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Challenges and opportunities for improving Nordic nuclear decommissioning

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Abstract

The overall goal of the NorDec project has been to explore challenges related to how decommissioning regulation is applied, and how projects are planned and performed in the Nordic countries, as well as collect best practices and share experiences between the Nordic stakeholders. The contributions for this project came from a wide range of stakeholders, including regulators, operators and contractors, and via the use of questionnaires, interviews and a workshop. The most frequently reported decommissioning challenges were: 1) Developing and maintaining competence and motivation; 2) Regulatory oversight and decision making; and 3) Safe and effective waste characterization and clearance. Workshop participants discussed around identified challenges and possible solutions enabling organisations to build up suitable competence for overcoming these issues. This report presents the results from the project.

Key words

Decommissioning, regulation, challenges, lessons learned

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Challenges and opportunities for improving Nordic nuclear decommissioning

Final Report from the NKS-R NorDec activity

(Contract: AFT/NKS-R(17)123/5)

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1. Introduction

Approaching large-scale nuclear decommissioning projects in the Nordic countries make it important for both regulators and operators to build new capabilities for handling up-coming challenges. Sweden and Finland both have a mixed legacy of nuclear sites, including commercial plants and research reactors in different stages of operation or decommissioning, whereas in Denmark, some decommissioning projects have been completed for research reactors and others are well on the way to completion (see Figure 1). In Norway, while no immediate large scale decommissioning activities are foreseen, information and lessons learned from the other Nordic countries are valuable for further detailing of the existing decommissioning plans.

The aim of this project has been to explore challenges related to how decommissioning regulation is applied, and how projects are planned and performed in the Nordic countries, as well as collect best practices and share experiences between the Nordic stakeholders. The contributions for this project came from a wide range of stakeholders, including regulators, operators and contractors. The Norwegian Radiation Protection Authority (NRPA), Swedish Radiation Safety Authority (SSM), Danish Health Authority (SIS), Finnish Radiation and Nuclear Safety Authority (STUK), the energy companies Fortum and Vattenfall, the consulting company ÅF in Sweden, VTT Technical Research Center of Finland, and Institute for Energy Technology (IFE) in Norway have participated in the project. The project collected information from experts based on their experience from completed and on-going decommissioning-related activities in Sweden, Finland, Denmark and Norway. Evaluation of this information aimed at identifying areas where stronger Nordic collaboration would facilitate improvements in processes, methods and tools. The project has fostered collaboration among Nordic stakeholders through providing a new arena for discussing challenges and best practices.

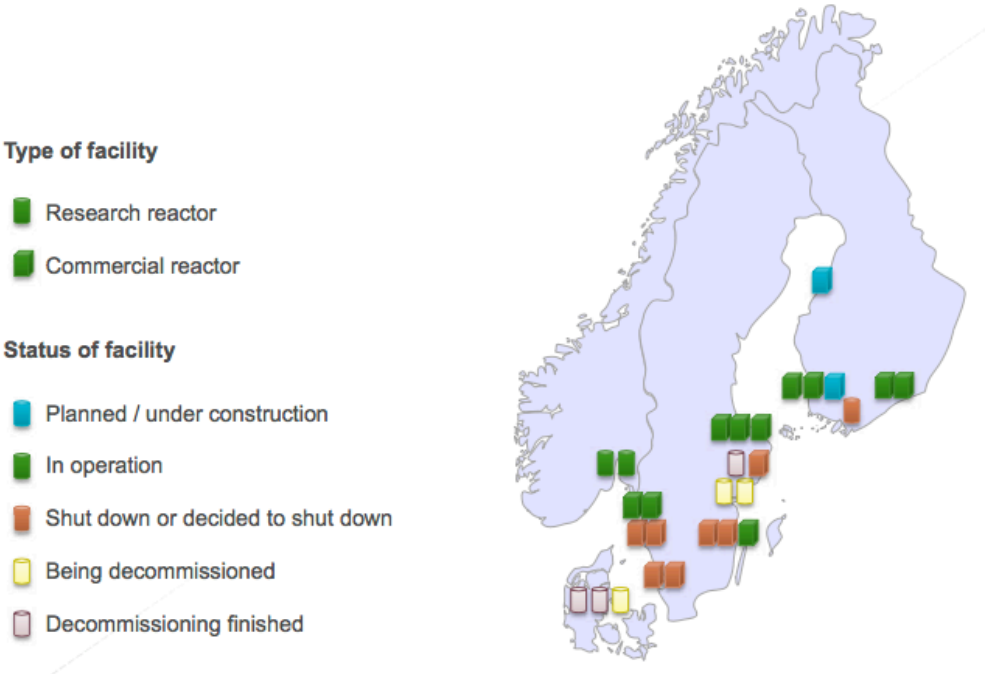


Figure 1. The landscape of nuclear decommissioning in the Nordic countries.

1. 1 Findings from literature review

In order to build on existing international work related to challenges in decommissioning, a short literature study was performed. Reports from international actors such as the European Commission [1,2], the IAEA [3,4,5,6,7,8] and OECD NEA [9] have been especially useful, and have helped inform the project.

In many aspects, decommissioning technology and decommissioning know-how is maturing as several decommissioning projects are progressing and completed around the world. Some challenges experienced in early projects are now being met by contractor expertise and new technologies. However, the nature of decommissioning projects and their settings vary greatly, and so do the solutions. Applicable strategies, practices and guidance will thus vary. One unifying trait seems to be that one should be prepared for encountering the unexpected, as well described in (**Fejl! Henvisningskilden blev ikke fundet.**). A holistic approach to decommissioning projects is not well established. Across nations and organisations, there is still a prevailing tendency towards planning decommissioning jobs and tasks more than planning decommissioning projects. Furthermore, the business still struggles with an historical reluctance to work together to invest in universal new technologies and practices, resulting in one-of-a-kind solutions and "time consuming cycles of re-inventions" (**Fejl! Henvisningskilden blev ikke fundet.**).

The following key areas were identified as initial candidates for further scrutiny in work meetings

- Staff retention and the development and maintenance of decommissioning competence
- Integrated planning and management of decommissioning projects
- Experience transfer between activities and projects
- Waste management and disposal
- Regulation and governance
- Costing

2. Data collection and analysis

2.1. Activities

Three activities were described in the original project plan, as follows:

- Activity 1: data collection to identify the main challenges and best practices for planning the decommissioning of Nordic legacy sites;
- Activity 2: data collection to identify the main challenges and best practices for planning the decommissioning of Nordic plant sites;
- Activity 3: comparisons of data collected to identify specific and common issues and practices relevant to a Nordic collaboration arena.

Activities 1 and 2 were performed in parallel during the two main data collection efforts (questionnaires and interviews), as described in Section 2. Data analysis was performed within activity 3. Results of the analyses are documented in this report.

2.2 Work meetings

Two work meetings were held during the project implementation. The first meeting was hosted via video conferencing on the 16th of March, with four participants from IFE, one from VTT, one from Fortum and two from Vattenfall. The second work meeting took place at Oslo Airport, Gardermoen on the 13th of June, with three participants from IFE and one participant from Vattenfall, STUK, Fortum, VTT, ÅF and NRPA respectively. For both events, separate communications (video/phone sessions, email exchange) were performed with participants from organisations of the project consortium that were not represented on the work meetings.
The purpose of the first work meeting was to agree on the project activities, methods and deliverables and to collect input on focus areas for the project. Project participants who were not present in the meeting were invited to provide input after the meeting by email or telephone. The purpose of the second meeting was to present and discuss the preliminary findings from the data collection activities.

2.3. Questionnaires

A questionnaire was developed and distributed to project participants to collect statistical and qualitative data on main challenges from their decommissioning experiences. The project participants were also invited to forward the questionnaire to relevant people within their organization and network. The questionnaire was hosted online and was made available to participants from the 15th May until 30th June 2017. The full questionnaire is included in Appendix A of this report.

2.4. Interviews

Interviews were conducted to collect more in-depth information on decommissioning experiences and challenges. They were conducted between 1st June and 16th August 2017. 3 interviews were conducted in person and 12 on phone. Each interview lasted approximately one hour. Interview respondents were project participants and people they had nominated. The full interview guide is included in Appendix B.

2.5. Workshop

A workshop was held in Halden on the 20th and 21st of November. The purpose of the workshop was to present and discuss the results from the questionnaires and interviews. 19 people participated in total on the two days. 10 participants were from IFE, 7 from other organisations of the project consortium (Fortum, NRPA, SSM, STUK and VTT) and 2 from organisations not in the consortium.

3. Results and discussion

3.1. Questionnaire results

3.1.1 General results from the questionnaire

27 responses to the online questionnaire were received in total. 17 responses were from participants who identified themselves as primarily interested in decommissioning of commercial sites, and 10 identified as primarily interested in decommissioning of legacy sites.

As shown in **Figure 2**, the majority of respondents came from Sweden (12 out of 27), and the majority identified themselves as coming from an operating organization (14 out of 27). Most of the respondents had some decommissioning experience, with the majority having between two and five years' experience (8 out of 27).

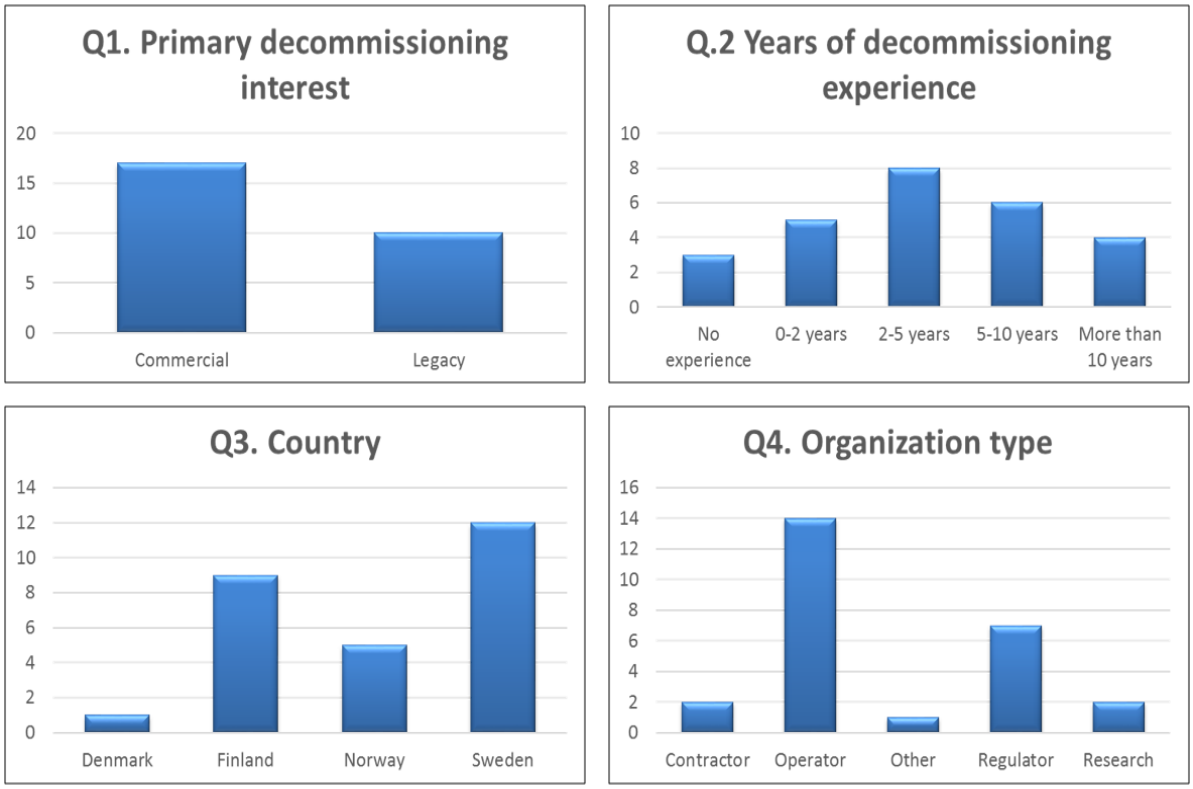


Figure 2: Statistics on the people that provided input via the questionnaire

In the questionnaire, respondents were asked to rate what they considered to be the three most important challenges for decommissioning, from a list of eleven challenges that were identified by project participants in the first work meeting.

Figure 3 shows a graphical representation of the overall results from the analyses of the responses from the questionnaire. For each area (challenge) on the vertical axes, a triplet of horizontal bars is shown in the figure. The top bar of each triplet (palest in colour) indicates the number of respondents who rated the challenge as the most important one. The middle bar shows how many rated the challenge among their top three. The last bar (darkest in colour) shows a weighted average from the two previous scores obtained as follows: answers given first priority were weighted by a factor 3; answers given second priority were weighted by a factor 2; and answers given third priority were not weighted. These scores were then summed up and divided by 3.

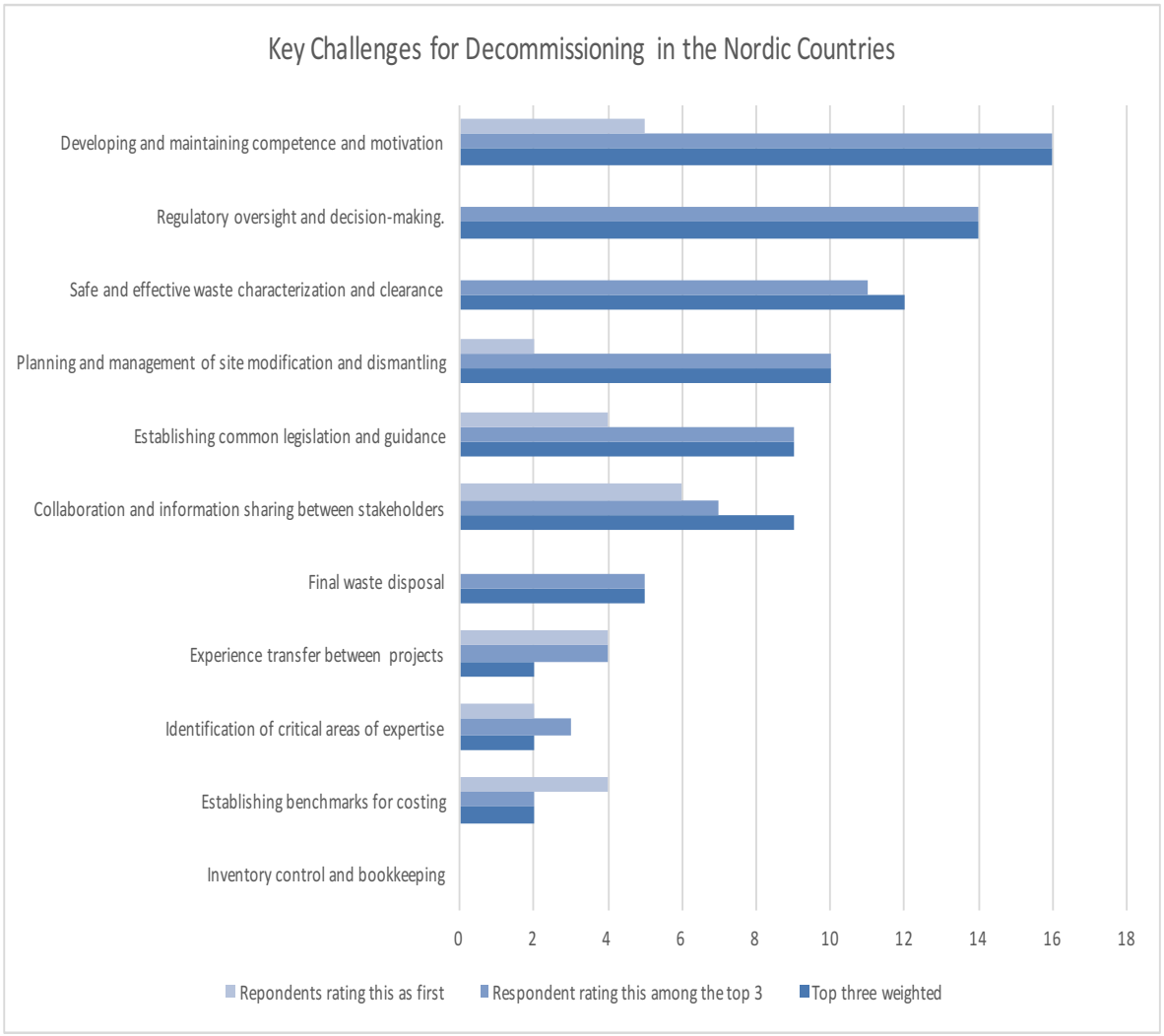


Figure 3: List of decommissioning challenge areas in order of their weighted average importance calculated from analyses of questionnaire responses.

As **Figure 3** shows that the top three highest rated challenges, in order of importance, are:

- Developing and maintaining competence and motivation,
- Regulatory oversight and decision-making, and
- Safe and effective waste characterization and clearance.

In addition, in comparison to an average, there is a clear increase in importance for the three challenge areas below:

- Planning and management of site modification and dismantling

- Establishing common legislation and guidance
- Collaboration and information sharing between stakeholders

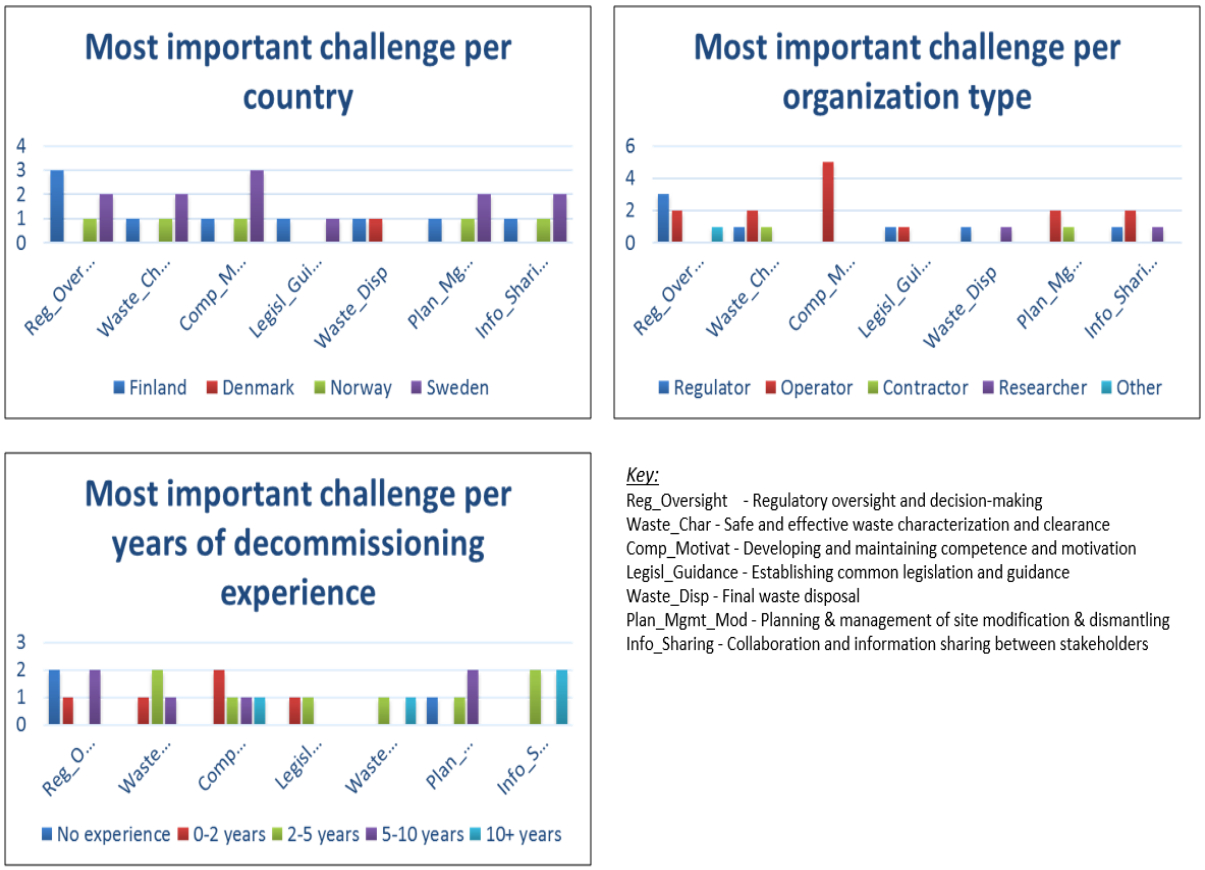
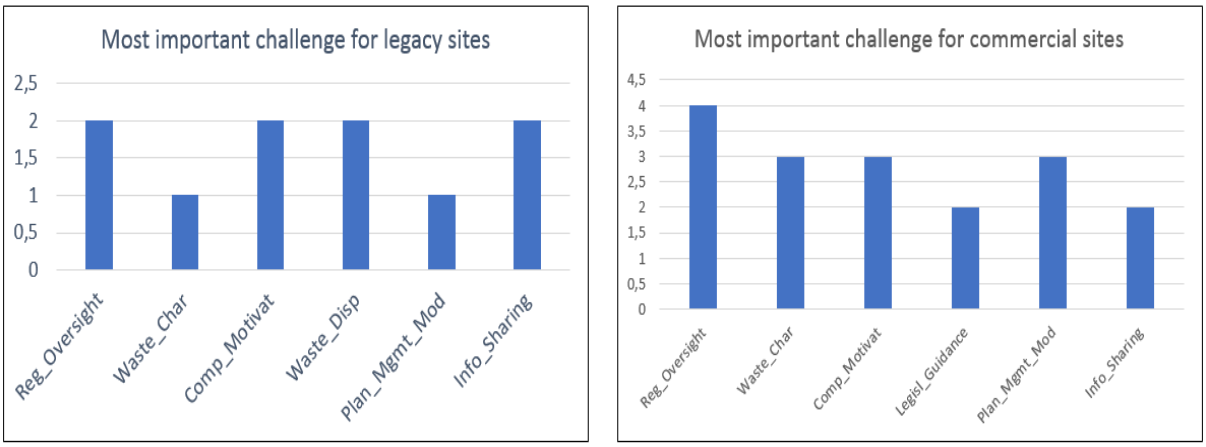


Figure 4: Breakdown of decommissioning challenges according to country, organization types and years of experience



Key:
Reg_Oversight - Regulatory oversight and decision-making
Waste_Char - Safe and effective waste characterization and clearance
Comp_Motivat - Developing and maintaining competence and motivation
Legisl_Guidance - Establishing common legislation and guidance
Waste_Disp - Final waste disposal
Plan_Mgmt_Mod - Planning & management of site modification & dismantling
Info_Sharing - Collaboration and information sharing between stakeholders

Figure 5: Breakdown of decommissioning challenges according to site type

Figure 5 shows the breakdown of the highest rated decommissioning challenge per country, per organization type and per years of decommissioning experience of the respondent. **Figure 5** shows the difference between legacy and commercial sites in terms of the highest rated decommissioning challenges.

As Figures 1 to 4 show, there are some small differences in the perceived importance of the various decommissioning challenges depending on how the results are quantified. However, it is clear from the questionnaire results that the challenges that are perceived as most important by the participants, with one exception (waste characterization and clearance), are centred around application of regulation/legislation and more knowledge management / decision making and organizational issues, rather than technical needs like cutting and decontamination technologies.

"Establishing benchmarks for costing" was selected as a secondary challenge by only two respondents. "Identification of critical areas of expertise" was selected as a secondary challenge by only one respondent, and as a tertiary challenge by two respondents. "Experience transfer between projects" was selected as a tertiary challenge by four respondents. No respondents selected "inventory control and bookkeeping" as one of their top three decommissioning challenges.

Respondents were also asked for details about why they selected the specific challenges, how these challenges could possibly be resolved, and any identified best practices that they would recommend for the identified challenges. These results are described in sections 3.1.2 and 3.1.3 below.

3.1.2 Questionnaire results specific to legacy sites

Ten questionnaire respondents identified legacy sites as their primary decommissioning interest. The most important challenges for these respondents are listed below:

- Regulatory oversight and decision-making (2 respondents);
- Developing and maintaining competence and motivation (2 respondents);
- Final waste disposal (2 respondents);
- Collaboration and information sharing between stakeholders (2 respondents);
- Safe and effective waste characterization and clearance (1 respondent);
- Planning and management of site modification and dismantling (1 respondent).

Each of the above challenges is discussed separately below, also taking into account the responses from those who listed these as their second-most important or third-most important decommissioning challenge.

The concern regarding **regulatory oversight and decision-making** is largely due to the lack of decommissioning experience at the Nordic regulators. The questionnaire respondents are not aware of any pre-existing legislation governing decommissioning projects and therefore there will be a challenge to develop legislation that is efficient and effective, to ensure that decommissioning projects can progress smoothly and without delay, but at the same time maintaining control of the process. Regulators will have to work to develop decommissioning competence to ensure they understand the technical aspects of decommissioning and the implications of their regulatory framework and decisions on the conduct of decommissioning projects. Respondents believe there is a risk that regulators might not have sufficient knowledge of a facility to be able to adequately evaluate decommissioning plans and implement effective regulatory oversight. Equally, operators will need to ensure they understand practical meaning of decommissioning regulations and the expectations of the regulators. Some respondents have suggested that a graded approach to regulation should be adopted, although there is no consensus as to what this means in practice. Early engagement of, and dialogue with all stakeholders in the process to develop regulation and its application to decommissioning may be a useful way to build a more shared perspective on these issues. The importance of a clear and effective decision-making processes and good communication between stakeholders throughout the decommissioning project was emphasised.

The respondents that were concerned with the **development and maintenance of competence and motivation** recognize that this is an essential task for safe and efficient decommissioning. There are some uncertainties about whether existing (operational) staff will have the necessary competence to participate in decommissioning projects. Decommissioning activities can differ significantly from normal operations, and hence, personnel will need a new set of skills to do decommissioning work safely and effectively. For smaller organizations, it may be difficult to develop and maintain new competences over time if the staff is already fully occupied with administrative and other line work duties. Personnel may also be less motivated to retrain for work on decommissioning projects because they believe that career opportunities in decommissioning are limited. Another aspect of this challenge is that it may be difficult to hire external competence because of the general lack of decommissioning experience within the Nordic countries, including amongst contractors. Organizations may have to look outside of Europe to find contractors with sufficient experience to provide support.

Final waste disposal is listed as a challenge because there are currently no final disposal sites available for much of the waste from research reactors and other legacy sites. Building waste disposal facilities can be a sensitive political issue which may explain why such decisions have not been made earlier. This creates subsequent uncertainties and delays for decommissioning projects. This problem is compounded by the fact that different countries are investigating different solutions depending on their waste inventories, so there are no large scale shared solutions between the Nordic countries.

For **collaboration and information sharing between stakeholders**, the primary concern is that different stakeholders have different interests and points of view, which can create challenges for collaboration. This is especially true for definition of final end state of decommissioning sites, as well as remediation and final disposal solutions. The differences between stakeholders can create difficulties in developing solutions and getting contracts in place.

Respondents noted that efficient **waste characterization** is key to all phases of decommissioning, and this must be done early in the process to avoid subsequent project delays. Although power generating companies have already defined acceptance criteria for the waste generated at their plants, there are no clear guidelines for waste from other (legacy) facilities.

The lack of decommissioning experience in the Nordic countries is, again, a significant driver behind the challenge of **planning and management of site modification and dismantling**. Nordic organizations have little experience with such requirements, and there may be uncertainties regarding radiation levels at the site. To ensure cost-effectiveness and time-efficiency, organizations must plan and set requirements for the whole decommissioning project (i.e. spanning several years). However, especially for decommissioning of legacy sites, conditions and requirements can significantly change over time and make it difficult to plan ahead for activities where risks are not fully known. Planning the "downgrading" of the facility over time can also be a challenge.

3.1.3. Questionnaire results specific to commercial sites

Seventeen questionnaire respondents identified commercial sites (NPPs) as their primary decommissioning interest. The most important challenges for these respondents are listed below:

- Regulatory oversight and decision-making (4 respondents);
- Safe and effective waste characterization and clearance (3 respondents);
- Developing and maintaining competence and motivation (3 respondents);
- Planning and management of site modification and dismantling (3 respondents);
- Establishing common legislation and guidance (2 respondents);
- Collaboration and information sharing between stakeholders (2 respondents).

Each challenge is discussed separately below, also taking into account the responses from those who listed these as their second-most important or third-most important decommissioning challenge.

Personnel concerned with commercial decommissioning also see that lack of decommissioning experience may pose a challenge for **regulatory oversight and decision-**

making. Specifically, some of the questionnaire respondents reported that they are not aware of any regulations that are in place yet for many Nordic decommissioning activities, and those that are in place have not yet been tested in practice. It is acknowledged that decommissioning is a learning process for both the regulator and the operator, and that the licensing (or approvals) process for decommissioning will not be straightforward, especially in cases where final waste route options are not immediately available. Some respondents pointed out that Nordic regulators may receive multiple applications in the same time period, as many reactors are expected to begin the decommissioning licensing process around the same time. There is a risk that the regulator will be overwhelmed with work which will have subsequent delays (and impact on costs) for these decommissioning projects. It is important that regulators are proactive and plan for this possibility, but it is acknowledged that this is difficult to do when there is so much uncertainty about what will be required. Another challenge that was identified is for multi-unit sites that may have one reactor still in operation while another reactor is being decommissioned. This will result in requirement for dual (operation and decommissioning) regulatory oversight for the same site, potentially creating some problems where there are overlapping or contradictory requirements. It is important to have clarification of definitions and licensing conditions, as well as procedures for decision-making, to ensure that there is a common view and understanding of what is required.

When it comes to **safe and effective waste characterization and clearance**, there is some uncertainty about whether plans for waste characterization and clearance for decommissioning should be the same as those for operations. However, it is acknowledged that the amount of waste generated during decommissioning is much greater than during operations, and so it is important to develop characterization and clearance plans well in advance of any D&D activity. It is important that efficient and economical processes are developed to avoid unnecessary delays and to keep costs under control. One crucial aspect of this, based on experience from other projects, is the need for early categorization of waste and identification of waste streams. A significant challenge for those tasked with the job of waste characterization is that information about waste is often lacking, and waste characterization is costly to do. The logistics required for waste management and clearance can also be difficult to plan, and there is a high risk of creating bottlenecks which can impact on the speed and efficiency of decommissioning work. In addition, it can be difficult to train contractors in proper waste management procedures.

One of the main challenges associated with **developing and maintaining competence and motivation** that was reported by several respondents reported is the difficulty of retaining knowledgeable plant staff once the decision has been made to shut down the plant. This is a challenge because staff may perceive that there is no future, or a very uncertain future, in decommissioning and will soon start looking for a more secure job elsewhere. This is especially true if there are not many other job opportunities in the local area, which could result in high unemployment after decommissioning has been completed. Even if staff are retained, it can be difficult to maintain motivation if staff feel that they are "decommissioning their own jobs". In particular, if early shut down and decommissioning is decided due to financial problems, this can have a significant negative impact on people, and levels of frustration and uncertainty about the future can be very high.

It can also be challenging to change mind-sets from operational thinking to decommissioning thinking, which can have subsequent impacts on safety culture and efficiency. There are some decommissioning activities that are very dependent on having plant specific knowledge.

Hence, the organization will strive to keep relevant experts at the plant. But if they maintain their operational mindset, this can cause problems and delays. One respondent noted that decommissioning can often involve many repetitive tasks that must be performed over and over again, and thus it is a challenge to maintain motivation and avoid taking shortcuts for people performing these tasks.

For **planning and management of site modification and dismantling**, the scale of commercial decommissioning projects presents a significant challenge. The activities performed during decommissioning are completely different from those in operation, and as a consequence it is a major challenge to develop a plan that can be executed to schedule, cost effectively and safely. It is important for organizations to establish a sound and feasible strategy that optimizes dismantling, logistics and waste management processes in parallel. A particular challenge for multi-unit sites when one or more units are still in operation is to figure out how to reorganize and classify common systems and to decide what can be dismantled and what is still needed for the operating units.

Establishing common legislation and guidance is considered a challenge because there is little or no experience of developing legislation and guidance for decommissioning in the Nordic countries. There is uncertainty about what organizations will have to do to fulfil licencing conditions required for proceeding with decommissioning activities. As with most decommissioning planning and preparation work, the concern is that this will result in delays while regulatory guidance is detailed, and legislation is solidified and tested.

Collaboration and information sharing between stakeholders is important and necessary to establish the basic framework for decommissioning projects. The large number of activities involved in a typical decommissioning project means that there are many internal and external stakeholders. To ensure an efficient process, all key stakeholders need to have a shared understanding of the issues at hand. Different stakeholders can have different mind-sets, experiences and even different goals for decommissioning which can create challenges especially with respect to cost-sharing and decision-making.
Multi-unit sites where one or more units are still in operation can also experience challenges internally with collaboration and communication between the operating organization and the decommissioning organization. Decommissioning demands a different approach than safe and stable operation, and requires different ways of working and different culture.

3.2. Results from the interviews

15 interviews were conducted. Figure 6 below shows the distribution of the respondents by country, type of organisation and decommissioning focus / experience.

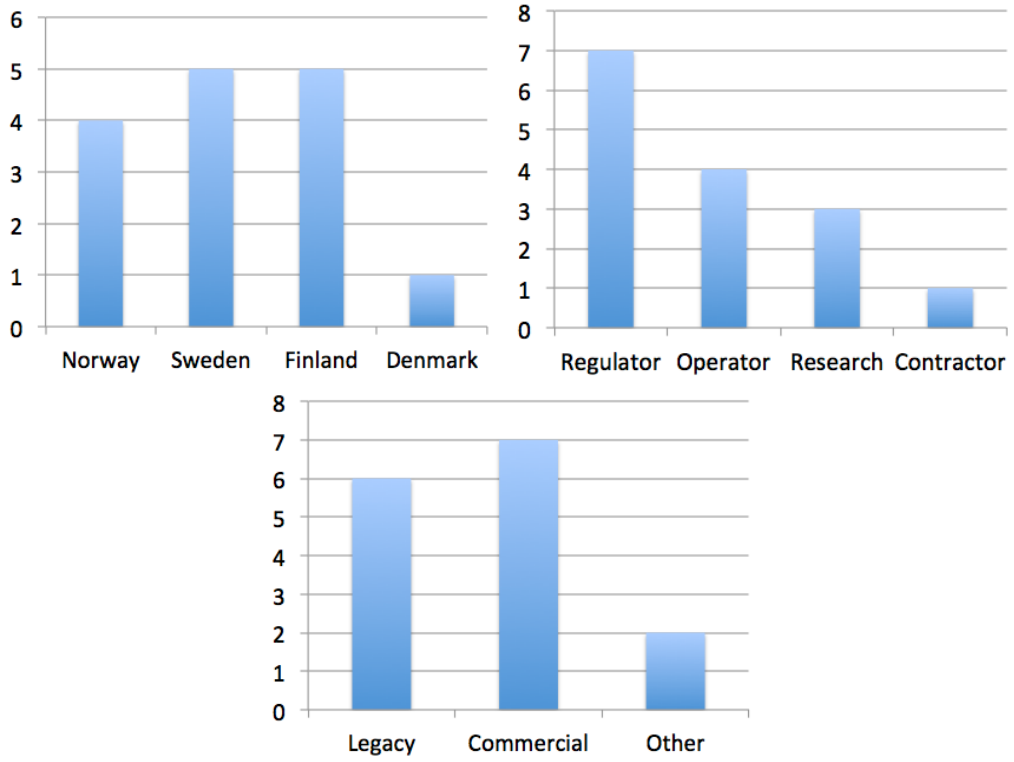


Figure 6: Distribution of respondents by country, type of organisation and decommissioning focus.

3.2.1 Interaction between regulator and operator

Challenges

In order to achieve a good and efficient regulatory process it is important to have good communication, cooperation and information sharing between the involved roles. The relationship between operator and regulator must be based on trust. Lack of trust may delay decisions and result in a suboptimal decision process. The regulator having a level of trust in the operator ensures that the operator has "space to work". On the other hand, the regulator must be sure that all risks are controlled and taken care of in a proper way. Good management and leadership is needed on all sides to build trust and relationships.

When treating an issue or problem, different stakeholders will have a different understanding and view of the problem. This is due to different competence, experience, priorities and the role that each stakeholder has. The operator usually has a better understanding of the radiological, nuclear and technical risks, and the specific operational conditions. The regulator must think about the interests of other stakeholders, to see risk from different perspectives. It is also important that the stakeholders understand each other's roles in order to calibrate expectations and to optimise communication. Contractors often have a prominent role in several phases of the decommissioning work in Nordic countries. However, contractors are usually not very involved in the dialogue between regulator and operator. One may consider whether it would be advantageous to involve contractors at an earlier stage.

There may be different views on how the regulatory oversight should work in practice. For instance, at an early stage the operator will not be able to describe their plans in great detail.

Hence, at such and early stage a very strict position from the regulator, where they demand detailed responses to the regulator's requirements, can fail.
There will be a lot more regulatory-related work during decommissioning than during operation, and a need for faster and simpler interaction. Smaller issues or changes that need less work to handle should be handled faster so that answers can be provided more quickly. External conditions can also impact the interaction. For instance large physical distance between regulator and operator can be challenging.

Good practices / proposed solutions
A graded decommissioning approach may be appropriate for some situations, especially for legacy projects. This allows discovering the way step by step as the project progresses and adapting to the demands and requirements accordingly. Active information exchange and frequent, open discussions between regulator and operator about documents and legislation has shown to be important for creating a good relationship and trust. Also more informal meetings can simplify work, e.g. to have a meeting with the regulator before sending in documents so they know what the operator is planning. Another example is regulators circulating drafts to operators to get input before a final version of a regulatory document.

Using local representatives from regulator that are situated on the operator's premises can speed up interaction and increase the knowledge of the regulator. It was suggested that the number of local representatives should be increased during decommissioning. Having the same regulator deal with the whole lifecycle can be an advantage, reducing the need for interfacing between different actors.

3.2.2. Organization and planning

Challenges
An important organizational and planning challenge is how to set up the organisation to achieve decommissioning in an efficient way that is tailored for the specific decommissioning project (its goals and conditions) and also in a way that is scalable for different phases. Most resources may be needed in the beginning of decommissioning. How can operators ensure that resources needed for starting decommissioning are in place in time, and how can resources best be utilised to achieve safe storage of fuel and high active waste. Planning on-site logistics is also very important to avoid bottlenecks and reduce costs, considering personnel work hours are major cost drivers.
Establishing a national final waste repository is a difficult decision to make - a process that is challenging in many countries. At the same time it is an essential element for decommissioning, and without it plans may be delayed and costs may increase due to the need for temporary solutions (e.g. on-site waste storages).

Some situations make planning especially challenging, e.g. when making plans for dismantling of systems shared between different units that will be decommissioned at different times, or when simultaneously planning to extend operational life and planning for later decommissioning.

Good practices / proposed solutions
A suitable level of planning is essential before actual dismantling activities start. Planning should start well ahead of decommissioning, preferably already during operation (rather than at the transition period to decommissioning). The operator should be aware that planning

activities are not only for producing documents and safety cases for the regulator, but also an instrument for the operator for ensuring efficient and safe project implementation.

3.2.3 Regulation and guidance

Challenges
Due to the early stage of decommissioning in most countries, there is little practical experience with the application of regulations for the decommissioning phase. High-level guidance exists, but not so much details when it comes to what regulators or licensees need to do, e.g. assessment criteria for the regulator or detailed guidance for the operator. The current regulations, to a large degree, regulates how to plan for decommissioning, but not how to execute it.

There is little decommissioning experience in the Nordic countries, with some exceptions for research reactors and other smaller facilities. When going into the decommissioning phase, one may therefore see a need to make interpretations or adaptations to fit the application of the regulations to the realities of the situation. Where there are gaps or bottlenecks in the process, there may arise temporary non-optimal solutions, e.g. that the licensee must apply for operating license for certain decommissioning activities because an overall decommissioning license has not yet been worked out.[1]

In some Nordic countries the decision to shut down coincides with a review of the existing regulations. It is not optimal to have these processes going on in parallel. It may lead to a lack of clarity as to which regulations are applicable, uncertainty as to the requirements and what is needed to meet the licence conditions and what is needed to fulfil the regulatory requirements.

In general, it can be difficult for licensees to know what to report to the regulator, what the main issues are. There needs to be a structured process for how the regulator and licensee should interact to efficiently handle a problem and make decisions.

Legacy sites are difficult to regulate, for instance in terms of planned exposure situations. Existing constraints for dose control can be used for workers, but it may be difficult to apply the same constraints for the wider public.

Good practices / proposed solutions
SSM has developed a set of licence conditions for reactor decommissioning in order to clarify and complement the existing high level regulatory documents. These conditions were developed through an extensive dialogue with the licensees and relevant stakeholders. They will be evaluated through practical application to the up-coming reactor decommissioning projects. Experience from this evaluation may form the basis for further development and revision of the regulatory framework.

[1] Note that not all countries require a specific decommissioning licence. In Sweden for example, a licence for a nuclear power plant covers its operation as well as decommissioning and, hence, separate decommissioning license is not needed. Regulatory approval is however required in advance of particular decommissioning activity.

Recommendations on how to use reference levels for introducing risk to the public are being worked out within the ICRP (International Commission on Radiological Protection) and can be used in communication about planned exposure conditions.

3.2.4. Development and maintenance of competence and motivation

Challenges

Both regulators and licensees reported that there is a lack of decommissioning competence in the Nordic countries. This is again related to the low level of experience with decommissioning projects.

At the regulator, the operational competence and plant knowledge may be limited. It can be a challenge to build and maintain a deep technical and scientific knowledge for decommissioning at the regulator due to the foreseen decommissioning related workload and other administrative tasks. On the other hand, the regulator cannot be expected to have the same level of competence as the licensee.

In some countries there may be a long time between decommissioning projects and the regulator may lose competence between these projects. There is also the challenge of losing competence due to retiring staff.

The operator organisation may lose staff when approaching decommissioning. Motivating staff to stay in the organisation can be problematic. The staff must be convinced that their expertise will be needed for a long time forward.

If the operator organisation does not have the adequate staff and competence, this must be found in other places. There will be a need for contractors to provide services, but contractors may not have experience from working within the nuclear industry and this may pose challenges to develop the needed nuclear competence and also challenges regarding collaboration with the operator organisation. With no new nuclear planned, there is generally no nuclear education on the national level. This can make it difficult to recruit new staff with the right competence.

Another choice is to build the competence of the existing staff for decommissioning. Due to the urgency of some decommissioning activities in Nordic countries, this may result in having to choose between either committing ample time to build up a good base of competence in the organisation, which may delay other activities, or to advance quickly without having suitable updated the necessary competence.

Additionally, as the needs change across the different phases of decommissioning, it may be difficult to know what competence is needed in the future and what competence to hire.

Good practices / proposed solutions

Even though each country may not be able to provide enough competent staff for upcoming decommissioning projects, it may be possible to utilise competence across the Nordic countries.

Closer interaction between the regulator and operator can, in addition to improving the regulatory process, also increase the competence of both parties. Work force mobility also helps improve this interaction. It is not uncommon that staff moves from regulator to operator and vice versa.

For the organisations that manage to build a solid competence for decommissioning early, there is a great potential to become a leader within this area.

3.2.5. Safe and effective waste characterization and clearance

Challenges
There will be much more waste resulting from decommissioning than during operation, and there will be (exotic) kinds of waste that have not been characterized before. Radiation characterization is key in all phases of the lifecycle of a nuclear facility, and will be eve more important during decommissioning. When dismantling, a lot of resources are used for characterization of wastes. Characterization plans need to be developed before the start of decommissioning, e.g. to decide clearance levels.

Due to the large amounts of waste, it is interesting to consider reusing parts of the waste. Cleared concrete rubble can be used for instance as filling compound in construction. Conditioning waste for reuse can be challenging and requires that risk is well communicated to the receiver of the cleared waste and to the public.

Effective characterization methods may need to be developed, for instance: how to know the number of samples needed and where to take them, and what is the most effective way of sampling big components such as large concrete blocks.

It is necessary to have a good understanding of the end state for decommissioning and remediation. The site may never be returned to the same clean state as before the activity started, but it can be released from regulatory control. The end state must be well defined.

Good practices / proposed solutions
No solutions or good practices proposed.

3.2.6. Decommissioning strategy

In line with international guidance, in the Nordic countries there is an overall preference for immediate decommissioning, with a few exceptions. The reasons provided by respondents for immediate decommissioning were:

- It is economical due to the costs of maintaining and monitoring during service operation, and it can solve decommissioning in a more efficient way.
- One would lose knowledge and competence if waiting.
- Regulation may change if waiting.
- With immediate decommissioning you may not to make so many modifications later to make the plant “decommissionable”, e.g. modify elevators.

The Nordic cases where deferred dismantling has been chosen are Olkiluoto and Barsebäck. Olkiluoto 3 will operate until approximately 2090, and it has been deemed most effective to dismantle all three units at the same time. At Barsebäck, a deferred decommissioning strategy was assumed due to a political decision.

Ideally, a final waste depository should be ready early, before decommissioning starts. Lack of final disposal may impact the decision on strategy, the decommissioning process cannot be finalised and, hence, cost estimations may be significantly altered.

3.2.7. Nordic and international collaboration

There is a common desire across the Nordic countries to collaborate and learn from each other. NKS is seen as a good forum to share experiences and learn. One can learn different ways of managing an issue. It is good to have new thinking, progress and development in such collaboration. The NKS meetings are seen as a good forum where it is possible to have free discussions. It is more informal than larger international meetings, which means that the participants can quickly get to know each other.

The conditions around decommissioning are different in each Nordic country. Finland is building new reactors, while Sweden is decommissioning. However, there are also similarities. One common issue is that all countries have research reactors that have been or are going to be decommissioned at some point. There is much experience and good practices that may be transferred within this area. Some bilateral agreements exist for exchange of information between organisations in different countries, but for other organisations there is currently less cooperation.

There is also a large body of international knowledge and experience from decommissioning. Much of this is not written down, but can be transferred in the form of meetings and visits. Due to national differences it may however be limited what kind of lessons can be transferred to a Nordic setting. It may not be possible to transfer experiences directly because of differences in legislation, clearance levels and waste management. It may be easier to transfer technical lessons, e.g. techniques or methods for dismantling, characterization or radiation protection, as these will be applicable independently of higher-level requirements of the projects. It may be more difficult to translate experiences to the Nordic countries when it comes to strategic issues, such as waste routes, economic features, or business cases. Guidance level lessons may also be easier to transfer than lessons on a legislative level because it takes a longer process to adapt lessons into the legislations.

3.3 Results from the workshop

The main findings from the questionnaires and interviews were presented and discussed at the workshop in November 2017. After the presentation of the results the participants were divided into groups to discuss the top two decommissioning challenges, i.e. “Development and maintenance of competence and motivation” and “Regulatory oversight and decision making”. The groups were asked to think about enablers and blockers for specific questions related to these two challenges, and to present their conclusions in plenary sessions. The third topic that was discussed was "Learning from other industries". Finally, the participants discussed the topic of Nordic collaboration in a closing plenary session.

Key findings from the workshop are described in the following sections.

3.3.1 Topic 1: Competence and motivation

On the question of **how to retain and develop competence**, one suggested solution was to promote “project carriers” in decommissioning, i.e. project managers who can act as consultants in the organisation to develop decommissioning project competence. Several issues were put forth as potential hinders for competence development; There is often lack of information from the early days of operation, information that can be critical for the safety or efficiency of the project. Maintaining competence over time as staff changes can be difficult, and especially younger staff may be attracted to opportunities in other companies or industries

and leave the organisation. Additionally, security issues may make it difficult to share information.
It was also discussed that there is not only a question of retaining and developing competence, but also attracting new competence, and that there are two general approaches to this question: one is to reduce the original organisation and hire new external competence as needed; the other is to keep a majority of the exiting personnel and maintain a core competence throughout the project. From a regulatory perspective, the core competence is needed in the end of operation and the defueling phase.

It was pointed out that a new emerging issue is that there is a lot of money being dedicated for decommissioning over the coming decades which makes it a very attractive business proposition for people who can sell themselves as decommissioners. Hence, it may not be a problem to attract people, but rather the question may be how to make the judgement that they are offering quality services and value for money? If there is a lot of money available, one may not be inclined to develop "quick & elegant" solutions. There may be no motivation to provide safe but also cost effective solutions.

On the question **how to motivate staff**, one group discussed that decommissioning is not the same threat for research institutes, regulators and consultants as it is for power plants. Outside the power plants, staff may be able to do other tasks in the same organisation. For plant, finding the right motivators for the right groups was suggested as an enabler. The motivators may differ: some want financial incentives, some see mobility as incentive. It was also discussed how to make decommissioning cool and more attractive, e.g. by using the environmental protection angle or stressing the "polluter pays" principle.
A point of discussion was also that motivation may depend on the context, whether the plant to be decommissioned is located in a remote area without other employers, or in a more urban area. Some work groups may also see decommissioning as an emerging field, while others fear for their job.
Finally, one group discussed the role of leadership for motivation; Leadership for normal operation may be different than the leadership needed for reorganisation for decommissioning. When reorganising, leadership is needed to motivate the staff and to inform about what is going to happen, so the staff will know their prospects for employment.
The groups discussed the question of **utilisation of decommissioning competence across Nordic countries.** It was proposed that Sweden could be seen as a model for this, having an already strong network across organisations with open communication. It was also mentioned that some organisations are already speaking to each other across the country boundaries. Another suggestion was to outsource planning work to experienced decommissioning consultants, which could be from other countries. The planning work can be done from the consultant's own location, making it easier to utilise their competence.

The final question discussed under this topic was how to **increase competence through interaction between operator and regulator.** It was suggested that the flow of communication could be helped through having open doors, easy information access and informal meetings. Mobility of staff was mentioned as a way to improve competence; that staff may move from research or regulator to power plants, and back. One other suggestion was that having exchanges with a counterpart for the purpose of competence development (e.g. operator having an exchange with regulator) in a different country might be easier than within one's own country because of the "special" relationship between regulator and operator within a country. Exchange programmes for operators with the regulators in another country

or for regulators with the operators in another country may be easier than within one's own country. It could be possible to do exchange by working on site for a period of time.

Experienced regulators have good knowledge of decommissioning legislation. However, it is not the regulator's role to train people. To overcome this challenge, STUK has established a commercial company (STUK international) offering training for other regulators.

3.3.2 Topic 2: Regulatory oversight and decision making

The work groups were asked to consider whether and how one could more effectively **learn from decommissioning experience**, and use the knowledge gained to refine and further develop regulations for future decommissioning projects. One of the groups described a good practice example from Finland, where regulatory guidelines are sent to licensees for review and comment, so that licensees have a possibility to inform the regulators of their opinions on these before publishing. In Finland, the first decommissioning project will be of a smaller research reactor, which provides an opportunity to test the regulations and guidelines, and the regulations may be updated based on the experience from this project.

When discussing regulation, legislation and decision making, one of the work groups emphasized the need for flexibility in decommissioning legislation. The group stated that if the legislation is too rigid, it can be difficult for licensees to apply the legislation for the specific circumstances of the different plants. At the same time, the legislation must be robust and help to ensure a stable regulatory regime.

One of the groups noted that Norway does not have any commercial reactors and, since is not a member of the EU, has more possibility to adapt regulation and legislation to match the specific needs of the two research reactors. In Sweden, there was an idea originally to develop regulations based on earlier decommissioning projects, but this did not work in practice. Now, the goal is to learn by doing, and to design feedback loops into the process to ensure that experiences from supervision and application of regulations can be incorporated in an on-going basis. The Swedish participants acknowledged that this approach is challenging as they are developing this framework whilst they implement the projects.

It was acknowledged during the workshop that issues are emerging regarding how to apply a general regulatory framework to a specific decommissioning context. The solution is not to change the framework requirements, but rather to modify how these are applied in practice. It is important that there is clarity about the responsibilities of the different stakeholders engaged in decommissioning projects, and that these are clearly communicated to develop and ensure a shared understanding of the requirements, how these may be interpreted and the expectations of the different stakeholders.

The workshop groups were asked to consider how to address the need for a **more efficient regulatory process to handle smaller issues** that may occur during decommissioning projects. One of the groups noted that, when performing decommissioning projects, one tends to set higher standards than for commissioning. It is important to remember that, in decommissioning projects, the risk is being reduced and removed from the site, and so the regulation needs to reflect this.

When considering the question of **how to optimise interaction between the regulator and the operator**, one of the groups noted that both the authorities and utilities are learning in parallel. This could be problematic if the utilities are advancing at a faster rate than the authorities, because then they will have to wait for the authorities to catch up before then can proceed.

In Norway, there are no informal meetings between the regulator and the operator, in order to maintain a strict division between the two. In Sweden, there is an appreciation of the usefulness of more informal meetings (in addition to formal arrangements); these are viewed as an opportunity to avoid misunderstandings and a chance for early identification of potential disagreements. The workshop participants also acknowledged the role and importance of formal meetings for communication and decision making, and emphasized that these should not be replaced. Rather, the informal meetings can be considered a helpful addition and should be encouraged.

One of the groups suggested that using the phrase "optimise interaction" may be misleading (suggesting that existing interactions are not optimal), and instead it may be better to consider how to balance, support or further improve interaction between regulators and operators. It was noted that, in decommissioning, this interaction could be considered more a form of collaboration because both parties have the same goal and interest in the decommissioning project, which is to reduce risk in a safe and efficient way. It is clear that regulators and operators have different roles and responsibilities in decommissioning, and there is good reason for this.

One of the groups described an emerging issue with the relationship between the regulator and contractors/sub-contractors. This can be especially difficult when regulatory tools and guidelines are directed towards operators. It is important to ensure that the work performed by contractor staff meets regulatory requirements. When considering the issue of whether there is a need for new requirements specifically for contractors, one of the groups noted that in Sweden they are already working on this issue because the reality is that there will be more contractors involved in decommissioning projects. The experience of executing decommissioning projects will highlight whether these requirements will need to be further developed in the future, based on lessons learned and experiences from the first decommissioning projects. In contrast, licensees in the UK are considering how to pre-qualify contractors so that certain companies are considered qualified to perform decommissioning work, rather than evaluating companies for individual activities.

3.3.3 Topic 3: Learning from other industries

The work group were presented challenges and opportunities from the petroleum industry related to planning and execution of maintenance work with major accident potential. A concept for integrated visualization of information related to risks associated with a planned maintenance work was also presented and discussed. It was acknowledged during the workshop that there are differences between the two industries, as well as between operation and decommissioning.

For the nuclear domain there is a strong focus on radiation issues during operation. In decommissioning phase however, one must have a more general risk focus as other hazards, which are also relevant for the petroleum industry. For instance, risk of falling objects and fire

must have high focus in decommissioning. General risk analysis methods with hazard logs and hazard definitions become more relevant. There can be other aspects that the nuclear can learn from oil and gas with respect to, for instance, project planning for efficiency and safety. Work permits are used in oil and gas for all kinds of risky maintenance activities, even minor jobs. This may not be an efficient way for nuclear decommissioning.

It was noted that, these are two completely different industries. Oil and gas is a hazardous industry. In nuclear decommissioning we usually don't have storms, offloading people from ships, and heavy machinery issues. The approach presented from the oil and gas industry is more directly applicable to high-risk activities. It may be applicable to some high-risk operations in legacy nuclear decommissioning, but in general decommissioning work will be more focused on smooth implementation of the project rather than avoiding catastrophic failure. The nuclear also has procedures for the high nuclear risk activities.

There are work operations in nuclear decommissioning where there will be elements of health and safety involved, but they are not high-risk fatality issues. Hence, planning tools would be more useful for supporting a smooth project roll-out.

Nuclear decommissioning is a complex project combining radiological risks with health and safety risks to personnel, and one must know where to integrate risk-related information into the planning processes. The transferable practices may be in risk planning and risk communication.

The visual concept can “condense down” what is important and can be beneficial for decommissioning. It can be useful to look at information visualisation in general, not only risk visualisation. In decommissioning such visualisation could also be used to identify bottlenecks to avoid. However, nuclear decommissioning is a different application, and would need a different set of data.

Being able to follow the radiological risks or other risks throughout the process seems useful, as well as linking planning to the potential risks. Use of tools for similar purposes is planned for operational plants; using 3D models, to map high risks to the environment. In risk analysis the focused has been shifted more to uncertainties, the uncertainty of knowledge, for instance. In nuclear decommissioning, we may not know the details of the work and possible way of working in the planning phase. Hence, we need suitable planning processes to handle such uncertainties.

When looking at a certain risk we usually see it from a narrow perspective, and do not see it in from a larger perspective of the surrounding environment and timeline. This may be the same for nuclear decommissioning. We use systems that may give a too narrow view of a system. The more holistic overview of the process is missing.

Support tools used need to provide a different perspective depending on what one is optimising for: risk, availability, or project planning. It would be an advantage to see the link between different activities related to each other.

Aviation has made significant changes that lead to much lower risks, based on an integrated systemic view and giving everyone access to the same information.

Decommissioning involves complex projects where it is important to understand what contractors are doing, and supervise their work with a right balance between trust and control. Could advanced visualisation techniques be used to present different information to different populations? Existing risk models only make sense to those who work with them. Communicating risk needs better visualisation, e.g. communicating to contractors. A powerful aspect of such tools would be to visualise information in different ways, e.g. by using a process view to show simultaneous operations in different places.

The petroleum industry has been focused on occupational risks more than major accident risks. To make such tools work in practice, they would have to be integrated with existing maintenance systems.

3.3.4 Topic 4: Nordic collaboration

The questionnaire and work meetings clearly identified a general need for an informal platform where Nordic countries can exchange more practical experience and work more closely together on specific common issues.

Blockers: The different countries and organisations are in different phases related to decommissioning. There are differences between legacy and commercial projects, and differences in scale and future challenges.

General scarcity and varying maturity of decommissioning experience world-wide has facilitated emergence of a number of international platforms for collaboration and sharing of experience in nuclear decommissioning.

These platforms are available for the Nordic countries too. However, due to differences in national regulations, constrains, and culture, these platforms are mostly taken advantage of for importing general (guidance level) recommendations and good practices from application of specific technologies.

There are many opportunities to share information in different conferences and meetings. Traveling for such events, however, takes time, time that is often not in balance with usefulness and practical applicability of the acquired knowledge.

A Nordic platform for nuclear decommissioning would help tackle some of these issues. Due to closer physical and cultural proximity, and some similarities in national framework among these countries, such a forum would further facilitate development of national capabilities for nuclear decommissioning in these countries. Application of a suitable collaboration form, including well prepared dedicated debates on specific issues of common interest through casual physical meetings combined with application of advanced digital and semantic techniques for information sharing and telepresence could be explored within a Nordic expert group. There could be monthly/quarterly informal video conference meeting with lose agenda, including telling topical news and progress reports.

The Nordic group could have mandate for facilitating sharing experiences from the different countries; training and education of decommissioning experts; share lessons from on-going projects on common specific issues like remote technologies, inspection, etc.

This Nordic group could also have mandate for collaboratively testing new concepts for supporting decommissioning, for instance using digital and semantic technology based approach for **regularity communication and compliance**. The questionnaire responses indicate that the participants believe that there is no detailed regulatory guidance for practical application of legislation to decommissioning projects. The general legislation governing nuclear activities is also applicable for decommissioning and there is typically no need for fundamental modifications to this legislative base to enable application of the regulation for

decommissioning. There is a variation from country to country on the extent to which detailed guidance specifically applicable for decommissioning projects have been developed and/or applied, but in general there is only limited experience with their application to decommissioning in the Nordic region. Therefore, the challenge is not to develop new legislation for decommissioning, but rather establish guidance and procedure for *effective* application of the regulation, and use an iterative learning process with feedback loops for consolidation of the regulatory process through lessons learned from projects. The Nordic platform could help operators and regulators discuss lessons learned and possible improvements through providing an unformal arena and possibly 3D digital visualisation of information relevant for the discussed topic.
It would also be interesting to hear the contractors' opinion, on what they are expecting from utilities and authorities. Could there be a collaboration platform where contractors would have incentive to share information for mutual benefit of utilities and authorities? Contractors produce a lot of extra information when developing plans that would be useful for utilities, but utilities don't have access to that. Could a digitally augmented arena, allowing contactors to demonstrate capabilities to regulators (in terms of compliance with legislation) and operators (in terms of efficiency and feasibility), provide an incentive for contractors to share more information at least in a restricted Nordic group?
It was also mentioned on the workshop that, taking lessons learned from past incidents in the nuclear and discuss opportunities for application in the planning phase could be a good focus for a Nordic collaboration.
The Nordic collaboration arena could support exploring and testing new methods for site/job specific training using a combination of traditional (class-room, physical mock-up, on-site) and digitally enhanced (mixed reality based) training concepts within a closed Nordic group, in collaboration with Nordic training organisations like KSU.
Finally, collaboration on assessment of organisational maturity for decommissioning for Nordic utilities could also be a specific topic for the collaboration arena.

Enablers: There needs to be some existing project and money that gives the opportunity to collaborate.
It is a possibility start-up such a collaboration platform using NKS financing for continuation of this project in 2018. Nordic participation in the OECD Halden Reactor Project (HRP) may provide some opportunities for supporting the start-up and continuation of the platform beyond 2018, by taking advantage of HRP activities and events. Opportunities for long term independent operation of the group will be explored within the next (2018) phase of the project.

References

The following reports and publications were included in the literature study

1. "Nuclear decommissioning, Management of Costs and Risks", European Parliament, Director general for internal policies, Policy department D, 2013
2. "Project Management and Planning", European Commission, Coordination Network on Decommissioning, 2008
3. "Decommissioning of Facilities, General Safety Requirements", IAEA Safety Standards Series no. GSR part 6, 2014
4. "Decommissioning of Nuclear Facilities: Training and Human Resource Considerations", IAEA Nuclear Energy Series, NG-T-2.3, 2008
5. "Managing the Unexpected in Decommissioning", IAEA Nuclear Energy Series, NW-T-2.8, 2016
6. "An overview of Stakeholder Involvement in Decommissioning", IAEA Nuclear Energy Series, NW-T-2.5, 2009
7. "Selection and use of Performance Indicators in Decommissioning", IAEA Nuclear Energy Series, NW-T-2.1, 2011
8. "Planning, Management and Organisational Aspects of the Decommissioning of Nuclear Facilities", IAEA TECDOC-1702, 2013
9. "R&D and Innovation Needs for Decommissioning Nuclear Facilities", OECD NEA, 2014

Remarks

It is important to remember that the findings presented in this report summarise the opinions and thoughts of the questionnaire respondents, interviewees and workshop participants. The findings have not been checked for factual accuracy because the goal of this project was to gain an insight to the experiences and perceptions of the different stakeholders regarding the challenges that they face with respect to Nordic nuclear decommissioning.

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Bibliographic Data Sheet **NKS-R NorDec**

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Abstract
max. 2000 characters

The overall goal of the NorDec project has been to explore challenges related to how decommissioning regulation is applied, and how projects are planned and performed in the Nordic countries, as well as collect best practices and share experiences between the Nordic stakeholders. The contributions for this project came from a wide range of stakeholders, including regulators, operators and contractors, and via the use of questionnaires, interviews and a workshop. The most frequently reported decommissioning challenges were: 1) Developing and maintaining competence and motivation; 2) Regulatory oversight and decision making; and 3) Safe and effective waste characterization and clearance. Workshop participants discussed around identified challenges and possible solutions enabling organisations to build up suitable competence for overcoming these issues. This report presents the results from the project.

Key words Decommissioning, regulation, challenges, lessons learned

Appendix A – NKS NorDec Questionnaire
NKS NorDec questionnaire

Dear Sir/Madam,
You have been invited to participate in this short questionnaire about nuclear decommissioning in the Nordic countries. The questionnaire should take no longer than 5 minutes to complete. In this questionnaire, we would like to find out more about your opinions on the most important decommissioning challenges and how you think these challenges can best be resolved.

All responses will be treated confidentially. We would appreciate the opportunity to talk to you more about your thoughts and ideas on decommissioning in a short follow-up interview. If you are available for an interview, please leave your contact details in the text box at the end of the form. Please feel free to forward the questionnaire link to anyone else in your organization or network that you think might be interested.

Thank you for your participation!

1. Please indicate whether your interest in decommissioning is primarily for legacy or for commercial nuclear sites.

- ☐ Legacy sites
- ☐ Commercial sites

2. Please indicate your level of decommissioning experience.

- ☐ No previous experience
- ☐ 0-2 years
- ☐ 2-5 years
- ☐ 5-10 years
- ☐ More than 10 years

3. Please indicate which country you are based in.

- ☐ Norway
- ☐ Sweden
- ☐ Finland
- ☐ Denmark
- ☐ Other (please specify):

4. Please indicate which type of organization you work for.

- ☐ Regulator
- ☐ Operator
- ☐ Contractor
- ☐ Research
- ☐ Other (please specify):

5. Please indicate the *three* most important decommissioning challenges for you from the following list.
Place a 1 in the text box next to the challenge that is of the most interest/concern for you; 2 in the text box next to the second-highest challenge, and 3 in the text box next to the third-highest challenge.

	Regulatory oversight and decision-making.
	Establishing common legislation and guidance.
	Identification of critical areas of expertise.
	Developing and maintaining competence and motivation.
	Collaboration and information sharing between stakeholders.
	Safe and effective waste characterization and clearance.
	Final waste disposal.
	Inventory control and bookkeeping.
	Establishing benchmarks for costing.
	Planning and management of site modification and dismantling.
	Experience transfer between projects.

6. Please specify why you consider these three to be challenging, and whether they are challenges that you have experienced previously, are currently experiencing, or expect to experience in the future.
Challenge #1:

Challenge #2:

Challenge #3:

7. Which of the following would help to resolve the challenges that you identified? Please specify in which way(s) you think these can help.

Technology development

Further research

Political measures

Internal organizational measures

Financial assistance

Other (please specify)

8. Are there any other major decommissioning challenges that are not listed in question 5 above? Please describe these below, and how you think these could be resolved.

9. Have you developed or identified a best practice for any of the challenges listed above? Please specify:

10. Are you available for a follow-up interview by telephone/Skype to discuss these issues in more detail? If so, please provide your contact information (email and telephone number) below.

Appendix B – NKS NorDec interview guide
NKS NorDec – Interview guide

1. I work in:

☐ Industry
☐ Regulator
☐ Research
☐ Vendor

2. Decommissioning experience / focus:

☐ Legacy
☐ Commercial

3. (If already responded to the questionnaire):

Please describe in more detail what are the main challenges for your organisation now and in the near future

4. What do you foresee to be the main decommissioning-related challenges for Nordic regulators/operators for the next 10 years?

5. What is you experience of interaction between regulator, licensee and contractors within the nuclear area in general? Are there any good practices that should be transferred to the area of decommissioning?

6. Do you have any experience with interaction between regulators/operators across the Nordic countries? Are there any good practices that should be transferred to the area of decommissioning?

7. What are the things that potentially block interaction between these actors, and what kind of tools or arenas can help enable it?

8. Are you currently involved in any collaboration between Nordic actors to share experiences and solve issues? If you are, please tell us more about it. If not, do you have any ideas about how such collaboration can be set up?

9. Are you involved in any other international collaboration on decommissioning? If yes, how could we implement lessons learned into a Nordic setting?

10. Is your strategy for immediate decommissioning or deferred decommissioning? Is this driven by radiation protection optimization, co-implementation of the decommissioning with other nuclear facilities, or the availability of disposal facilities or some other reason? (checkbox)