar.

The research programme website (http://kyt2014.vtt.fi/) and email are the primary means of communicating about the programme. Reports of the research programme and of research projects are published on the website, alongside with documents concerning project call. The website contains also information on seminars arranged under the research programme and on steering group decisions. The presentations in seminars will also be published at the website. The research program has webpages also in English.

5 Cooperation

To avoid overlaps, the KYT programme requires that research conducted under the programme is well coordinated with other nuclear waste research performed in Finland[12]. Awareness of the contents of Posiva's research programme is particularly important, since it is Finland's most extensive nuclear waste management research programme. The latest published research program by Posiva was published in 2012 (Posiva 2012). A new research program by Posiva will be drawn for the next three year period in 2015. Topical projects within Finnish nuclear waste management research are also described in annual reports prepared by nuclear industry (see e.g. Posiva 2013).

The KYT program will follow the themes in SAFIR–programme, especially the topics common to KYT and SAFIR programmes. Thematic seminars will be arranged around these topics, if needed. The co-operation between these research programs aims to avoid blind spots, to effective utilisation of the knowledge and equipment developed, and to avoid overlaps.

Although the KYT program is a national research programme, the research itself is international in nature, being based mostly on individual researchers' personal networks. The aim is to encourage international cooperation between individual research projects, such as participation in relevant EU or other international research projects. This is because such projects facilitate participation in broad international multidisciplinary consortia that would probably be beyond the reach by means of only Finnish financing.

The nuclear waste management research in EU is included in Horizon2020 framework program and in the research program of Implementing Geological Disposal – Technology Platform (IGD-TP). Research on using nuclear energy is done in Sustainable Nuclear Energy – Technology Platform (SNE-TP). A national support group is providing support to Finns participating in EU's research programmes.

The KYT programme encourages active participation in international expert workgroups, because they offer a channel for communicating key organisations within various countries on the overall status of Finland's nuclear waste programme and nuclear waste research. They also rapidly provide information on the general status of other countries preparing nuclear waste management. OECD/NEA's, IAEA's and NKS's expert groups are key forums for Finland.

12 In a way this is related to e.g. the parallel research NKS (Nordic Nuclear Safety Research) funded by the Nordic authorities and nuclear power industry.

References

Apted, M., Karlsson, F. & Salomaa, R., 2013. KYT 2014 Review Report, Publications of the Ministry of Employment and the Economy, Energy and Climate 10/2013, 29 p.

KYT Steering Group 2005. National Nuclear Waste Management Research Programme, KYT. Framework Programme for Research Period 2006 – 2010. http://www.ydinjatetutkimus.fi/tiedostot/Puiteohjelma%202010.pdf, 20 p.

Posiva, 2012, YJH-2012, Nuclear Waste Management at Olkiluoto and Loviisa Power Plants: Review of Current Status and Future Plans for 2013-2015

Posiva, 2013, Nuclear waste management of Olkiluoto and Loviisa. Summary of the activities in 2012 (in Finnish). http://www.posiva.fi/files/3013/YJH-toimintakertomus_2012.pdf.

Rasilainen, K. (ed.) 2002. Nuclear waste management in Finland - Final Report of Public Sector's Research Programme JYT2001 (1997-2001). Helsinki: Kauppa- ja teollisuusministeriö, Ministry of Trade and Industry Finland Studies and Reports 15/2002. 258 p.

Rasilainen, K. (ed.) 2006. The Finnish Research Programme on Nuclear Waste Management (KYT) 2002-2005. Final Report. VTT Research Notes 2337, 246 p. + app.

TEM, 2010, Finnish Research Programme on Nuclear Waste Management KYT 2014. Framework Programme for the Research Period 2011 – 2014, Publications of the Ministry of Employment and the Economy. Energy and the Climate 72/2010.

TEM, 2012, Report of the Committee for Nuclear Energy Competence in Finland, Publications of the Ministry of Employment and the Economy, Energy and the Climate 14/2012.

TEM, 2014, Nuclear Energy Research Strategy, Publications of the Ministry of Employment and the Economy Energy and the climate 17/2014.

Vuori, S. (ed.) 1990, 1991, 1993. Publicly financed nuclear waste management research programme. Annual reports 1990, 1991, 1993. Helsinki: Ministry of Trade and Industry, Energy Department. Reviews B:101, B:121, B:147.

Vuori, S. (ed.) 1997. Publicly administrated nuclear waste management research programme 1994-1996. Final report. Helsinki: Kauppa- ja teollisuusministeriö, Ministry of Trade and Industry Finland Studies and Reports 22/1997. 204 p.

Vuori, S. (ed.) 2000. Public administration's JYT2001 nuclear waste research programme 1997-2001. Mid-term report. Helsinki: Kauppa- ja teollisuusministeriö, Ministry of Trade and Industry Finland Studies and Reports 11/2000. 159 p (in Finnish)

Appendix 1

The structure of Finnish know-how in nuclear waste management as analysed by the Nuclear Waste Management Division in the Nuclear Energy Research Strategy Group (YES) in 2014.

Properties of spent fuel

- Characterization of waste (radionuclide inventories)
- Reactor physics: burn up and criticality analyses
- Thermal properties
- Mechanical and chemical properties of the fuel (release models and their validation)

KBS-3 disposal concept

- Canister
  - Manufacturing and sealing
  - Inspections and quality control
  - Reliability analyses
  - Mechanical durability (isostatic and dynamic loads, creep)
  - Corrosion properties
- Buffer, backfill and closure
  - THMBC behaviour of clay components (including erosion and deformation)
  - Manufacturing, procurement and quality control of clay components

Operating waste and decommissioning

- Characterization of waste (radionuclide inventories)
- Waste treatment techniques
- Ion-exchange cleaning techniques for liquid waste
- Decontamination techniques
- Demolition and cut-off techniques for concrete and metal structures
- Ageing of concrete

Bedrock and groundwater

- Geology
- Geophysics
- Geochemistry (including microbes)
- Geohydrology, groundwater flow modelling and radionuclide transport studies
- Rock mechanics
- Thermal properties of host rock
- Earthquakes (including post-glacial movements)
- Climate and ice age research

Biosphere

- Characterization of surface environment and radionuclide transport modelling
- Exposure for radionuclides and dose calculations

Safety case

- Methodologies for spent fuel, operating waste, decommissioning waste
- Formulation of scenarios
- Performance assessment
- Transport modelling of radionuclides
- Uncertainty and reliability analyses

R&D in support of repository design and construction

- Facility design
- Engineering geological site studies
- Materials, manufacturing and quality assurance
- Monitoring and instrumentation

Operation safety of nuclear facilities

- Transfers from reactor to interim storage
- Interim storage
- Transports
- Final disposal facility

Safeguards

Cost assessment of nuclear waste management

New and alternative nuclear waste management technologies

- Alternative methods of waste treatment
- New fuel cycles incl. partitioning and transmutation
- New storage and disposal techniques, e.g. remote operating

Social science research related to nuclear waste management

Appendix 2

Nuclear waste management know-how which require special attention as analysed by the Nuclear Waste Management Division in the Nuclear Energy Research Strategy Group (YES) in 2014. The critical research topics, which require active assuring are marked in red italics.

Research area	Research topic	Situation in resources
Properties of spent fuel	*Mechanical and chemical properties of the fuel (release models and their validation)*	Presently fairly good, continuation should be ensured, own research is needed e.g. in IRF (instant release fraction)
KBS-3 disposal concept	*Canister: manufacturing and sealing*	Presently good, in the future the need will diminish
	Canister: inspections and quality control	Presently good, in the future, the need will diminish
	Canister: reliability analyses	Presently good, in the future the need will diminish
	Canister: mechanical durability (isostatic and dynamical loads, creep)	Presently fair, basic know-how should be ensured, needs attention
	Canister: corrosion properties	Presently good, basic know-how should be ensured
	Buffer, backfill and closure: THMBC behaviour of clay components (including erosion and deformation)	Researchers exist but special expertise is lacking, know-how should be maintained, basic research is needed
Operating waste and decommissioning	Characterization of waste (radionuclide inventories)	Presently good, basic know-how should be ensured
	Ion-exchange cleaning techniques for liquid waste (a commercial aspect)	Presently fair, new products should be developed and old ones improved for commercial markets
Bedrock and groundwater	Geochemistry (including microbes)	Presently scanty, the know-how should be developed, research is needed
	Geohydrology, groundwater flow modelling and radionuclide transport studies	Presently fair, should be maintained, the integration of geohydrology and groundwater flow modelling should be taken care of, in addition more chemical aspects should be introduced to the transport modelling, own research is needed
	Thermal properties of host rock	Presently fair, maintenance should be taken care of
Biosphere	*Characterization of surface environment and radionuclide transport modelling*	Presently scanty (partly), maintenance should be taken care of

Safety case	*Methodologies for spent fuel, operating waste, decommissioning waste*	Presently fair, maintenance needs attention
	Formulation of scenarios	Presently fair, maintenance needs attention
	Performance assessment	Presently fair, maintenance needs attention
	Transport modelling of radionuclides	Presently fair, maintenance needs attention
	Uncertainity and reliability analyses	Presently fair, maintenance needed
Safeguards	Safeguards	Presently fair, maintenance needs attention
Cost assessment of nuclear waste management	Cost assessment of nuclear waste management	Presently fair, maintenance needs attention
New and alternative nuclear waste management technologies	*Alternative methods of waste treatment*	Presently scanty, demand depends on nuclear trends, follow-up is needed, connection to costs analyses
	New fuel cycles, incl. partitioning & transmutation	Presently scanty, demand depends on nuclear trends, follow-up is needed, connection to costs analyses
	New storage and disposal techniques, e.g. remote operating	Presently scanty, demand depends on nuclear trends, connection to costs analyses, know-how can be transferred from fusion research
Social science research related to nuclear waste management	Social science research related to nuclear waste management	Social science research is broad, research on nuclear waste is only a small part of it. Transportation of spent fuel may sensitize the atmosphere. Are there nuclear waste specific resources available when needed?

Työ- ja elinkeinoministeriön julkaisuja Energia ja ilmasto 51/2014
Arbets- och näringsministeriets publikationer Energi och klimat 51/2014
MEE Publications Energy and the climate 51/2014

Tekijät | Författare | Authors

KYT2018-tutkimusohjelman suunnitteluryhmä
Puheenjohtaja Jarkko Kyllönen
Sihteeri Kari Rasilainen

Julkaisuaika | Publiceringstid | Date
Marraskuu 2014

Toimeksiantaja(t) | Uppdragsgivare | Commissioned by
Työ- ja elinkeinoministeriö
Arbets- och näringsministeriet
Ministry of Employment and the Economy

Toimielimen asettamispäivä | Organets tillsättningsdatum | Date of appointment
26.9.2013

Julkaisun nimi | Titel | Title

Kansallinen ydinjätehuollon tutkimusohjelma KYT2018
Puiteohjelma tutkimuskaudelle 2015–2018

Tiivistelmä | Referat | Abstract

KYT2018 on työ- ja elinkeinoministeriön tutkimusohjelma, jossa tavoitteena on varmistaa, että viranomaisten saatavilla on riittävästi ja kattavasti sellaista ydinteknistä asiantuntemusta ja muita valmiuksia, joita tarvitaan ydinjätehuollon erilaisten toteutustapojen ja menetelmien vertailuun. Ydinjätehuollon valvontavelvollisuuteen liittyvä tutkimus kuuluu viranomaisten muihin ohjelmiin. Ydinjätehuollon suunnitteluun, toteutukseen ja kehittämiseen liittyvä tutkimus kuuluu puolestaan ydinjätehuoltovelvollisten omiin tutkimusohjelmiin.

Puiteohjelma on laadittu työ- ja elinkeinoministeriön nimeämän työryhmän toimesta. Puiteohjelma on laadittu vuosille 2015–2018.

KYT2018-tutkimusohjelman sisältö muodostuu kansallisen osaamisen kannalta keskeisistä tutkimuskohteista, jotka ovat ydinjätehuollon teknologiat, ydinjätehuollon pitkäaikaisturvallisuus sekä ydinjätehuoltoon liittyvä yhteiskuntatieteellinen tutkimus. Tutkimusohjelmssa pyritään laajoihin ja koordinoituihin kokonaisuuksiin. Perinteiset yksi- ja monivuotiset hankkeet sopivat myös tutkimusohjelmaan.

KYT2018-tutkimusohjelma toimii viranomaisten, ydinjätehuoltoa toteuttavien organisaatioiden ja tutkimuslaitosten välisenä keskustelu- ja tiedonvälitysfoorumina, jossa luodaan edellytyksiä rajallisten tutkimusresurssien hyödyntämiselle. Samalla pyritään varmistumaan, että tutkimushankkeisiin saadaan monipuolinen ja poikkitieteellinen tutkimusryhmä. Tutkimusohjelman tavoitteena on myös osaltaan varmistaa olennaisen kansallisen asiantuntemuksen jatkuva saatavuus, edistää tieteellistä ja korkeatasoista osaamista sekä lisätä yleistä tietämystä ydinjätehuollon alalla.

TEM:n yhteyshenkilö: Energiaosasto/Jaana Avolahti, puh. 029 506 4836

Asiasanat | Nyckelord | Key words
Ydinjätehuolto, tutkimus

Painettu julkaisu | Inbunden publikation | Printed publication
ISSN **ISBN**

Verkkojulkaisu | Nätpublikation | Web publication
ISSN 1797-3562 **ISBN** 978-952-227-908-8

Kokonaissivumäärä | Sidoantal | Pages
43

Kieli | Språk | Language
englanti, engelska, English

Julkaisija | Utgivare | Published by
Työ- ja elinkeinoministeriö
Arbets- och näringsministeriet
Ministry of Employment and the Economy

Vain sähköinen julkaisu
Endast som elektronisk publikation
Published in electronic format only

Työ- ja elinkeinoministeriön julkaisuja Energia ja ilmasto 51/2014
Arbets- och näringsministeriets publikationer Energi och klimat 51/2014
MEE Publications Energy and the climate 51/2014

Tekijät | Författare | Authors

Planeringsgruppen för forskningsprogrammet KYT2018
Ordförande Jarkko Kyllönen
Sekreterare Kari Rasilainen

Julkaisuaika | Publiceringstid | Date
November 2014

Toimeksiantaja(t) | Uppdragsgivare | Commissioned by
Työ- ja elinkeinoministeriö
Arbets- och näringsministeriet
Ministry of Employment and the Economy

Toimielimen asettamispäivä | Organets tillsättningsdatum | Date of appointment
26.9.2013

Julkaisun nimi | Titel | Title

Nationellt forskningsprogram om kärnavfallshantering KYT2018
Ramprogram för forskningsperioden 2015–2018

Tiivistelmä | Referat | Abstract

Programmet KYT2018 är arbets- och näringsministeriets forskningsprogram vars syfte är att säkerställa att det till myndigheternas förfogande finns tillräcklig och heltäckande kärnteknisk sakkunskap och annan beredskap som behövs för jämförelse av sätten och metoderna att genomföra kärnavfallshanteringen. Forskningen kring skyldigheten att övervaka kärnavfallshanteringen hör till myndigheternas andra program. Forskningen om planering, genomförande och utveckling av kärnavfallshanteringen å sin sida hör till de kärnavfallshanteringsskyldigas egna forskningsprogram.

Ramprogrammet har utarbetats av en arbetsgrupp som tillsatts av arbets- och näringsministeriet. Ramprogrammet täcker åren 2015–2018.

Innehållet i forskningsprogrammet KYT2018 består av forskningsobjekt som är viktiga med tanke på det nationella kunnandet. Sådana är teknik för kärnavfallshanteringen, forskning i kärnavfallshanteringens långtidssäkerhet samt den samhällsvetenskapliga forskningen kring kärnavfallshanteringen. I forskningsprogrammet eftersträvas omfattande och samordnade helheter i forskningen. Traditionella ett- och fleråriga projekt lämpar sig också för forskningsprogrammet.

Forskningsprogrammet KYT2018 fungerar som ett forum för diskussion och informationsutbyte mellan myndigheter, organisationer för kärnavfallshantering och forskningsinstitut på vilket förutsättningar skapas för användning av de begränsade forskningsresurserna. Målet är samtidigt att säkerställa att en mångsidig och tvärvetenskaplig forskargrupp kan samlas kring olika forskningsprojekt. Forskningsprogrammet syftar för sin del också till att säkerställa en kontinuerlig tillgång på nationell sakkunskap, till att främja vetenskapligt och högklassigt kunnande samt till att öka den allmänna kunskapen om kärnavfallshantering.

Kontaktpersoner vid arbets- och näringsministeriet: Energiavdelningen/Jaana Avolahti, tfn 029 506 4836

Asiasanat | Nyckelord | Key words
Kärnavfallshantering, forskning

Painettu julkaisu | Inbunden publikation | Printed publication
ISSN **ISBN**

Verkkojulkaisu | Nätpublikation | Web publication
ISSN 1797-3562 **ISBN** 978-952-227-908-8

Kokonaissivumäärä | Sidoantal | Pages
43

Kieli | Språk | Language
englanti, engelska, English

Julkaisija | Utgivare | Published by
Työ- ja elinkeinoministeriö
Arbets- och näringsministeriet
Ministry of Employment and the Economy

Vain sähköinen julkaisu
Endast som elektronisk publikation
Published in electronic format only

Finnish Research Programme on Nuclear Waste Management KYT2018

Framework Programme for the Research Period 2015–2018

The Framework Programme for 2015–2018 is prepared by a working group appointed on September 2013 by the Ministry of Employment and the Economy. The objective of the Finnish Research Programme on Nuclear Waste Management is to ensure the sufficient and comprehensive availability of the nuclear technological expertise and other capabilities required by the authorities when comparing different nuclear waste management ways and implementation methods.

Electronic publications
ISSN 1797-3562
ISBN 978-952-227-908-8

TYÖ- JA ELINKEINOMINISTERIÖ
ARBETS- OCH NÄRINGSMINISTERIET
MINISTRY OF EMPLOYMENT AND THE ECONOMY