

## **KYT2014 – Research Programme to Support Finnish Nuclear Waste Authorities – 14245**

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### **ABSTRACT**

The Finnish Research Programme on Nuclear Waste Management (KYT2014) extends from 2011 to 2014. It is the current member in a chain of coordinated public research programmes in Finland that started in 1989. The research programme is “owned” by the Ministry of Employment and the Economy (TEM), which is the leading Finnish authority in nuclear matters. The basic aim of KYT2014 is to produce high quality research results for the use of Finnish nuclear authorities. The emphasis is on nationally central research topics. Topics directly belonging to the respective nuclear waste management duties of waste producers or authorities are excluded from KYT2014. The research work in KYT2014 is based on annual calls for project proposals. Overall research topics within KYT2014 cover three main themes: (1) New and alternative technologies in nuclear waste management, (2) Safety research in nuclear waste management, and (3) Social science studies related to nuclear waste management. Safety research forms the absolute main body of research. The annual funding of the research programme by the State Nuclear Waste Management Fund is around 1,7 million Euros (M€). Individual research organisations also provide their own funding in their projects, in 2013 about 1 M€altogether. The total volume of KYT2014 in 2013 is about 25 person-years. The number of research projects in 2013 is 32. The KYT2014 research programme serves as a national discussion and communication forum between the authorities, nuclear waste organisations, and research institutes. Examples of results are presented in some recent doctoral theses.

### **INTRODUCTION**

The Finnish environment for nuclear waste management is currently in an active stage. Posiva Oy submitted a construction licence application (CLA) for a spent nuclear fuel disposal facility to the Finnish Government at the end of 2012. The Nuclear Safety Authority (STUK) is currently assessing Posiva’s application, and aims to finish the work in 2014.

In addition, several decision-making processes concerning nuclear construction are in progress, directly and indirectly related to nuclear waste management. Olkiluoto 3, the nuclear power plant unit currently under construction, is due for commissioning in 2016-2017. A completely new nuclear energy company, Fennovoima Oy, has had a favourable Decision in Principle issued by the Finnish Government for a nuclear power plant at Pyhäjoki in Northern Finland. In addition, there are plans at Teollisuuden Voima to apply for a construction licence for an Olkiluoto 4 unit.

Finnish nuclear waste management is linked to international developments with numerous collaborative projects and agreements. In Sweden, the review of Svensk Kärnbränslehantering AB’s (SKB’s) CLA, submitted in 2011, is underway at the Swedish Radiation Safety Authority (SSM = Strålsäkerhetsmyndigheten). In the United States, the Blue Ribbon Commission on America’s Nuclear Future (BRC) has reported on alternatives to the geological final disposal of HLW planned, since 1976, at the Yucca Mountain in 2012 [1]. Based on that work a new strategy for USA’s nuclear waste management was formulated by the Obama administration in January 2013 [2].

The European Union conducts nuclear energy and nuclear waste research as part of the Euratom framework programmes. At the moment, the 2-year continuation of the 7th Framework Programme

(2007–2011) is coming to an end and a new programme, Horizon 2020, is being finalised. The technology forum “Implementing Geological Disposal – Technology Platform” (IGD-TP) was established in 2009, with the purpose of assuming a major role in coordinating the nuclear waste management research conducted within Euratom. Currently the Finnish participants in IGD-TP are Posiva and VTT.

## OVERALL DESCRIPTION OF THE RESEARCH PROGRAMME

The Finnish Research Programme on Nuclear Waste Management (KYT2014) extends from 2011 to 2014. It is the current member in a chain of coordinated public research programmes in Finland that started in 1989, see e.g. [3, 4]. Public research programmes aim to serve the research needs of the Finnish authorities. KYT2014 is “owned” by the Ministry of Employment and the Economy (TEM) which is the leading Finnish authority in nuclear matters.

The premises of the KYT2014 Research Programme are based on the Nuclear Energy Act (990/1987), according to which the aim of a 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 (19.12.2003/1131)).

The basic aim is to produce high quality research results to be used by STUK and TEM. Research topics to be studied must be nationally central. Topics directly related to the respective nuclear waste management duties of waste producers or authorities do not belong under KYT2014. The results of the research programme are public and thus available to all participants. The long-term aim of KYT2014 is, for its part, to maintain independent national know-how in nuclear waste management, and to promote collaboration between the authorities, the nuclear industry, and scientists.

The overall organisation and structure of KYT2014 is given in the Framework programme [5]. The administration of the research programme is based on the following components:

- Steering group: TEM appoints the members. The Chair of the Steering group is either from STUK or from TEM. The Steering group is responsible for the research programme’s strategic guidelines and Framework programme. It can also propose annual focus areas of research in annual calls for proposals.
- Support groups: these groups act as technical specialist bodies supporting the Steering group, which appoints their chairpersons and members. The Chairs of the two technical support groups are from STUK. Support groups are responsible for evaluating the proposed research projects, alongside the follow-up and guidance of projects receiving funding. Currently there are 3 support groups: (1) Buffer, backfill and canister, (2) Safety assessment and innovations, and (3) Society and man.
- Coordinator: responsible for programme management, the programme coordinator of KYT2014 is from VTT. The coordinator is selected on the basis of competitive bidding. His or her tasks are specified in a separate annual order.
- Website: material concerning the research programme is mainly published on the research programme website (<http://kyt2014.vtt.fi/eng/index.htm>).

The research work in KYT2014 is based on annual calls for project proposals. The calls usually refer to the Framework programme of KYT2014 (defining the general contents and structure) and to the annual guidance of the Steering group (defining the up-to-date research needs). Project proposals are assessed by the three support groups, and the proposals that receive funding form the annual ensemble of projects.

Assessment criteria for project proposals are defined by the Steering group, and research needs are considered as the main criterion. Altogether, there are five specific criteria: (1) Relevance and usability of results are assessed against research needs, (2) Networking with other actors in the field, KYT2014 seeks well-integrated joint projects, (3) Training and education of new experts and new expertise, (4) Efficiency shown in previous KYT or other projects, and (5) Realism in cost and work amount estimates.

Annual funding for the research programme is 1,7 M€ Funding is provided by the State Nuclear Waste Management Fund (VYR) into which nuclear waste producers annually pay 0,08 % of their assessed liability, respectively. Research organisations can also direct their own funding to their projects, and, for instance, in 2013 the annual total budget was 2,7 M€

In order to be sure that the research programme is on track, TEM (formerly the Ministry of Trade and Industry) has organised repeated international reviews of public research programmes. KYT2014 was reviewed in 2012 [6]. Its predecessor KYT2010 was reviewed in 2007 [7] and those results were carefully utilised in the planning of KYT2014.

## RESEARCH TOPICS

Research topics in KYT2014 are divided into: (1) New and alternative technologies in nuclear waste management, (2) Safety research in nuclear waste management, and (3) Social science studies related to nuclear waste management (Fig. 1).

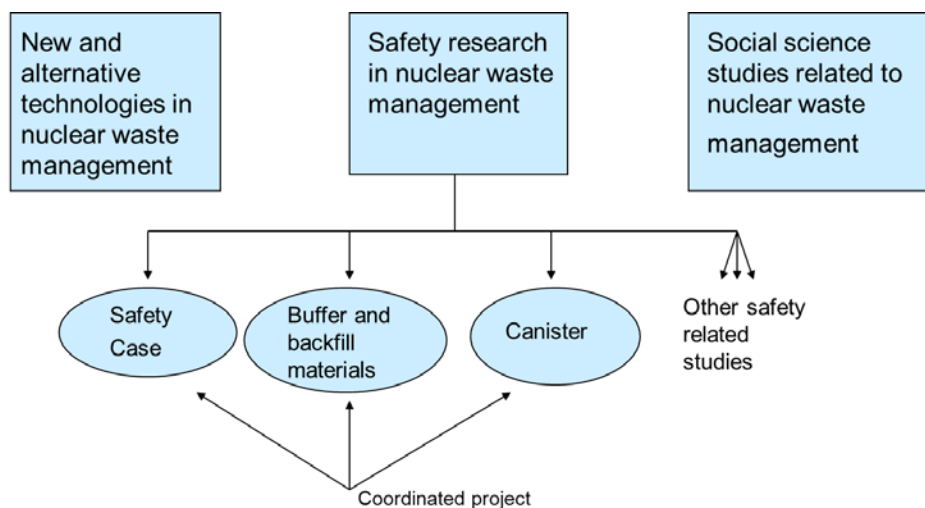


Fig. 1. KYT2014 research topics [5].

Safety research within the KYT2014 programme is primarily targeted at three research areas: (1) Safety case, (2) Buffer and backfill materials, and (3) Canister. One coordinated project is sought for each research area. Coordinated projects aim to focus collaboration between individual research groups and they are in practice small research programs. Cooperation between the coordinated projects is vital, in order to ensure that, as far as possible, topics fundamental to safety remain in focus.

## New and Alternative Technologies in Nuclear Waste Management

Knowledge of new and alternative technologies would enhance the feasibility of implementing nuclear waste management in Finland, if the current main option, geological final disposal, is not realised as planned, or if new methods are developed, for example, to reduce the amount of waste. This type of research can best be done through participation in international cooperation.

Research subjects suitable for the KYT programme may be as follows:

- Nuclear waste management solutions based on the reprocessing of spent fuel.
- Nuclide partitioning and transmutation (P&T).
- Alternatives in geological final disposal, e.g. deep bore holes.
- Retrievability.
- Storage options, e.g. dry storage, long-term storage.
- Potential new solutions for the management of operating waste e.g. disposal of very low-level waste in the ground.
- New solutions for implementing decommissioning.

### **Safety Research in Nuclear Waste Management**

**Safety case.** A coordinated project has the aim of educating new experts in Finland, qualified in compiling and assessing safety cases for nuclear waste disposal facilities. A further goal is to devise new methods of assessing the long-term safety of geological disposal. Through hands-on work, the idea is to understand the philosophy (based on safety case scenarios), methods of acquiring and generalising information, the performance of practical analyses (based on different calculation models), and methods of assessing the reliability of results and the related uncertainties.

Attention should be paid to the following:

- The way in which scenarios are formed.
- Alternative conceptual models and interpretations.
- The development of uncertainty analysis methods.
- New sources of information (work conducted outside nuclear waste management research and tangential to the safety analysis methodology), e.g. geological final disposal of carbon dioxide.
- The development of safety case presentation methods, so as to make them as comprehensible to as wide an audience as possible (safety case principles, methods and restrictions).

**Buffer and backfill.** In the KBS-3 final disposal concept, a bentonite buffer forms the key part of the engineered barrier system (EBS). This is because, if the buffer fails to function as assumed, the long operating life of the disposal canister inside can be endangered, due to the increasing mass flow of substances that cause corrosion. Bentonite or other clay materials are also likely to be utilised in the backfill material and sealing structures of tunnels.

The topics of a coordinated project can include analytical and numerical descriptions of coupled processes in the near-field environment, and the microstructure of bentonite. Process and microstructure expertise provides a scientifically justified basis for quantitative research into subjects considered crucial as regards the safety of final disposal, including:

- Erosion phenomena (mechanic and chemical).
- Long-term stability (mineralogical changes).
- Impacts of a high pH.
- Interaction with iron.
- Impact of high salinity.
- Impacts of freezing.

**Canister.** When assessing the service life of a copper-cast iron canister, account must be taken of the impact of different manufacturing techniques and faults on the durability of the canister, and of tensions forming within it. Both pure basic material and welded copper must be examined as canister material. The welding method and the related heat supply influence the microstructures formed, and thus the canister's material characteristics. Posiva's current reference method is electron beam welding (EBW), whereas SKB in Sweden has selected friction stir welding (FSW).

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.

**Other safety-related research.** When assessing the safety of nuclear waste management in general, and the safety of geological final disposal in particular, information is needed from several disciplines and beyond the coordinated projects mentioned above. Other safety-related research topics within the KYT2014 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 characteristics 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, such as mixed oxide (MOX).
- The significance of C-14 in final disposal (spent fuel, operating waste, and decommissioning waste).
- Bedrock research as regards the safety of final disposal.
- Biosphere research as regards the safety of final disposal.
- Assessment of the grounds for nuclear waste management costs.
- Techniques and methods for the decommissioning of nuclear facilities.
- Operational safety of the final disposal repository.

### **Social Science Studies Related to Nuclear Waste Management**

The purpose of social science studies related to nuclear waste management within the KYT programme is to support the decision-making process and the related preparations. Individual decisions are steps in the licencing procedure, based on Finnish nuclear legislation that is mandatory in all nuclear waste operations. Decisions include public discussion, which in turn is influenced by societal values and expectations.

Social science studies have been conducted in a number of previous public research programmes since the 1990's. KYT2010, the previous research programme, analysed local views on nuclear waste management and their evolution with time.

The views of various actors and groups on nuclear waste management, and on 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 and reliability. The following viewpoints may also be involved:

- Ethical debate.
- Issues related to long time scales in nuclear waste management.

First, long time scales raise the question of justice between generations, that is, are we imposing an unreasonable burden on future generations in the form of nuclear waste, and who will bear responsibility for the costs? Secondly, a related issue is the reliability of information and its preservation in the long term.

### Distribution of Funding

The annual funding of the research programme by VYR is around 1,7 M€ Individual research organisations also provide funding for their projects, in 2013 about 1 M€altogether. The total hour-volume of KYT2014 in 2013 is about 25 person years.

During 2013, a total of 32 research projects received funding from VYR. The distribution of the funding between research topics is shown in Figs. 2 and 3. One may note three major topics: Buffer and Backfill (23 %), Canister (19 %) and Other safety related studies (39 %).

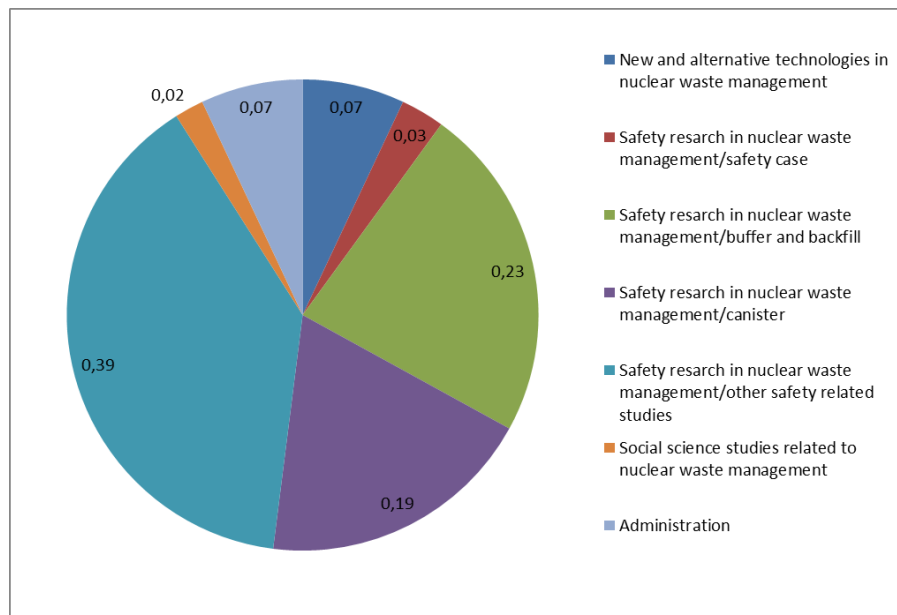


Fig. 2. Distribution of VYR funding 1795 k€between research topics in 2013.

The fine structure of research within the block Other safety related studies is presented in Fig. 3. One can note the almost equally large topics Nuclide migration and Microbiology. Concrete and Biosphere are clearly smaller research topics.

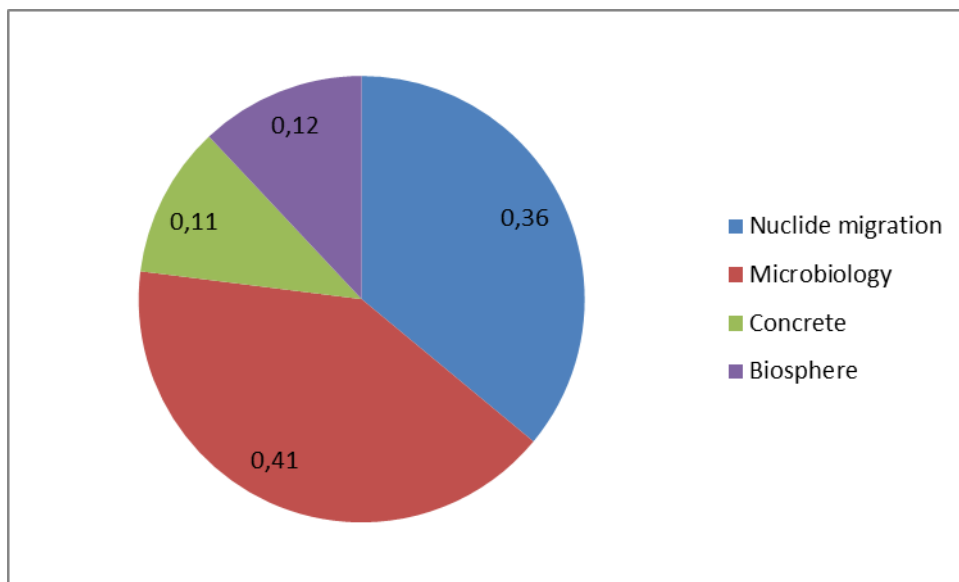


Fig. 3. Relative fractions of research topics within the block Other safety related studies in 2013.

The distribution of funding between research institutes is shown in Fig. 4. One may note the three main organisations: VTT (50 %), Aalto University (17 %) and the University of Helsinki (16 %).

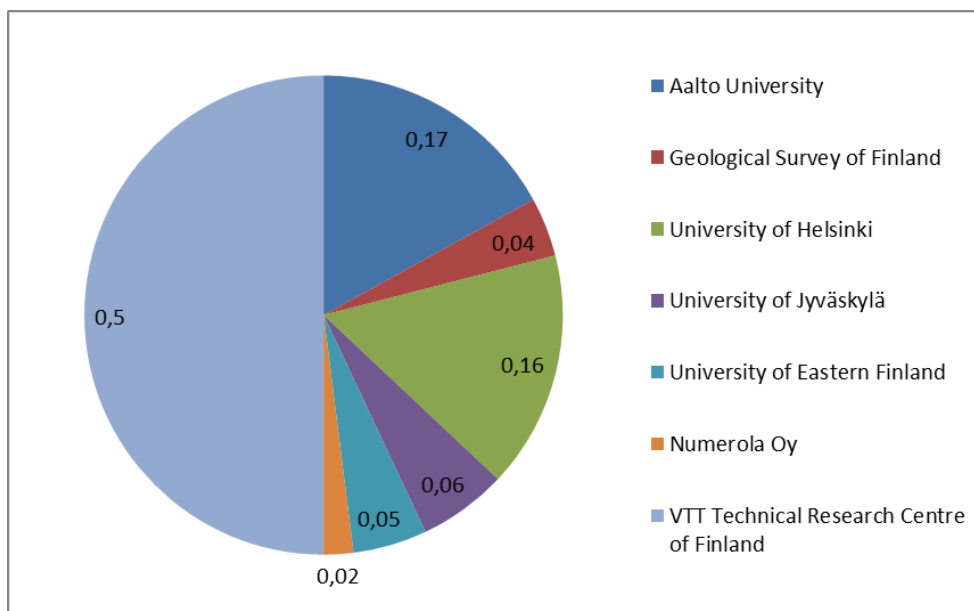


Fig. 4. Distribution of VYR funding 1795 k€ between research institutes in 2013.

## EXAMPLES OF RESEARCH RESULTS

The KYT2014 research programme has been active since 2011 and 2014 will be the final year. One of its main tasks is to educate new experts in the field. Table I shows some publication statistics available so far, however it is clear that the publications are often based on long-term research that started many years earlier, during the predecessor(s) of KYT2014. Continuation of research is therefore of high importance, as it takes years to educate an expert in nuclear waste management.

TABLE I. Statistics of KYT2014 publications.

<b>Number of Publications</b>	<b>2011</b>	<b>2012</b>
Doctoral theses	1	3
Master level or lower theses	9	14
Articles in peer reviewed journals	16	19
Conference papers and working reports	36	51

The distribution of publications between different research topics can, in general, be derived from the overall allocation of resources to the respective topics. Three of the doctoral theses belong to the topic Other safety related studies and one to the topic Canister. The thesis by Roivainen [8] discusses biosphere studies and, in more detail, the soil-to-plant transfer of radionuclides. The thesis by Voutilainen [9] discusses radionuclide migration issues in bedrock and, in more detail, the influence of micrometre scale structure of rock matrix on radionuclide migration, applying both experiments and modelling. The thesis by Huittinen [10] discusses radionuclide migration and, in more detail, spectroscopic methods to study the sorption of trivalent actinides on mineral surfaces. The thesis by Savolainen [11] discusses canister issues and, in more detail, the structure and properties of copper welds resulting from friction stir welding (SKB's current reference welding technology).

Concerning on-going studies, one may mention that there are many doctoral theses, both experimental and theoretical (modelling focused) under work within the topic Buffer and backfill. There is a separate presentation [12] of the actual coordinated project "Assessment of bentonite characteristics" (BOA) in the WM2014 conference.

## COOPERATION

KYT2014 has limited resources and therefore it is quite interested in scientific cooperation, both domestic and international. Domestic scientific cooperation covers for instance the research program of Posiva (many topics in nuclear waste management), and the Finnish public research programme on nuclear power plant safety SAFIR2014 (mainly radionuclide inventory related issues, <http://safir2014.vtt.fi/>).

International cooperation at a topical level covers direct participation of KYT2014 projects in the 7<sup>th</sup> Framework Programme of Euratom (currently two KYT2014 projects), and indirect participation of individual researchers of KYT2014 projects in EU projects. On a more general level, the coordinator of the research programme is a member of the OECD NEA Radioactive Waste Management Committee (RWMC).



## OUTCOME OF THE INTERNATIONAL REVIEW 2012

In 2012, TEM nominated an international group of independent experts to evaluate the scientific output of KYT2014, see [6]. The evaluation was based on written material submitted in advance and on interviews with relevant Finnish shareholders.

With reference to the Ministry's original questions, the evaluation panel concluded that the results achieved are in balance with the funding. The scientific and technical results obtained are utilised in practice by actors in Finnish nuclear waste management, as the results are public. The expertise in the research programme covers the field of research reasonably well with respect to the funding. The research programme as a whole is balanced between different fields in nuclear waste management with current emphasis on spent nuclear fuel disposal. KYT2014 has raised new experts, however, systematic quantitative statistics were not available at the time of the evaluation. Finally, the evaluation panel noted that the results of the evaluation of the previous research programme KYT2010 (see [7]) had been utilised effectively in the planning of the KYT2014 programme.

Along with its review, the evaluation panel made a number of comments and recommendations. The topics commented on included: (1) Visibility of KYT2014, (2) KYT2014 training course, (3) Collaboration between KYT2014 and the Finnish public research programme on nuclear power plant safety SAFIR2014, (4) National plan<sup>1</sup> for education in nuclear waste management, (5) Centres of excellence, (6) Funding issues, (7) Tracking of progress in the research programme, (8) Support group management, and (9) Steering group management. Readers interested in details of the review are well-advised to consult the original report [6]. The review, with its recommendations, will be of great help when planning the successor of the KYT2014 programme.

## CONCLUSIONS

KYT2014, the Finnish Research Programme on Nuclear Waste Management, aims to support the Finnish nuclear authorities. It has its basis in Finnish nuclear legislation. Coordinated public nuclear waste management research programmes have been active in Finland under different names since 1989. The nuclear energy and nuclear waste environments are currently at an active stage in Finland with new nuclear energy under construction and under planning, and, for instance, Posiva's CLA for a spent nuclear fuel disposal facility.

The research work in KYT2014 is based on annual calls for project proposals. Funding is provided by VYR, and by individual research institutes. Annual VYR funding is around 1,7 M€

The research topics in KYT2014 cover roughly: (1) New and alternative technologies in nuclear waste management, (2) Safety of nuclear waste management, and (3) Social science studies related to nuclear waste management. Safety related studies form the main body of research, and the most important topics (Safety case, Buffer and backfill, and Canister) are being studied as coordinated projects that are actually small research programs.

Some examples of results were given by describing the latest doctoral theses from biosphere research, radionuclide migration research, and disposal canister research. Due to limited resources, the KYT2014 research programme is directed towards scientific collaboration with both domestic and international research programmes. TEM ordered an international review of the research programme in 2012. This

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<sup>1</sup> One may note that background work concerning the whole nuclear energy competence in Finland has already been reported, see [13].

review indicated that the research programme is on track; the review is one important element in planning the next stage of the research programme.

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