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# KYT2018

## Review Report



Ministry of Economic Affairs  
and Employment of Finland

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# 1 Introduction

## 1.1 Background

The Nuclear Energy Act (990/1987) stipulates that the nuclear waste generated in Finland must be handled, stored and permanently disposed of in Finland. Responsibility for the management of nuclear waste lies with those who hold a license to operate a nuclear facility. This includes the needed R&D and associated costs arising from that obligation.

The power companies, Teollisuuden Voima Oyj and Fortum Power and Heat Oy, running nuclear power units at Olkiluoto site and Loviisa site operate disposal facilities for low and intermediate level operational waste. The task for constructing and operating the facilities required for disposal of spent nuclear fuel, including the needed R&D, is given to Posiva Oy a company jointly owned by Teollisuuden Voima Oyj and Fortum Power and Heat Oy. Fennovoima Oy, which is planning to start construction at its Hanhikivi site in a few years after granting of the license, is planning final disposal of low and intermediate level operational waste at the plant site and of spent nuclear fuel at two alternative sites.

The Ministry of Economic Affairs and Employment (MEAE) is responsible for the supreme command and control of nuclear energy matters in Finland. The Radiation and Nuclear Safety Authority (STUK) is responsible for the regulatory oversight of the safe use of nuclear energy. In regulating safety, STUK uses the necessary external experts and, when necessary, commissions research or analyses directly associated with the regulation. STUK's support programme for regulatory oversight has mainly focused on the final disposal of spent nuclear fuel, and its purpose has been to produce assessments and analyses on issues concerning the safety of final disposal.

KYT2018 research programme originates from the previous publicly financed and administered nuclear waste management programmes JYT, JYT2, JYT2001 and KYT, KYT2010, and KYT2014. Its present content is based on the Framework Programme for KYT2018, recommendations from the previous Review Report of KYT2014 and two strategy reports Report of the Committee for Nuclear Energy Competence in Finland in 2012 and Nuclear Energy Research Strategy in 2014 (Appendix 5). The purpose of the JYT and KYT programmes has been to ensure that nuclear waste management authorities have access to expertise independent of licensees and license applicants.

## 1.2 Objectives of the KYT2018 evaluation

The KYT2018 research programme on nuclear waste management (NWM) is based on the Nuclear Energy Act according to which the goal is to pursue “research aimed at ensuring that the authorities have such sufficient and comprehensive nuclear engineering expertise and other readiness at their disposal that are needed for assessing of the various ways and methods of carrying out nuclear waste management”. The KYT2018 evaluation team was told that the intent is not to cover systematically all the potential routes suggested in the NWM, but rather to leave the door open to research on some alternatives to the national “reference option”, i.e., to the geological disposal; in the KYT2018 research programme, the alternative NWM topics are not studied in order to make an inter-comparison between the various NWM solutions but to support the understanding of some alternatives. Further, as proposed by the KYT2018 management before the review site visit, the purpose was not to review each individual project of the KYT2018 research programme but to get a view of coverage of the research areas.

In respect to the tasks mentioned above and as agreed in the formal agreement by MEAE, the main questions of the review were formulated in the Terms-of-Reference (TOR) as follows:

- Does the KYT2018 research program cover all the necessary elements of nuclear waste management taking into account operating environment (types of nuclear facilities and their current life span and types of waste produced) as well as the scope of the research program set in the Nuclear Energy Act.
- Challenges and recommendations.

As compared to, e.g., the KYT2014 review, the present TOR expresses only in rather general terms the objectives for the review. Thus the review team has made a compromise between the time and resource limitations of its expedition and the needs presented by the Nuclear Waste Management Fund (VYR).

## 1.3 Methodology of the review

The review team consisted of Delphine Pellegrini (National Institute for Radiological Protection and Nuclear Safety, IRSN, France), Eva Simic (Strålsäkerhetsmyndigheten, SSM, Sweden), and Rainer Salomaa (Aalto University, Finland). Jaana Avolahti served as a MEAE contact person for the review team. The team met in 31.5.-1.6.2017 in the context of project presentations and preliminary discussions. Brief introductions by MEAE, STUK and the programme coordinator were provided. The subsequent work by the review team involved a video conference in 28.6.2017 and the preparation of the final review report during July to September 2017.

The main review material consisted of the document presenting the Framework Programme for KYT2018 and the Project descriptions provided by the applicants as a part of the funding proposals in autumn 2015, together with the Application summaries 2016 (not comprehensively) which very briefly also indicated the progress achieved. In 31.5.–1.6.2017 during the visit of the review team, these elements were complemented with overview presentations. Presentations lasted 40 minutes for co-ordinated projects and 20 minutes for “single” projects. Discussions on each presentation on the basis of reviewers’ questions took about 5–10 minutes.

The Finnish versions of the KYT Annual Reports 2015 and 2016 contained more explicit data on the project results. Unfortunately, this material was not available in English.

Besides the opening presentations on administration there were no discussions with KYT stakeholders like Posiva and the Finnish nuclear power companies. The review team was offered to interview Jussi Heinonen, the general director of nuclear waste management of STUK which is the main user of KYT results. Such a discussion took place in 4.9.2017 and its findings are included in this final review report.

# 2 Findings of the review

## 2.1 Displayed material and site visit organization

The review team acknowledges the arrangements facilitating its work. The basic KYT2018 documents provided informative high-class background material. The review team notices as a positive feature that the detailed objectives of the research programme are well met in widely various areas of NWM and relevant explanations are given why those areas have been selected.

In addition to the present topics, there are a few topics that could lead to new research and are pointed out by the review team:

- Post-accidental situations with large quantities of waste and effluents, the management of which would require, e.g., specific characterization techniques at large scale etc., is not considered in KYT2018;
- In the same way, Naturally Occurring Radioactive Materials (NORM) from mining activities are out of the scope of KYT2018 despite that the future/present behavior of such legacy of radioactive substances and their impact are of concern in several countries;
- As far as geological disposal is concerned, research in operational safety is not accounted for in the present KYT2018 (e.g., surveillance, risk assessment, accident scenarios, ...)

In later discussions it turned out that NORM had already been considered in earlier KYT programmes, but due to funding limitations this research was abandoned in KYT2018. Operational safety and accident management, as also topics like decommissioning of power plants and transport of spent nuclear fuel deserve attention in future KYT-programmes, assuming that these topics will not directly fall into the mandate of the licensees.

### **Suggestion S1.**

*As a reminder, the opportunity to enlarge the research projects to post-accidental waste, NORM and operational safety of geological disposal would still be worth reassessing and, where appropriate, the non-relevance or low priority of these research areas made explicit.*

During the project presentations of the KYT2018 research programme, the review team took note that:

- Clear and comprehensive overviews of the research work in KYT2018 were given;
- The free atmosphere during the interviews turned out to be a good practice. The principle was that only project co-ordinators, leaders, and representatives were attending the presentations;
- Sufficient information was provided on the contributions of the projects to education and competence building objectives as required by KYT2018;
- The interviews had a short duration, and, therefore, an effort was to make concise presentations and to focus on priority questions. Longer timeslots had, perhaps, not significantly increased the basic information. On the other hand, the tight schedule of project presentations allowed just a few key questions to be made;
- The tour in the new labs of the Center for Nuclear Safety (CNS) of VTT was very instructive and valuable;
- The presence of the chairman of the KYT2018 steering group and the programme coordinator, and the MEAE representative during the visits helped to catch the framework and functioning of the programme. During the interviews other NWM stakeholders were absent;
- Local arrangements (locations, rooms, catering, etc.) were highly satisfactory.

Concerning possible further improvements we note that the available written material, except in a few cases, described inadequately the key highlights of the projects regarding safety and/or radiation protection that STUK needs for assessing the Finnish safety case. Also the expected added value in comparison to international state of the art was missing, leading to some difficulties to judge the benefits as regards technical support to the authority. Such information would enable to trace research projects into topics where the authority needs support for its safety case review or, in more general, to fields where to build further competence or specific expertise. A further point, as mentioned above, is that the material provided before the visit did not help to obtain the actual progress status which hampered the review preparation. Later, it turned out that such progress reports existed, but only in Finnish.

#### **Suggestion S2.**

*In planning of future reviews, the safety issues and associated technical/scientific needs should be introduced in more detail by the stakeholders of the KYT2018 program.*

**Suggestion S3.**

*The Authority should provide clear guidance to the applicants regarding the need for depicting the technical context of the proposal (state-of-the-art, remaining issues, ...) and the added value of the expected/obtained outcomes for safety case reviews.*

**Suggestion S4.**

*The Authority should display the last annual progress reports in English, as well as the slides ahead of the visit in case a deeper review of the relevance of the projects and of their scientific outputs is required.*

In addition to the earlier mentioned material, references of published papers were given for most of the projects and quoted in the presentations. However, the time allocated for the present review did not allow any thorough study of these papers. Thus, the present review remains as a general overview, and is not intended to be an in-depth technical peer review.

## **2.2 Organization and program funding**

The KYT2018 programme organization comprises a steering group, research support groups and a programme coordination. The main role of the steering group is to conduct the framework programme and annually recommend projects and their funding. The Nuclear Waste Management Fund (VYR) makes the final funding decisions. Occasional comments by researchers suggested that the steering group could have a more active role; means for that already exists since the main stakeholder STUK is properly represented in the KYT2018 organization allowing the guidance required. The programme coordination is efficiently done and has extensive and deep competence of NWM issues. The support groups dealing with thematic areas have created active national research networks. The overall organization of KYT2018 and its predecessors has been well established and seems to operate well. Some additional scattered notions are given below.

The organization of KYT2018 enhances dialogue between authorities, those responsible for nuclear waste management, and researchers. In this regard, the evaluators were told that STUK is no more carrying out or funding research on its own. This is understood as a reallocation of the national research funds to support the national expertise capacity to VTT as the national Technical Support Organization (TSO) and the KYT2018 coordinator. Thus, a strong steering role of STUK in the KYT organization and its funding has to be maintained.

It is well understood that the VYR funding for KYT activities is limited and an optimized solution satisfying the needs for regulator support, competence building, and broadness of the NWM research areas, has to be made. The annual reassessment of the funds allocated to each project is a proper way to encourage work to be done. In general, the research objectives have been satisfactorily met although in many cases the project funding has fallen close to a critical edge and KYT funding plays just a catalytic role. The funding into subcritical projects keeps in various units alive the NWM activity, only because of additional external money or other cross-cutting funding instruments. Instead of a short research orders covering a few weeks to a few months, true scientific research projects call for more sustainable funding.

The budget cuts made in 2016 and in 2017 which resulted partly from the investments on the Centre for Nuclear Safety (CNS), have hit many projects, in particular in the academic units. The cross-disciplinary research NWM complicates the situation because usually university research focuses on narrow spearhead topics. One should also realize that the funding objectives have evolved. For instance, today universities mainly value the number of degrees and do not earmark particular research fields in their internal funding, implying the advantage of basic research to applications. Academic researcher education and training requires continuous and sufficient funding for several years. Concerning the degradation of experimental facilities in the universities, a challenge of the near future is to fully exploit the benefits that the infrastructure developments through the CNS will offer both in terms of research equipment and of prospering the research collaboration in the area. This point is discussed further in section 2.5.

Most project leaders of KYT2018 reported that the budget cuts have had a noticeable impact on their project plans. They, however, appreciated the advice from the steering group and the support groups concerning decisions on which actions had to be abolished. Due to the fact that the budget cuts seem to have occurred when the projects were ongoing, it would be worth investigating how the cuts have affected the results versus the initial expectations of KYT2018. The review team did not get information on the constraints and criteria regarding the selection of funded projects and budget cuts.

As a last issue, in the previous KYT project calls many projects were abolished mainly because of funding restrictions. It would be instructive to analyze the implications of these decisions: loss of competence, renovation of withering projects, or the new research needs as mentioned above.

Assuming that the new nuclear power plant unit Olkiluoto 3 will start the operation in the near future, the funding situation of KYT-programme due to a rise in the VYR fund will gradually improve. In order to keep the high scientific quality, it is important that the different research teams are provided with enough funding, since otherwise the feasibility of the projects might be at risk.

A practical organizational issue that was mentioned is the schedule of funding decisions: the research work usually starts already in the beginning of the year whereas the Fund makes decisions only in March. Unless rather reliable predictions of project funding and anticipated budget cuts are known, this may cause considerable uncertainties especially in recruiting. A rule that may introduce some problems is that project money must not be transferred (reallocation of projects but keeping the overall program funding) over to a new budget year. For instance, in small projects this situation could rather readily arise when key researchers leave the unit or change the position.

**Suggestion S5.**

*A more secured budget should be preserved for the KYT multiyear projects.*

## 2.3 Research projects

No doubt, in all JYT and KYT programs appropriate research issues have been addressed and important new research directions have been introduced to update prevailing needs. Of course, budget and resource limitations have put strict boundary conditions to carry out the activities. The framework programme has reasonably allowed to preserve the acquired know-how of the research groups and, on the other hand, opened various new areas of NWM worth exploring the needs to even more extensively support the safety case assessments.

Also the contents of the KYT2018 research programme have experienced updates from the previous JYT and KYT topics and their respective review assessments that have been taken into account. The latest main programme re-evaluation took place after the KYT2014 review and has been documented in the KYT2018 framework report. The present intermediate KYT2018 programme review does not contain any detailed comparison of the actualized recommendations or a discussion on the motives for which topics of improvement were selected. In general, all projects launched are well in accordance with the orientations identified in KYT2018 (see chapter 3 of KYT2018 Framework Programme) and most of them may breed high quality research. A majority of the projects are devoted to geological disposal (GD) of spent nuclear fuel, a few consider other nuclear waste types and only a minor number on new routes of NWM than that presently adopted in Finland. This is an acceptable balance between i) the needs for continuity/stability of funded research topics and ii) efforts to launch new

research areas both in technologies and in societal issues of NWM. The former point involves long term safety of NWM, mainly on GD due to the national context of the GD project development in order to develop well-consolidated knowledge and expertise capacity to support the authorities for the licensing process. A list of the KYT2018 projects is given in Appendix 4.

A prominent novelty in KYT2018 is the funding aimed for building the nuclear infrastructure, the Centre for Nuclear Safety in VTT. The thematic areas on bentonite and microbes were launched already in KYT2014 and continued in KYT2018. The active collaboration of the respective support groups has been enhanced and research networking improved. In the KYT2018 programme the other research areas are classified as canister, other topics (systems studies, societal issues, etc.), and the safety case. In corrosion studies fruitful collaboration network between many of the thematic research areas has been created, e.g., interaction between the canister and the buffer material.

As mentioned in section 2.1, based on the material distributed before the review and the presentations given by the researchers, it was difficult to judge in detail what way the KYT-programme will support authorities' activities (especially those of STUK) and how the KYT-research issues address open or uncertain issues identified during STUK's reviews of the Posiva research programme and license application. Similarly, some added value projects undoubtedly had a relation to nuclear waste management research, but it was hard to clarify their role as regards competence building or safety needs or both (i.e. training through duplication of studies already carried out elsewhere, whatever at the national or international level, versus research valuable for supporting the authorities in reviewing the remaining safety issues for the national GD project).

Somewhat troublesome is that truly challenging and innovative research particularly dedicated to KYT2018 objectives appeared quite rare: research on issues that may impact safety and need confirmation so as to support requirements from the authority to the waste management organization (WMO) for further research on this issue, research on conditions that may influence a process differently from that considered by the WMO for a reference scenario, etc. This kind of non-reference cases provide academically interesting problems which serve both scientific challenges and widening of the understanding of the uncertainties of the engineered reference scenarios. If the main aim is basic science related to NWM topics and competence building in different areas in Finland, then several of the specific research issues addressed in the programme might be of less importance. In such a case it might be most important that the research is of high scientific quality, as well as of high international standard and relevance, in order for the Finnish researchers to be competitive on the international scene.

## Some specific comments

- The organization into topical areas (advanced fuel cycle, bentonite, canister, safety case, other safety studies on technologies, societal issues and infrastructure) enables improved collaboration between the small KYT subprojects. The stakeholder STUK should clearly prioritize its needs and balance the resource allocations, accordingly, and to make interactively the decisions using support group recommendations and project leader views for guidance.
- Many of the projects appear to be subcritical as regards working days and funds. Besides KYT2018 additional funding is usually indispensable and it is worth pondering how to preserve the objectivity and independence of the research. During the present project review it was in some cases challenging to distinguish core contributions of KYT2018 from the larger framework of the research activities of the research group. A broader description of the project links and their resources would have helped.
- Formal technical information exchange between the thematic KYT2018 buffer studies and the respective Posiva activities could be further improved. The expertise of Posiva could be further utilized to generally advance researcher training in the field.
- Canister studies considering their corrosion properties and mechanical integrity appear to be topical and significant research collaboration between materials and microbial effects has arisen. These activities benefit also studies of low and intermediate level waste management.
- Microbes form a problem area where many questions are still to be addressed. This research field is huge and, therefore, in KYT2018 actions, there is a clear need to focus on topics which clearly support STUK for its safety case evaluation. Many interesting scientific results have been obtained although most of them do not yet give to a regulator, convincing answers concerning the safety case.
- In a few projects (e.g., RENGAS, TURMET) the main aim of the work was not fully argued. A clear link to the safety case was not obvious although an added value for STUK was found through educational aspects.
- In the scenario studies the long term time span considered may lead to extreme uncertainties and therefore a too detailed modelling may be non-productive. A clear challenge is to quantitatively describe the uncertainties and parameter variations. One example is the worst case analysis adopted in Posiva scenarios. Some of these steps have also been done within KYT projects. Analogies of Probability Risk Assessment (PRA), severe accident and beyond basic design accident analyses could be useful also in the safety case studies of NWM.

- In the socio-economic studies the retrospective view helps in understanding but gives little use for predicting the numerous possible futures; further efforts to elaborate prospective views would be welcomed. In general, there appears to be a need to promote social science projects (efforts were already made by the KYT call). This societal research might benefit from collaboration with experts from systems and operation studies (TURMET) together with futurologists. Presuming the Finnish situation, some recent Euratom activities on nuclear energy acceptance (cf. EASAC and EU strategy and opinion papers), may be worth pondering.

#### **Suggestion S6.**

*The motivation why the project supports the safety case should always have a prime emphasis in the project planning and goal setting. Besides, innovations and research that would challenge the WMO safety case should be encouraged.*

## **Scientific level of research and publications**

Although the review team did not have extensive quantitative statistics on KYT2018 deliverables such as a number of publications, theses, conference presentations, etc. it appeared that within the available resources, the projects have been quite productive and have remarkably increased scientific understanding in the field. Based on the project presentations and other information obtained, in general, the research is conscientious. Because of the many complications and factors involved very laborious straight-forward work is required. As mentioned above, a challenge is to find new innovations and views to further tackle the issues of safety case.

In the final report of KYT2018, publications, these and other accomplishments can be listed and evaluated quantitatively.

## **Research collaboration**

Domestic collaboration in KYT2018 projects ranges from a reasonable level to areas needing improvement. Links between R&D of KYT2018 and Posiva could, perhaps, be discussed: the fields of action sometimes seem to have too strict demarcation lines. It is clear that the research details are distinct as also the final licensing goal, but know-how and other information could be more freely utilized. Similar restrictions between the actors are smoother in the nuclear safety programme Safir2018 and the R&D work of the power utilities. Another issue

is the border between Safir- and KYT-programmes: it is pleasing that cross-cutting research topics between operational nuclear safety studies and NWM have been found, e.g., in studies of LLW and ILW, and new nuclear fuels in Generation 4 concepts. As expected, more common questions on nuclear safety operations will be encountered when disposal operations of nuclear fuel waste start in Finland.

**Suggestion S7.**

*Links with nuclear operators should be strengthened to anticipate potential further issues that would need R&D and competence building regarding nuclear waste management.*

Regarding international collaboration, KYT2018 “supports and encourages participation in international nuclear waste research. For example EU projects can have joint funding by the VYR and other national or international financers” (page 16). Because of the large extent of the KYT programme and small size of its individual projects, the review team fully supports close international collaboration between the researchers. The activity level of KYT2018 projects varies from very close contacts to almost non-existing collaboration. There are a couple of KYT projects involved in EU programmes (CAST, MIND...), with very good feedback from the point of view of the interviewed researchers; also the training activities like PETRUS and CINCH are worth mentioning. Further participation in EU projects, from the point of view of the review team, would lead to:

- Enhance the dialogue between WMO, authorities and researchers (one of the KYT premise, as written page 9);
- Contribute to educate new experts: overview enlarged to other countries, first experiences in international groups (IAEA, NEA...);
- Help to compensate the national budgets;
- Increase the visibility of KYT.

A general improvement of the international collaboration would imply more challenging individual actions like longer research visits, invited and plenary conference talks, contributions to steering bodies of international organizations, invitation of foreign experts, etc. KYT should

further encourage, in a practical way, contributions to EU projects and help its funded staff to follow and participate in such projects. In many NWM areas, Finland is in the frontier and, therefore, the scientific framework to reach these goals forms no obstacle.

The IGD -TP, mentioned in the KYT2018 document, is a platform devoted to WMOs and associated research entities. The review team would also like to point out the SITEX initiative which is devoted to the Expertise Function. This SITEX initiative has been consolidated in two successive EU projects<sup>1</sup> and is expected to become a formal network in 2017. Both IGD -TP and SITEX, as well as academic research entities (REs) and civil society representatives are working on the preparation of a European Joint Programming (EJP) within the EU JOPRAD-project that could be launched in 2019.

#### **Challenge C1.**

*Synergies should be developed with international organizations dealing with NWM to further disseminate and exchange research results of KYT via various means.*

#### **Suggestion S8.**

*International collaboration should be further enhanced and in this work Finnish contributions could involve all national participants together (including all stakeholders in the Finnish team: KYT2018, Posiva, STUK, utilities, etc.).*

#### **Suggestion S9.**

*The opportunity/benefits for KYT to enter the SITEX network and the EJP in case they take place should be evaluated.*

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1 SITEX (2012-2013) and SITEX-II (2015-2017)

## 2.4 Competence building, education and training

The review team has not attempted to make a quantitative study of the outputs education and training activities have created. That effort would require data of achieved academic degrees, participation in training courses and conferences, and of course the scientific papers published. In general, the KYT2018 projects almost systematically involve young researchers, which is a good way to educate new experts. The programme has efficiently produced new PhDs, although in most cases solely under additional support from external sources or own internal funding.

A budgetary controversy is that academic education of research personnel requires sustainable funding: a doctoral degree typically takes a minimum of four years. In later career development deeper expertise has to be acquired on-the-job in research institutes and utilities, and in very few cases in quasi-permanent academic positions. Besides of his/her research speciality, a true professional has to have a comprehensive understanding what nuclear safety means.

Regarding training, a positive development in Finland is that the nuclear waste management course YJH has established its continuity and its connection to YK, the nuclear safety course. This unification will serve both communities. In addition to obtain a global vision of NWM issues and their integration in conception and operation of nuclear facilities, the operational safety of a nuclear waste disposal facility will benefit from experiences from other facilities, and, furthermore, the common views on safety philosophy and culture are expected to increase when nuclear safety becomes more topical as the nuclear waste disposal facility starts to operate. Improvements in this area could be found in increased participation in the international research and training activities (see “research collaboration” in section 2.3). In the domestic side knowledge and information management make a new challenge to KYT programmes where especially the continuity of projects and personnel can be at risk.

In KYT2018 a key question is whether “the authorities have such sufficient and comprehensive nuclear engineering expertise”. Quantitative estimates for personnel in NWM have been given in the 2012 and 2014 competence and strategy reports by the ministry. An update of the career development and the employment situation of students in NWM field in Finland would illustrate the current situation and would perhaps deserve further assessment. The regulator’s need for new personnel turns out to be rather modest. Presently about 20 professionals in NWM work at STUK and their age distribution is sound. The future local inspectors in Olkiluoto can be shared with those working at NPP. VTT is the prime TSO (but also strongly funded by Posiva); HYRL and Geological Survey have permanent staff; in other university units there are only occasional positions related to NWM. Thus the market for expertise is rather limited.

As regards the level of competences, the regulator is decisive: does it find the scientific support for its safety reviews from abroad or is domestic research units like VTT or universities credible sources? A basic concern in a small country is that there are not enough resources to have double crews each purely serving only either the regulator or the licensee. In R&D and competence building collaboration should be preferred and the independence can usually be managed (e.g. joint training, immersion courses, etc.) but one must not forget that judging of the incapacity risk remains to STUK.

### **Challenge C2.**

*Ensure a good balance in the development of the national know-how in the NWM field which secures the needed level of independent expertise to support the authorities.*

As mentioned in previous sections of the present review, it is evident that one central impact of KYT2018 is the education of new experts; a number of new PhD-students are trained with the support from KYT. It is, however, difficult to judge the importance and added value of specific research issues/topics addressed in the KYT programme. It would be useful to explain in more detail how the identified research topics/issues relate to knowledge gaps that were identified by STUK in previous reviews of the safety case, as identified in suggestions S2 and S3.

KYT2018 visibility has slightly improved as compared to previous programmes. The review team suspects that a part of the scientific impact of projects is still rather low, although some pleasing exceptions exist, too. A more detailed argumentation of this statement of impact can be substantiated by a search on literature references. In general, more challenging research tasks seem to be needed as well as international collaborations, as already pointed out above (see challenge C1, suggestions S6, S8 and S9). It is clear that the goal to achieve important scientific impact requires long term commitment to funding and, on the other hand, one needs to realize that a top-project can arise only from a broad average performance.

### **Challenge C3.**

*The steering group must have an important role to increase the visibility of the programme and quality of the KYT2018 projects.*

## 2.5 Centre for Nuclear Safety (CNS)

After decommissioning of the research reactor FiRI, Centre for Nuclear Safety of VTT is the only large Finnish nuclear research facility enabling versatile radiation work and it has to serve at least the next half a century. The analytics tools and methods available in CNS are very interesting to researchers outside VTT, too. Concerning LLW and ILW management and decommissioning the hot-cell options may become crucial. Therefore, though spent nuclear fuel cannot be handled in CNS, it plays a central role in the nuclear research in Finland.

The CNS is also a highly valuable asset, as regards to the opportunity for national and international collaborations in NWM: it enables maintaining and developing partnerships, which are essential in this field. CNS has been built according to time schedules and impressive progress on equipment has been made: the process enables efficient planning of near-future research programmes.

Unfortunately, CNS has also been a main cause for severe cuts in the previous annual budgets of KYT2018 leading to difficulties in carrying out the initially planned tasks. In the initial project plans the CNS investments were not anticipated neither for research use nor as an extra funding item; separate lines for investments (heavy equipment) and projects would have avoided many difficulties. In the first place, it is assumed that CNS would be exploited for (partly already existing) studies on nuclear power plant safety whereas several present NWM applications do not have an acute need for high-radiative work in sophisticated hot cell facilities. It is important that KYT management clearly states its motivation for the CNS funding and encourages the use of this new asset.

### **Challenge C4.**

*CNS is a very important research asset for the whole country and it is necessary that it will be fully exploited as a part of common R&D infrastructure of the country with enhanced national and international collaborations.*

### **Suggestion S10.**

*Access to CNS for KYT funded teams should be favored where requested.*

# 3 Conclusions and a summary of recommendations

The review team finds that, in general, the KYT2018 research is reasonably extensive, addresses right topics and research objectives. Organization to a programme form, instead of establishing individual projects, is preferable because of the clear benefits a collaboration yields, in particular, when small individual projects are involved. The current situation in the Finnish NWM clearly suggests that a “KYT2022” is needed. Its funding would be rather predictable and there is a need for both continuing present research topics and new ones may appear when the operation of disposal facilities starts. The main objectives remain presumably the same as before, support activities for STUK and competence building in the field. The steering committee has created efficiently and wisely the framework programme KYT2018 and the same is expected for the next programme planning.

The review team has made several recommendations which have been expressed as “Suggestions” or “Challenges”. The difference between these two is that a suggestion is usually rather precise and readily accessible, if actions are found necessary, whereas a challenge tackles a broader issue that requires more argumentation and innovative views.

A key issue related to KYT2018 programme management is the need to further emphasize both the role to authorities and to competence building in the field. Steering bodies, STUK, researchers and other stakeholders should all contribute. Besides making recommendations to annual funding plans the steering group could use even stronger guidance that the project objectives will be followed and the project groups recognize also their support role for authorities. STUK, as the main “customer”, has to assure that KYT2018 activities lead to practical authority support. This demand is, however, rather complicated since acute well-defined problems are readily forwarded to the license holder. In this respect all stakeholders should together make suggestions to proper research topics. Research units should keep in mind the primary objectives search and digest them in their projects, of course, without compromising scientific freedom. These observations have brought to several suggestions and challenges:

## **Challenge C2.**

*Ensure a good balance in the development of the national know-how in the NWM field which secures the needed level of independent expertise to support the authorities.*

**Suggestion S3.**

*The Authority should provide clear guidance to the applicants regarding the need for depicting the technical context of the proposal (state-of-the-art, remaining issues, ...) and the added value of the expected/obtained outcomes for safety case reviews.*

**Suggestion S6.**

*The motivation why the project supports the safety case should always have a prime emphasis in the project planning and goal setting. Besides, innovations and research that would challenge the WMO safety case should be encouraged.*

**Challenge C3.**

*The steering group must have an important role to increase the visibility of the programme and quality of the KYT2018 projects.*

A detailed assessment of the individual projects was not pursued. Although some research issues were explicitly mentioned above, the report is aimed to obtain an overview. Concerning the research contents of the KYT2018 programme, review team has spotted some possibly new areas and notes the importance of the newly commissioned Centre for Nuclear Safety of VTT:

**Suggestion S1.**

*As a reminder, the opportunity to enlarge the research projects to post-accidental waste, NORM and operational safety of geological disposal would still be worth reassessing and, where appropriate, the non-relevance or low priority of these research areas made explicit.*

**Challenge C4.**

*CNS is a very important research asset for the whole country and it is necessary that it will be fully exploited as a part of common R&D infrastructure of the country with enhanced national and international collaborations.*

**Suggestion S10.**

*Access to CNS for KYT funded teams should be favored where requested.*

Some comments on possible future assessments were included:

**Suggestion S2.**

*In planning of future reviews, the safety issues and associated technical/scientific needs should be introduced in more detail by the stakeholders of the KYT2018 programme.*

**Suggestion S4.**

*The Authority should display the last annual progress reports in English, as well as the slides ahead of the visit in case a deeper review of the relevance of the projects and of their scientific outputs is required.*

Admittedly the budgets strongly restrict the activities that could be performed, and research areas have been selected to meet the current needs of various KYT/JYT programmes. To keep the know-how and competences is a challenge, and, in addition, in many cases the projects have diminished to such a size that the researchers can survive only by additional external funding.

**Suggestion S5.**

*A more secured budget should be preserved for the KYT multiyear projects.*

Collaboration and networking was discussed in the review team and the findings led to recommendations as follows:

**Suggestion S7.**

*Links with nuclear operators should be strengthened to anticipate potential further issues that would need R&D and competence building regarding nuclear waste management.*

**Challenge C1.**

*Synergies should be developed with international organizations dealing with NWM to further disseminate and exchange research results of KYT via various means.*

**Suggestion S8.**

*International collaboration should be further enhanced and in this work Finnish contributions could involve all domestic participants together (including all stakeholders in the Finnish team: KYT2018, Posiva, STUK, utilities, etc.).*

**Suggestion S9.**

*Evaluate the opportunity/benefits for KYT to enter the SITEX network and the EJP in case they take place.*

A more quantitative assessment of KYT2018 is to take place after the final reporting of the programme.

- Appendix 1: Terms of Reference provided to the Review Team
- Appendix 2: List of interviewees 31.5.-1.6.2017
- Appendix 3: List of reference documents provided to the Review Team
- Appendix 4: Research projects for 2015-2016
- Appendix 5: List of reference documents provided to the Review Team

# Appendix 1

## Terms of Reference provided to the Review Team

The Ministry of Economic Affairs and Employment invited a team in an evaluation of the scientific output of the Nuclear Waste Management Research Programme “KYT2018”. The evaluation of KYT2018 addressed the following main questions:

- a Does the KYT2018 research program cover all the necessary elements of nuclear waste management taking into account operating environment (types of nuclear facilities and their current life span and types of waste produced) as well as the scope of the research programme set in the Nuclear Energy Act?
- b Challenges and recommendations.

## Appendix 2

### List of interviewees 31.5–1.6.2017

#### **Project representatives:**

- Tiina Heikola, VTT Technical Research Centre of Finland Ltd
- Silja Häkkinen, VTT Technical Research Centre of Finland Ltd
- Pirkko Hölttä, University of Helsinki
- Jukka Juutilainen, University of Eastern Finland
- Wade Karlsen, VTT Technical Research Centre of Finland Ltd
- Suvi Karvonen, VTT Technical Research Centre of Finland Ltd
- Riikka Kietäväinen, Geological Survey of Finland
- Matti Kojo, University of Tampere
- Eevaliisa Laine, Geological Survey of Finland
- Jukka Lehto, University of Helsinki
- Markku Leivo, VTT Technical Research Centre of Finland Ltd
- Tarmo Lipping, Tampere University of Technology
- Mira Markovaara-Koivisto, Geological Survey of Finland
- Keijo Mattila, University of Jyväskylä
- Tapani Pakkanen, University of Eastern Finland
- Juhani Rantala, VTT Technical Research Centre of Finland Ltd
- Mikael Rinne, Aalto University
- Marja Siitari-Kauppi, University of Helsinki
- Wojciech Solowski, Aalto University
- Lauri Uotinen, Aalto University
- Elmo Wiikinkoski, University of Helsinki
- Minna Vikman, VTT Technical Research Centre of Finland Ltd

#### **Lab tour guides at VTT Centre of Nuclear Safety (CNS) 31.5.2017:**

- Tiina Heikola, VTT Technical Research Centre of Finland Ltd
- Joonas Järvinen, VTT Technical Research Centre of Finland Ltd
- Anumaija Leskinen, VTT Technical Research Centre of Finland Ltd
- Michal Matuszewicz, VTT Technical Research Centre of Finland Ltd

#### **KYT programme organization:**

- Jaana Avolahti, Ministry of Economic Affairs and Employment
- Liisa Heikinheimo, Ministry of Economic Affairs and Employment
- Petri Jussila, STUK – Radiation and Nuclear Safety Authority
- Ville Koskinen, Fennovoima Oy
- Jarkko Kyllönen, STUK – Radiation and Nuclear Safety Authority
- Kari Rasilainen, VTT Technical Research Centre of Finland Ltd

# Appendix 3

## List of reference documents provided to the Review Team

### **KYT2014 Review Report**

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

Nuclear Energy Act, Chapter 7 a

Documents related to the process of the decision making on research projects under the KYT2018 programme:

- Letter of invitation
- Instructions for applicants
- Proposals for research projects and studies for 2016
- Research projects in 2016 divided into the main topics
- Financing recommendation
- Feedback on project contents

# Appendix 4

## Research projects for 2015–2016

### **Technologies in nuclear waste management**

- Advanced fuel cycle – New adjustable separation materials (SERMAT), University of Helsinki
- Advanced fuel cycle – Scenario and Inventory Analysis, VTT Technical Research Centre of Finland Ltd

### **Long term safety of nuclear waste management – Safety case**

- TURMET – Systematization of the Safety Case Methodology, Part 1, VTT Technical Research Centre of Finland Ltd
- TURMET – Systematization of the Safety Case Methodology, Part 2, Aalto University
- Long term safety of nuclear waste management – Buffer and backfill performance
- THEBES – THMC Behaviour of the Swelling Clay Barriers, Aalto University, VTT Technical Research Centre of Finland Ltd, University of Jyväskylä, Numerola Oy
- Bentonite erosion and radionuclide interaction processes (BENTO), University of Helsinki
- Bentonite swelling pressure, University of Eastern Finland

### **Long term safety of nuclear waste management – Canister performance**

- Experimentally verified model based predictions for integrity of copper overpack (PRECO), VTT Technical Research Centre of Finland Ltd
- Mechanical strength of copper canister (MECHACOP), Aalto University
- The effect of reaction product layers on copper corrosion in repository conditions (REPCOR), Aalto University
- The effect of microbial activity on corrosion of copper in anoxic state of repository (BASUCA), VTT Technical Research Centre of Finland Ltd
- Microbially induced corrosion during the oxic stage of repository (MICOR), VTT Technical Research Centre of Finland Ltd

### **Long term safety of nuclear waste management – Microbiological effects**

- Microbiology related to geological disposal of low- and intermediate level waste (MAKERD), VTT Technical Research Centre of Finland Ltd
- Microbially induced corrosion of low and intermediate level radioactive waste (CORLINE), VTT Technical Research Centre of Finland Ltd
- Microbial sulphur cycle in final nuclear waste repository conditions (GEOBIOKIERTO), VTT Technical Research Centre of Finland Ltd
- Nutrients, energy and gases in bedrock biosphere (RENGAS), Geological Survey of Finland

### **Long term safety of nuclear waste management – Other safety studies**

- Behaviour of radionuclides in the geosphere; in situ studies, University of Helsinki
- Release of C-14 from metallic waste (Carbon-14), VTT Technical Research Centre of Finland Ltd
- Modelling fracture flow, matrix diffusion and sorption using the lattice-Boltzmann method, University of Jyväskylä
- Chemical forms and sorption of radiocarbon in geosphere, University of Helsinki
- Applicability of Geopolymers in Nuclear Waste Management, GeoP-NWM, VTT Technical Research Centre of Finland Ltd
- Risk assessment of radioactive waste: development of radioecological modelling for terrestrial and aquatic ecosystems, University of Eastern Finland
- Alternative methods for biosphere modelling and their evaluation (VABIA), Tampere University of Technology
- KARMO II - Mechanical Properties of Rock Joints, Aalto University
- Fracture simulator which respects the measured fracture length and orientation distributions (ROSA), Geological Survey of Finland

### **Nuclear waste management and society**

- Governing Safety in Finnish and Swedish Nuclear Waste Regimes (SAFER), University of Tampere

### **Infrastructure projects**

- RADLAB (Radiological Laboratory Commissioning), VTT Technical Research Centre of Finland Ltd
- RADCONS (Radiological laboratory facility costs of the Centre for Nuclear Safety), VTT Technical Research Centre of Finland Ltd
- RADINFRA (Radiological laboratory equipment infrastructure investments), VTT Technical Research Centre of Finland Ltd

## Appendix 5

### List of reference documents provided to the Review Team

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.

(<http://tem.fi/documents/1410877/3437250/Report%20of%20the%20Committee%20for%20Nuclear%20Energy%20Competence%20in%20Finland%2023052012.pdf/20fdc87f-f4d3-4bd6-b464-fdb6a15c16ae>)

TEM 2013. KYT2014 Review Report. Publications of the Ministry of Employment and the Economy. Energy and the climate 10/2013.

(<http://tem.fi/documents/1410877/3437254/KYT2014%20review%20report%2020032013.pdf/bfb2674b-0a70-4fc6-bfea-69eacb4a1e61>)

TEM 2014. 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. (<http://tem.fi/documents/1410877/3437254/Finnish%20Research%20Programme%20on%20Nuclear%20Waste%20Management%20KYT2018%2012112014.pdf/99327c3a-7175-4b6a-8327-b0689293d62e>)

TEM 2014. Nuclear Energy Research Strategy. Publications of the Ministry of Employment and the Economy. Energy and the climate 17/2014. (<http://tem.fi/documents/1410877/3437254/Nuclear%20Energy%20Research%20Strategy%2024092014.pdf/1b63c385-9623-412a-aaeb-4adcc2199b10>)

# KYT2018 Review Report

A panel of three members was asked by the Ministry of Economic Affairs and Employment to evaluate the KYT2018 research programme on nuclear waste management. The panel carried out the evaluation by reviewing of written materials and by meeting some key individuals. The results are provided as general conclusions, responses to questions posed by the Ministry, challenges and recommendations. The panel provides useful guidance for the future of the programme.



Ministry of Economic Affairs  
and Employment of Finland