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International Symposium on Preparation for Decommissioning

Lyon Convention Centre, France
16-18 February 2016

Rapporteur's Report

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BETTER POLICIES FOR BETTER LIVES

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Unclassified **NEA/RWM/R(2016)2**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

English - Or. English

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 35 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission takes part in the work of the OECD.

OECD Publishing disseminates widely the results of the Organisation's statistics gathering and research on economic, social and environmental issues, as well as the conventions, guidelines and standards agreed by its members.

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 33 countries: Argentina, Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Romania, Russia, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission also takes part in the work of the Agency.

The mission of the NEA is:

– to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally sound and economical use of nuclear energy for peaceful purposes;

– to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies.

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

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List of abbreviations and acronyms

AGR	Advanced gas cooled reactor
BAT	Best available technique
BSS	Basic safety standards
BWR	Boiling water reactor
CANDU	Canada deuterium uranium reactor
CEA	French Alternative Energies and Atomic Energy Commission
CNL	Canadian Nuclear Laboratories
CZT	Cadmium zinc telluride
D&D	Decommissioning and demolition
DA	Digital autoradiography
DOE	United States Department of Energy
DTOs	Decommissioning task outlines
DWM	Decommissioning and waste management
EDF	Electricité de France
EPRI	Electric Power Research Institute
FBR	Fast neutron reactor
HLW	Higher level waste
IAEA	International Atomic Energy Agency
JRC	European Union Joint Research Centre
KINAC	Korea Institute of Nuclear Nonproliferation and Control
KINS	Korea Institute of Nuclear Safety
LFE	Learning from experience
LLW	Low level waste
LLWR	Low level waste repository
MCNP	Monte-Carlo-N-Particle
NaI	Sodium Iodide
NDA	United Kingdom Nuclear Decommissioning Authority

NEA	Nuclear Energy Agency
NPP	Nuclear power plant
NSSC	Nuclear Safety and Security Commission
OECD	Organisation for Economic Co-operation and Development
OPEX	Operational experience
POCO	Post-operational clean out
PWR	Pressurised water reactor
R&D	Research and development
SG	Steam generator
SSM	Swedish Radiation Safety Authority
VLLW	Very-low-level waste
VR	Virtual reality
WNA	World Nuclear Association

Acknowledgements

The International Symposium on Preparation for Decommissioning (PREDEC2016) was jointly organised by Électricité de France (EDF), AREVA, French Alternative Energies and Atomic Energy Commission (CEA) and Studsvik in co-operation with the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA).

The programme committee included the following members: Christine GEORGES, CEA, France; Gilles CLEMENT, AREVA, France; Arne LARSSON, Cyclife (formerly Studsvik), Sweden; Vladimir MICHAL, IAEA; Jean-Marie RONDEAU, EDF, France; and Inge WEBER, NEA.

The programme committee was supported by Anders APPELGREN (Studsvik, Sweden) who contributed with his experience from previous workshops held at Studsvik, Sweden to the organisation of PREDEC2016; and by Michael JEANJACQUES (formerly CEA, France) providing secretariat services to the organisation.

Special thanks are due to Christine MARTINEU (EDF) and her team who made extensive efforts in supporting the organisation of the symposium.
Special thanks also go to Gérard LAURENT (formerly EDF), one of the initiators of the symposium.

The symposium owes its success to the active involvement of all participants.

This report summarises the presentations and discussions at the symposium. It was prepared by Karen BECKWITH (Cyclife, United Kingdom), Arne LARSSON (Cyclife, Sweden) and Inge WEBER (NEA) with support by students of the Masters in Nuclear Energy – Decommissioning and Waste Management (École des Ponts et Chaussées/Paris Tech; École Centrale-Supélec and Institut national des sciences et techniques nucléaires).

Introduction

Initiated by two task groups within the NEA Working Party on Decommissioning and Dismantling (WPDD), the International Symposium on Preparation for Decommissioning (PREDEC2016) was held in the Lyon Convention Centre on 16-18 February 2016.

The objective of the PREDEC2016 symposium was to share current practices, experiences and innovations relating to the preparations for decommissioning of nuclear facilities. The symposium was intended to be a forum to

- learn about current practices;
- highlight strategic issues related to radiological characterisation and decommissioning;
- exchange experiences;
- discuss innovative and new techniques and needs for improvements;
- develop and maintain networks in the area of radiological characterisation.

The aim was to bring together operators, regulators, decision makers, scientists, consultants, contractors and other stakeholders.

More than 230 participants from Asia, Europe and North America attended the symposium and discussed diverse issues related to preparation for decommissioning, including general decommissioning strategies, workforce transition, flexibility and knowledge management, relations between the regulator and the industry, and important parameters for efficient and cost-effective waste management.

All presentations and papers of the symposium are available for download at:

www.oecd-nea.org/rwm/wpdd/predec2016/

Session 0 – Introductory session

Session 0 was chaired by Mr Ivo TRIPPUTI (Sogin Italy) and Mr Jonathan LEECH (Dentons UKMEA, United Kingdom).

Sylvain GRANGER – Électricité de France (EDF)

Mr Sylvain GRANGER welcomed all participants to this important and timely conference and presented some key points for the conference and for the vision of decommissioning in the framework of the entire nuclear industry and nuclear energy sustainability.

Électricité de France (EDF) is the main electricity provider in France and one of the biggest companies in the nuclear industry that covers all stages of a nuclear facilities' lifetime: from the conception of new reactors to decommissioning and waste management. In decommissioning, sharing knowledge and expertise between companies and with the public is necessary to ensure acceptance of nuclear power as an energy source. France relies on nuclear for nearly 80 % of its electricity production, but decommissioning and radioactive waste management is still controversial discussed and there are still many challenges left, obstacles to be overcome and solutions to be found.

EDF is challenged by the number of reactors in decommissioning or planned to be decommissioned and by their design differences; this challenge could become a real opportunity to improve techniques and knowledge. In particular Mr Granger underlined that proving that decommissioning can be done safely, efficiently and economically is a key element for public acceptance of the entire nuclear energy cycle. And this can be proved better and better if the decommissioning lesson learnt could be embedded directly into the design of new reactors.

The stakeholder concern could be reduced if the long-term issues related to decommissioning and waste management were solved and the success stories shared publicly. This approach has led EDF to create a new organisation dedicated to these topics.

EDF needs sound long-term solutions available for radioactive waste as it has technical and financial responsibility for the wastes produced during operation and decommissioning (polluter pays principle). EDF deploys treatment technologies to reduce the volume of waste produced and is collaborating with the geological repository for high level wastes project to ensure those wastes produced have a final disposal route. EDF also completes research and development in areas where no current treatment or disposal route exists.

Mr Granger stated that the PREDEC2016 symposium is a great occasion to share the knowledge and expertise across the international community, inspire innovation and build confidence with stakeholders so that the industry is able to successfully manage the nuclear back-end issues.

Vladimir MICHAL – IAEA

The current nuclear worldwide nuclear industry is made up of reactors generating power, research reactors, shut down and dismantled reactors, and supporting facilities such as fuel processing plants, fuel reprocessing plants, waste management and treatment facilities and laboratories. All these facilities will need to be decommissioned when their operational life is finished. There are currently about 160 nuclear power reactors permanently shut down worldwide. In addition, more than 480 research reactors and critical assemblies, and several hundred of other fuel cycle facilities have been shut down for decommissioning, have been undergoing active decommissioning or have already been fully dismantled. Mr Vladimir MICHAL underlined that these numbers show that decommissioning is a current and future challenge.

Decommissioning projects typically involves long timescales and are often full of uncertainties. In order to decrease the risks linked to these projects it is very important to prepare thoroughly for the project ahead. Preparing for decommissioning is one goal of the International Atomic Energy Agency (IAEA) is working on the issue of preparation for decommissioning. By its projects, such as R2D2P and DACCORD (Data Analysis and Collection for Costing of Research Reactor Decommissioning), development of safety and technical guidelines and other activities (training courses, workshops etc.) the IAEA deals with general lessons learnt and facilitate information and knowledge sharing. According to the IAEA, early planning is essential for success along with actions to secure competence and to maintain workforce motivation.

Links: presentation

Michael SIEMANN – Nuclear Energy Agency (NEA)

The Nuclear Energy Agency (NEA) within the Organisation for Economic Co-operation and Development (OECD) is an international organisation that was created in 1958 and has today 31 member countries. Within seven technical committees, 75 working parties and 21 international joint projects, the NEA offers various platforms for its member countries for experience exchange and information sharing on different aspects of nuclear energy, including generation, safety, regulations and radioactive waste management. In the area of decommissioning, the NEA has currently four ongoing projects: decommissioning cost estimation, radiological characterisation, nuclear site restoration and preparation for dismantling and decommissioning. The current decommissioning challenge will grow, as a large number of facilities will be permanently shut down and enter decommissioning in the coming decades.

Mr Michael SIEMANN stated that the decommissioning will become more important than the market for new build of new nuclear power plants. He underlined first that most reactors in decommissioning and the 15 already fully decommissioned are (and will be in the next years) in NEA member countries and in particular in Europe. Worldwide a decommissioning peak (reactors entering into a decommissioning regime) has to be expected between 2025 and 2045 depending on the application of the "life-extension" concept to the fleet of currently operating reactors. From the regional viewpoint, Asia will enter into play of decommissioning expenditures significantly around 2050, and North America will increase its efforts until 2055.

The current decommissioning challenge will grow as a large number of nuclear facilities will be permanently shut down and enter in the decommissioning phase in the coming decades. The NEA supports its member states with a number of task groups composed of selected experts. Two of the task groups, the Task Group on Preparing for Decommissioning during Operation and after Final Shutdown (TGPFD) and the Task Group on Radiological Characterisation and Decommissioning (TGRCD) have initiated the organisation of PREDEC2016.

Links: presentation

Michael MONONEN – Studsvik

Studsvik is a Swedish company founded in 1947 with subsidiaries around the world. The areas of expertise within the company are in radioactive waste management including facility design and physical treatment, consultancy services in decommissioning and other areas, as well as nuclear fuel performance and reactor materials technology. More than 40 000 tonnes of metals and waste from nuclear facilities all over Europe has been successfully treated in the Studsvik facilities during the last few decades.

Mr Michael MONONEN underlined the need of using the experience and the knowledge accumulated during a facility operation, which should be key to minimise and control associated risks. Understanding and managing the whole process from strategic planning up to a de-licensed site and having cost efficient processes with focus on safety and environment are vital for a successful decommissioning. A decommissioning project is a complex project and also a team work. Good and open communication with all stakeholders is as well important in a project that has also relevant social implications.

According to Studsvik experience, he stressed the advantages of minimising the decommissioning resulting wastes by using proper technologies, by recycling and by clearance.

Links: presentation

Guillaume DUREAU – AREVA

AREVA is dealing with decommissioning projects at their own sites as well as for customers in France and on the international market. Mr Guillaume DUREAU stated that the cornerstone of decommissioning is to remember that transitioning from plant operation to plant decommissioning is a deep change and not "business as usual". Surprises are always possible and the project management shall be ready and flexible to cope with them. Key challenges among others are: planning and managing the social transition, prevention and plans for mitigation of disturbances, caused unknowns, and definition of end-state conditions.

Waste management is a central part of a decommissioning project. Larger amounts of waste with more different physical, chemical and radiological characteristics are generated during decommissioning than managed during the operation of a nuclear facility. Strategies for waste management and disposal and implementation criteria should be clear from the outset of a project. From AREVA's experience there is the need to find better and agreed solutions for the treatment, conditioning and disposal of chemical species and mixed waste that currently cannot be accepted by the disposal facilities. Mr Dureau also highlighted the importance of a clear and transparent interface with the regulatory authorities.

Links: presentation

Laurence PIKETTY – CEA

For the Commissariat à l'Énergie atomique et aux énergies alternatives (CEA), decommissioning and waste management are in focus as they are directly concerned by it. Today 22 of CEA's facilities are undergoing decommissioning. These facilities are diverse in size and in type. The objectives and strategy for the CEA is to perform immediate and total decommissioning to reach the green-field state where possible.

The CEA Research & Development programme in decommissioning and dismantling aims to help decrease costs, schedules, dose uptake and waste as well as to improve safety and security. CEA leads

R&D actions and develops expertise in the areas of development of new technologies and tools for decommissioning, improved waste treatment, enable work in a hostile environment, improve initial state characterisation, develop robotics and virtual reality and support reduction of doses to people with dose calculation software.

Links: presentation

Round table – Session 0

Panellists: Sylvain GRANGER, Vladimir MICHAL, Michael SIEMANN, Michael MONONEN, Guillaume DUREAU, Laurence PIKETTY

When should decommissioning preparations start?

The panel was in agreement that decommissioning preparations should start as soon as possible. In the case of existing nuclear facilities at the latest three or more years prior to the final shut down. For new built nuclear facilities, decommissioning should already be considered during the design phase.

What are the main considerations for a good preparation of a decommissioning project?

The panel members agreed that the main considerations for good preparation of a decommissioning project include characterisation, consideration of stakeholders' demands and public acceptance, determining the financial elements of the project, having a well-defined end state and sharing knowledge and experience where possible.

Countries with major nuclear programmes are encouraged to share lessons learnt with countries that have smaller programmes. It was noted that some of these countries do not currently have decommissioning plans which could cause issues at a later date. Nuclear new comers should use existing knowledge and experience of decommissioning during their design phases of their nuclear facilities in order to minimise decommissioning challenges later on in the facility's lifecycle.

Decommissioning starts with strategic planning that builds on information from the facility operations team, inventories, historical documents and characterisation results. It is an iterative process and the plans and schedules need to be reviewed and updated as knowledge and experience is gained or made available.

How does the existence of waste disposal routes effect decommissioning projects?

Having a waste management strategy ready enables sites to advance with the decommissioning programme and identify where there are gaps in waste disposal options. Waste management has a huge impact on the overall schedule of the decommissioning project. The early implementation of characterisation strategies helps to identify which material is suitable for free release and recycling, and thus support waste volume reduction strategies which may lead to cost saving in the decommissioning life cycle. A reduction of radioactive waste volumes requiring disposal by up to a factor of 10 has already been observed. R&D can bring new solutions not considered at the beginning and enable disposal of problematic waste streams.

In France, for example, VLLW and LLW can be disposed of directly. But for HLW, like in most countries, there is no nuclear storage facility yet available. This has led to most sites having to build interim storage facilities, as it was done on a CEA site, in order not to delay the decommissioning programme. Missing or preliminary waste acceptance criteria for the final repositories imply additional complexity and uncertainties for decommissioning.

Communication between producers and radioactive waste treatment facilities is considered as vital to enable optimisation and minimise the handicap placed on either the site or the supply chain.

Waste repository sites are often faced with social reluctances, creating delays in creation of needed disposal facilities and setting of waste acceptance criteria. Sharing of good practices and positive experience with the wider nuclear community may raise the stakeholders' confidence that the industry can manage the waste generated.

How are the non-radiological aspects of decommissioning considered, for instance in the context of preparing reactors for safe store?

Beside the radiological characteristics of the site, it is important to know the real conditions and state of the facilities/of the building(s) to be transferred to a safe enclosure. Supporting systems and physical conditions of the building(s) need to be assessed and possibly improved. Carrying out a characterisation programme is only one main element for gaining information about the plant. A closed information exchange loop between the planning team and plant operators who maintain and look after the plant is also considered as vital.

Attention needs also to be paid to the comprehensive and effective transfer of information about physical buildings and systems as well as radiological properties when transitioning from operations to decommissioning which usually involves a need for shift of mindsets of concerned staff.

NEA Task Group on Preparing for Decommissioning during Operation and after Final Shutdown – Boris BRENDEBACH (TGPFD Chair, GRS, Germany)

The NEA Task Group on Preparing for Decommissioning during Operation and after Final Shutdown (TGPFD) is composed of experts from nine different countries. The objective is to optimise and supply recommendations, share lessons learnt, and to highlight any constraints in the preparation for decommissioning. The work is divided into the four topic areas:

- Regulatory framework and licensing process;
- Decommissioning planning – Selection of strategies;
- Decommissioning organisation and staff management;
- Technical arrangements and practical activities.

The preliminary conclusions are that it is essential to understand the drivers of the project and the targeted end state of the decommissioning project as this will influence the strategy selection. Good site characterisation is imperative, along with a comprehensive waste management strategy and knowledge management. The main challenges identified are related to the availability of final disposal sites, funding and availability of resources, and the culture when transferring from operations to decommissioning. The final report is expected to be published in 2017.

Links: presentation

NEA Task Group on Radiological Characterisation and Decommissioning – Arne LARSSON (TGRCD Chair, Studsvik, Sweden)

The NEA Task Group on Radiological Characterisation and Decommissioning (TGRCD) was initiated in 2010 and is composed of experts with a broad experience from 11 different countries. The aim of the work is to identify the best practice in characterisation during the different stages of decommissioning and to point out areas that could or should be developed further via international co-operation and co-ordination. The work has been conducted in two phases: phase 1 related to overall strategies and general characterisation issues whereas the second phase focuses on facility characterisation from a material and waste the end/state perspective. Several activities have been performed including international workshops and surveys, case studies, as well as the collection and analysis of national and international regulations, guidelines and standards. The first phase of the project was completed in 2013 with the publication of the report *Radiological Characterisation for Decommissioning of Nuclear Installations*. The second phase is ongoing and a summary report is expected to be published in 2017.

Links: paper, presentation

Session 1 – Preparation for decommissioning: strategic issues

Preparation for decommissioning requires several strategic decisions with significant impact on the activities. Session 1 on “Preparation for decommissioning” was intended to cover a wide span of strategic issues such as

- Immediate vs. deferred dismantling;
- Timing and strategic approach for the decommissioning preparations;
- Prioritised strategic decisions in case of a non-scheduled final shutdown.

This session was chaired by Mr Konrad SCHAUER (AREVA, Germany) and Mr Jean-Marie RONDEAU (EDF, France).

Preparation for future defueling and decommissioning works on EDF energy’s UK fleet of advanced gas cooled reactors – John BRYERS (EDF Energy, United Kingdom)

EDF Energy’s nuclear fleet in the United Kingdom (UK) is comprised of 14 Advanced Gas Cooled Reactors (AGRs) and one Pressurised Water Reactor (PWR), all in operation. EDF Energy has the legal and moral responsibility for decommissioning and discharging the associated nuclear liabilities. EDF Energy is committed to returning the existing power station sites to a state suitable for alternative uses and delicenced. EDF Energy Power Station Decommissioning funding comes from the Nuclear Liability Fund (NLF) with any shortfall paid for by the government (UK taxpayer).

EDF Energy has chosen a strategy of early safe store for graphite reactors with all reactors on the sites placed into a safe store state within 10 years after their final shut down, followed by final deconstruction on ALARP grounds to Geological Disposal Facility (GDF). The driver behind the safe store strategy is that waste disposal routes are not available for the large volume of graphite waste (2 000 m^3).

There will be three key phases to AGR decommissioning projects:

- pre-closure transition & defueling of the reactor core during the transition period;
- safe enclosure with site surveillance, care & maintenance that may last up to 80 years;
- reactor building decommissioning & final site clearance at 80+ years.

One hundred years in total will be needed to decommission the AGR fleet and this duration will greatly depend on the availability of waste management routes being available for the graphite waste upon final site clearance. It is anticipated that disposal routes for the higher activity wastes will be available circa 2040 and that the radioactive inventory of the graphite will have decayed to enable disposal as low level waste.

The presence of workers on site during the safe enclosure period will be minimal: the facility will be operated remotely during this period of time. EDF Energy will be responsible for the defueling and decommissioning process with the aim to have a seamless transition. There is a well-developed plan, where a range of factors have been taken into account. The plan is under constant review to ensure that best value for money is generated to maximise the quantity of work that can be completed with the money available in the NLF. The early safe store strategy (which is still a deferred dismantling project) represents Best Available Technique (BAT) and As Low As Reasonably Practicable (ALARP) for dose management.

Links: paper, presentation

Compilation and analysis of national and international OPEX or safe enclosure prior to decommissioning – Paul DINNER (Science Concept International, Canada)

Mr Paul DINNER focused with his presentation on the operational experience (OPEX) gained from the safe enclosure prior to decommissioning of the CANDU reactors fleet in Canada. The current preferred option for the CANDU reactors (Canada Deuterium Uranium, a Canadian-developed, pressurised heavy water reactor) is deferred dismantling, in order to take advantage of three main developments: the decay of short-lived, high-energy gamma radionuclides to minimise occupational dose; the licensing and construction of an available waste disposal facility and the accumulation funds to enable decommissioning.

The choice of a deferred dismantling implies the establishment and the maintenance of an extended safe enclosure, which comes with significant challenges of structural integrity maintenance due to harsh climates on the Canadian lake fronts.

Lessons to be learnt from deferred dismantlement and safe enclosure strategy include management of buildings to prevent deterioration from water ingress and the elements, animal infestation and intrusion, and breakdown/failure of required systems. The suggested measures to mitigate such safe enclosure issues will depend upon the buildings function going forward: Draining of all liquids, removal of all fuel and isolation of systems not required and suitable reconfiguration of those that are should be completed prior to entry into safe store state. Abandoned buildings should be monitored and barriers installed to prevent infestation. Water ingress is to be prevented by reconfiguring the shoreline along which buildings are located and increase stability and group buildings by status to minimise the inspection workload.

In conclusion, mitigation of issues regarding the safe enclosure integrity can be resolved following the application of regulatory guidelines, codes and standards, and using good engineering practices. These include periodic inspections for building during safe enclosure whose frequency is dependent on the speed of physical changes, and a focus on the most vulnerable systems and structures. OPEX is available that should be used to ensure safe stores remain suitably maintained.

Links: paper, presentation

Applicability of the EPRI Decommissioning Pre-planning Manual to international reactor decommissioning – Leo LESSARD (AREVA, United States)

Reactor decommissioning may be represented by a puzzle comprised of the four easy pieces: *Knowledge, Experience, Technology* and *Planning*. Only all four pieces placed together lead to effective planning and ensures an efficient decommissioning programme with a suitable cost control.

In 2001, the Electric Power Research Institute (EPRI) published a *Decommissioning Pre-Planning Manual* in order to develop a framework of 65 key decommissioning activities that have been consolidated into 32 Decommissioning Task Outlines (DTOs) for use as guidance in pre-planning the decommissioning of a nuclear power plant.

The objective was to develop a roadmap linking the 32 DTOs of the manual with the equivalent topics present in the IAEA library of decommissioning knowledge as a cross-referenced matrix in order to be used as a very useful decommissioning planning tool across the industry. This matrix thus has become a communication tool between the United States and other international decommissioning sites to find common ground when working together to develop innovative decommissioning solutions and ensure the safety of nuclear facilities both operational and undergoing decommissioning throughout the world.

Links: paper, presentation

The importance of experience based decommissioning planning – Per LIDAR (Studsvik, Sweden)

Mr Per LIDAR focused in his presentation on the interdependency between technical and management aspects of each step to each other. The planning process needs to define the boundary conditions and end state preference to allow development of strategies to inform an effective plan. It can take several years from initial planning to full site clearance.

Success can be affected by various factors including defining an end state, making decisions on degree of self-performance and not at least defining clear objectives.

Decommissioning of a nuclear facility is an extensive and multidisciplinary task that can be detailed and structured in several major steps, from initial planning and licensing documentation, decommissioning strategy and detailed planning, through defueling of the vessel and management of the fuel, inventory assessment and radiological characterisation of systems, installations, structures and site. Decontamination to lower the radiation level and occupational exposure for workers is undertaken and dismantling of structures before implementation of the waste management plan, building of the required facilities and conditioning of the waste. Demolition of the final structures, clearance measurements and documentation for final site clearance is the final step.

Links: paper, presentation

EPRI project: guidance for transition from operations to decommissioning – Richard McGRATH and Michel SNYDER (EPRI, United States)

The EPRI Decommissioning Technology Programme is comprised of members from Europe, North America and Asia and aims to assist the planning efforts of future decommissioning projects. Mr Michael SNYDER presented the EPRI Transition Project with its three major goals

- To compile country-specific transition period regulations;
- To compile industry transition period operating experience, and
- To provide guidance for the development of a plan to transition from operational to decommissioning status.

Good and careful preparation is a key factor for the success of a decommissioning project. It should take place prior to shut down in an ideal scenario. The main activities of the transition period are cost analysis, preparation of regulatory documents, organisation of human resources and collection of data and information.

In addition, costs are an important issue, as while the planning of the project might evolve the funding will probably remain the same. One of the challenges that project managers have to face is how to decrease decommissioning durations and therefore costs.

Links: paper, presentation

Round table – Session 1

After the five presentations, a discussion was held around the advantages and drawbacks of immediate dismantling and demolition and deferred dismantling. When there are disposal routes available for all waste streams generated during decommissioning and clearance of a site then immediate dismantling is considered the preferred decommissioning strategy. For BWR and PWR reactors immediate dismantling is usually envisaged whereas for graphite-moderated reactors there is no available disposal route for the large volume of graphite waste in Europe, i.e. deferrals in decommissioning are mostly parts of a long-term strategy.

Should decommissioning always wait for the availability of waste routes?

The opinions were divided over this issue. Some members of the panel felt that if there is no waste disposal route and/or no waste acceptance criteria being available to determine how the waste should be conditioned then a facility should be transferred to a safe storage state. in situ storage is considered more appropriate than removal, conditioning, interim storage and the repackaging for final disposal.

Others on the panel stated that decommissioning should drive the development of waste routes to allow final site clearance to be completed as soon as possible after shutdown. Waste should not be packaged in a form that prevents retrieval. Nor should storage impede decommissioning. Global knowledge and experience should be used to determine suitable conditioning of wastes for which there is not a current waste disposal route.

What metrics should be used for decommissioning?

Cost and schedule are usually used to determine success of the project, i.e. whether value for money has been achieved by looking at the work completed in a given time frame against the money spent.

Site characterisation information has a large impact on the schedule. Once characterisation is completed, decommissioning activities can be defined and tailored, such as decontamination, dismantling and waste management. Once a detailed schedule has been produced progress should be measured. Key performance indicators are to be defined to indicate low performance/shortage of resources, problem areas etc.

Session 2 – Early characterisation challenges

There are significant advantages with an early characterisation of a facility to be decommissioned but an early characterisation is faced with constraints, limitations and challenges. Session 2 on "Early characterisation challenges" is open for all approaches and strategies for early characterisation issues, including facility characterisation using theoretical models.

This session was chaired by Ms Sue AGGARVAL (NMNT International, United States) and Mr Thierry VARET (AREVA, France).

Characterisation of solid building structures with NaI gamma spectroscopy – Nadine LIEHR (E.ON Kernkraft, Germany)

After the Fukushima Daiichi accident in March 2011, the German authority decided for the nuclear phase out. E.ON and the University Rostock have jointly developed a method for characterisation of solid building structures NaI gamma spectroscopy. This technique is, according to Ms Nadine LIEHR, efficient in terms of time and material demands as well as being reliable and accurate. It may reduce the cost and time required to complete the dismantling activities.

Since 2013, this method has been approved for use in characterisation activities at the German nuclear power plant Isar 1 (KKI), to allow conditional clearance of material. The InSpector 1 000 system (NaI based) is relatively small and light when compared to other gamma spectrometry instruments making it ideal for the intended measurement setup and for being moved around on a frequent basis in order to characterise a large surface area. One main advantage of this NaI spectrometer is that it operates at room temperature instead of requiring liquid nitrogen cooling as with most gamma spectrometry instruments and reduces the risk of human error during measurements.

The results from this testing method were compared with intrusive samples taken at the same time. The comparison has proven that the characterisation of large concrete structures is accurate, reliable and achieves reductions in term of costs, time and required personnel. Until today, 1 600 tonnes of concrete slabs have been cleared and demolished using this technology.

Links: paper, presentation

Virtual Reality: a way to prepare and optimise operations in decommissioning projects – Caroline CHABAL (CEA, France)

Virtual Reality (VR) is an immersive and interactive experience that displays virtual objects on a screen and uses sounds to place users into a simulated version of an environment. The immersive simulation can use equipment like stereoscopic systems, 3D glasses and joysticks with tactical feedback. The use of VR in a nuclear facility may reduce the costs associated with decommissioning projects and can be used across the whole lifecycle of nuclear plants, from design to dismantling in NPP, such as ITER design, to design new equipment, dose rate and manual operation simulation, and to train future operators and assist them during operation. In decommissioning projects it can enable validation of intervention scenarios, verify accessibility and to train future workers. It provides useful support to engineers in charge of scenario design, by verifying the suitability of equipment for decommissioning tasks.

Since 2009, the Marcoule immersive room has been used to simulate, at a real scale, decommissioning projects including the APM cell 414 and MAR200. The freedom of movement availability based on the location of equipment within the cells to be decommissioned could be tested and validated, with changes made as appropriate.

In the future this technology could be used in augmented reality to provide visual information to operators such as real time dose rate information and operating instructions as a task is being completed.

Links: paper, presentation

Geostatistics for radiological characterisation: overview and application cases – Yvon DESNOYERS (Geovariances, France)

Today nuclear facilities are faced with the challenge of dismantling and decommissioning activities; radiological evaluation is required and the results will affect the cost and dismantling plan. The geo-statistics process can be used to determine the average activity levels, to allow the categorisation of surfaces or volumes and to localise hot spots by exploring data gathered in the field.

The geo-statistical approach uses a deterministic model that uses the input of historical data, non-destructive measurements and laboratory analysis of samples. The aims of this technique are to describe structured phenomena in space with a specific “variogram” varying in time, and quantify global or local estimation uncertainties. From a partial sampling, an estimation of the contamination is calculated, by including interpolation mapping with an algorithm called "kriging". Its benefit is its ability to quantify uncertainty and then to allow for optimisation of additional sampling campaigns to reduce that uncertainty.

Links: paper, presentation

New concepts and instruments for C-14 and Cl-36 measurements in i-graphite – Philippe LE TOURNEUR (AIRBUS Defence and Space, France)

23 000 tonnes of irradiated graphite waste is estimated to be generated from first generation nuclear power plants. In order to dispose of the waste there is a need to understand the activity and isotope composition. This can be achieved through sampling and laboratory measurements by radiochemical techniques and the results correlated to calculations and knowledge of reactor history. Once the waste is defined the choice of methods, tools and means of decommissioning can be selected; this step is key for the design of packages and future storage.

A new technique for the measurement of the Cl-36 activity has been developed which uses the 511 keV energy resulting from the annihilation of the Cl-36 positron. The drawbacks of this gamma gamma coincidence detection technique are distinguishing the Cl-36 positrons from those of other isotopes typically found in reactor graphite as a rare signal from the decay of Cl-36. With a growing number of gamma spectroscopy detectors surrounding a sample the accuracy in the calculation of Cl-36 activity increases.

For the measurement of the C-14, the conventional way of calorimetry but with a new instrument able to lower the usual detection limits was explored with 2 drawbacks: being able to measure very low heating powers and being able to subtract the other isotopes heating contribution. Calorimetry measures thermal output from radioactive decays with instruments being able to detect from 50 µW to 100 mW. An understanding of other beta emitters in the sample is fundamental to remove the heating from these isotopes and obtain an accurate measurement for the C-14. C-14 has a very low thermal output so without great activities in the sample it cannot be detected. Instrument development is ongoing to enable detection of lower thermal outputs.

Links: paper, presentation

State of the art of Monte Carlo technics for reliable activated waste evaluations – Mathieu CULIOLI (AREVA, France), Sylvain JANSKI (EDF, France)

In order to determine waste management routes, AREVA and EDF used a numerical simulation method to calculate the activation by neutron flux of reactor. The AREVA calculation method is based on a Monte Carlo calculation (MCNP) and allows large and different spectrum ranges and localised effects. Hybrid variance prediction methods were developed to decrease the time used in these calculations.

This tool provides inputs for the EDF calculation method. The precision of these calculations for the evaluation of waste against waste acceptance criteria (WAC) is important, as the French Higher Activity Waste vault, ANDRA, requires highly detailed information to enable acceptance of radioactive waste for disposal.

The use of MCNP requires high fidelity source modelling, including detailed geometry modelling and advanced variance reduction methods, as well as an efficient transport and depletion calculation. These methods have been used for many studies supporting EDF's DP2D (Direction de Projets Déconstruction et Déchets) efforts to predict the activities of shutdown 1st generation nuclear reactors. The calculations accurately assess the activities of the wastes generated and the subsequent waste category selected was correct as validated by destructive sampling techniques. This demonstrates the robustness of this methodology.

Links: paper, presentation

Round table – Session 2

How can temperature of NaI detectors be controlled in the area?

It is not necessary to control it.

Can the Virtual Reality approach replace the normal qualification?

Only complex operations are tested by VR and it can replace the requirement for multiple mock-up scenarios to be built. Some operations will always need some real testing.

Comparing level against the threshold, how can geostatistics be used when there are a lot of measurements?

They use matrices, statistical distribution non-linear geostatistics is used due to the shape of the distribution. There are adapted kriging to improve the analysis.

How are non-radioactive substances taken into account for characterisation?

Non-radioactive substances like asbestos need to be characterised. UK waste acceptance criteria include non-radioactive characterisation. Non-radioactive hazardous materials need to be accounted for when considering disposal options.

What is the value and impact of historical information in planning characterisation activities?

Samples are mainly just collected to confirm and validate what was anticipated from historical analysis. Historical data can be a valuable starting point to identify where more information is needed.

What is the best added value derived from the early characterisation?

It may lower the costs of a decommissioning programme.

How and when should early characterisation be performed in areas that are normally classified as inaccessible?

The reactor vessel is considered inaccessible at most times. This is why its characterisation is mainly based on modelling and calculations supplemented by a few samples. Field data is always needed when an area becomes available to validate model calculations.

It was pointed out that when the characterisation objective is not the same, the sampling will not be the same.

What may cause, what are the impacts of and how to tackle an unplanned need for the change of the characterisation strategy?

Collecting measurements, designing a sampling strategy if there is a gap then it is changed in order to avoid surprises.

Session 3 – Workforce transition, flexibility and knowledge management

The transition from normal operation to facility dismantling involves several important evaluations, decisions and actions. Session 3 on "Workforce transition, flexibility and knowledge management" covered project organisation issues like:

- Dismantling by former operators or by specialised teams;
- Concepts for how the transition could be structured to secure that the required knowledge is kept within the organisation
- Ways to achieve the required workforce flexibility for a cost efficient decommissioning project

This session was chaired by Mr Jean-Marie RONDEAU (EDF, France) and Mr Leo LESSARD (AREVA, United States).

Development of a systematic approach to Post Operational Clean Out (POCO) at Sellafield – Alister DUNLOP (Sellafield Ltd., United Kingdom)

The Sellafield site in the United Kingdom is known for its variety of different types of research facilities, nuclear fuel reprocessing plants, as well as nuclear power reactors. Many facilities have already stopped operation. Several more facilities are expected to be shut down within the next 15 years, including THORP (Thermal Oxide Reprocessing Plant) and Magnox reactors, and are waiting to be decommissioned. The United Kingdom has chosen deferred dismantling as decommissioning strategy, i.e. that is to shut down the reactor, remove fuel and residual activity and facilitate decommissioning before placing the facility into a safe state for 20 years before performing the remaining dismantling operations.

The ONR (Office for Nuclear Requirements) and NDA (Nuclear Decommissioning Authority) requirements are that Sellafield plants are subject to Post Operational Clean Out (POCO) directly after operations cease. The primary aim of POCO is to reduce risk and hazard from that plant, but also to reduce the forward lifetime cost of that plant. For Sellafield, POCO programme benefits are also in enabling redeployment of resource and capability.

In recognition of the challenges in the forthcoming 20 years, a systematic approach to POCO was developed. The POCO programme was set up in 2013 with the mission to establish the site standards for POCO preparation to enable Sellafield Ltd. to realise the full benefits by successfully preparing the people and plants for transition, i.e. to ensure that successful transitions are consistently achieved.

A key output of POCO is knowledge, i.e. to create records of the plant configuration and status – and how that status was achieved. These records need to enable and support the safe and effective eventual decommissioning and demolition of the plant.

To implement POCO, a facility post-POCO final end state is to be determined during the POCO planning. For the POCO task delivery, an outage philosophy will be applied. Existing resources will be used for the POCO task delivery, including former operators, existing plant processes, available waste routes and safety case. When necessary, new technologies will be implemented. These POCO tasks will be performed after a significant planning and training phase, with all stakeholders on board.

The goal for the Sellafield POCO team is to organise and perform a successful POCO and to improve how decommissioning plans are progressed in the future. The Sellafield POCO Programme has established a common and consistent approach to POCO at Sellafield. High level strategies and tactics have been set. Co-ordination across the various facilities has started. POCO task delivery is owned by the facility workforce.

Links: paper, presentation

Applicability of learning from experience to Sellafield Post-Operation Clean Out and Decommissioning Programmes – Bertrand YTOURNEL (AREVA, France)

Sellafield Ltd. and AREVA operate, prepare for decommissioning and decommission very unique nuclear fuel commercial recycling facilities. All recycling plants differ in their design and operation history so that transferability of Learning From Experience (LFE), best practices and decommissioning tools and techniques, repeatability of tasks may appear at first less applicable to decommissioning recycling plants than a fleet of reactors. In addition, regulatory, economic and social drivers differ from France to the United Kingdom.

Mr Bertrand YTOURNEL reflected in his presentation the sharing and exchange of experience between AREVA and Sellafield Ltd. that provided significant input to the POCO preparation of Sellafield.

In the following areas, AREVA LFE has been transferred to and applied in the Sellafield POCO programme:

1. Extensive characterisation: The performance of a POCO programme is heavily dependent on detailed and precise knowledge of the initial state of the plant, and subsequent evolution through rinsing operations. An appropriate characterisation plan is necessary and feasible.
2. Waste strategy: In a decommissioning project the waste is about a third of the total cost; that is why an appropriate waste strategy has to be in place early in the decommissioning planning process.
3. Specific safety issues: Once the facility is operated outside of its reference case, the risks and associated safety cases are very different. It is important to maximise how much POCO can be done under the commercial operations safety case. However, a switch from the operating safety case to a decommissioning safety case is considered as mandatory.
4. Competencies, resources and knowledge management: The management competencies, resources and knowledge, and the skills required are different from operation to decommissioning and training is needed to enable the transfer of employees from the operational to the decommissioning phase. It is vital that knowledge of the facility is maintained.
5. Major change in culture: When shutting down the facility and switching to decommissioning, there is a strong need to focus on new and continuously changing references, dealing with unexpected issues and requiring new skills. The implementation of an explicit performance improvement and change management programme as early as possible is highly recommended.

Furthermore, both companies underlined that the end state of the facility has to be defined as soon as possible to organise the decommissioning project.

As conclusion, LFE sharing between operators is considered key to optimise future POCO and decommissioning programmes.

Links: paper, presentation

The turnover process at Chalk River Labs from operations to decommissioning – Paul POTTELBERG (Canadian Nuclear Laboratories, Canada)

Mr Paul POTTELBERG presented the process that is followed by at Canadian Nuclear Laboratories (CNL) to turn over facilities that perform licensed activities from operation to decommissioning by the example of the Chalk Rivers Laboratories (CRL). The CRL site comprises 200 facilities with currently 23 facilities undergoing decommissioning. In 2016, additional 30 facilities are scheduled to be turned over to decommissioning. All licences were transferred to Canadian Nuclear Laboratories (CNL) in 2014 and CNL remains the licence, regardless of the facility state (construction, commissioning, operations, decommissioning. CNL is currently restructuring to transition to a Government Owned/Contractor Operated (GoCo) organisation and there will be a focus to accelerate the decommissioning of legacy facilities resulting in a project strategy change from deferred dismantling to immediate dismantling.

The turnover process follows the following steps:

1. Declare a facility "redundant".
2. Develop a permanent safe shut down state plan (PSSSP): The objective of the transition to a permanent safe shut down state (PSSS) is to place the facility and systems in a condition requiring minimal staffing, maintenance and monitoring to maintain the facility in a safe state and controlling or preventing the release of materials to the environment.
3. Licensing Process for transferring nuclear facility from an operating state to a Storage-with-Surveillance (SWS) or Decommissioning State.
4. CNL internal transfer: preparation of CNL transfer document ("turnover document") & Transfer Certificate.

At CNL there is a need manage the interdependency between buildings and keep facilities operating even though they are connected with facilities which are under decommissioning. The main lesson learnt is to understand the history of the facility (maps, records, maintenance and incidents) is essential for decommissioning and a comparison between the records and physical state should be undertaken as soon as possible.

Links: paper, presentation

Control and maintenance of the Superphenix knowledge and its specific sodium skills through an EDF and AREVA strong partnership – Jean-Claude RAUBER (EDF, France) and Hervé MARTIN (AREVA, France)

The Superphenix decommissioning is a partnership project between AREVA and EDF. Superphenix, located in Creys Malville, France, is the biggest fast breeder reactor in the world at 1 200 MW_e and was shut down after political decision in 1998.

The goal of this partnership is to benefit from the knowledge and experience of the two companies: the knowledge of the Superphenix operator EDF and AREVA as the designer of Superphenix. A key ingredient to achieving success was to ensure that existing local and specific sodium skills were controlled and maintained.

The presence of sodium and a complex primary vessel internal structures as well as numerous interfaces and technical uncertainties meant that a specific skill and knowledge set was critical to successful decommissioning. Feasibility and strategic studies were first completed before on site work activities commenced including sodium draining of the primary vessel in 2010.

This strong partnership led to deadlines being met and budget being kept under control from the beginning, in spite of the numerous difficulties encountered.

Links: paper, presentation

Education and training in nuclear decommissioning – Needs, opportunities and challenges – Pierre KOCKEROLS (European Commission, Joint Research Centre)

In Europe there are 220 nuclear power plants, of which 135 are shut down or under dismantling and only three are fully dismantled. Decommissioning is the last step in the life of a nuclear facility, but it is essential for the credibility of the nuclear field that this step be successfully completed. The goal of the Joint Research Centre (JRC) decommissioning programme is to capitalise on the knowledge in technical, management, juridical, social and economic skill sectors. Even if there is a difference between decommissioning projects, sharing knowledge is possible and fundamental to help one another. Collaboration between countries is essential to learn from prior difficulties and ensure they do not happen on future projects.

The University of Birmingham in association with the JRC have organised a joint seminar to address questions relating to education and training in nuclear decommissioning. Improving clarity in public understanding of nuclear decommissioning will enable an improvement in the image of the decommissioning and the nuclear field in general.

Links: paper, presentation

Round table – Session 3

It was said that decommissioning is the future and that operations will tend to disappear. However, there is no need to oppose operation and decommissioning, as careers can move from one field to the other, because some skills are very similar.

Education is a way to do it. For managers and team leaders it is necessary to identify who would be most suitable for adapting for decommissioning, and those who need to be kept in operation. But this is still in a lead and learn phase.

Education is key, but also there is also a need for communication, job profiling, career paths mapped and building of bridges between the operational and decommissioning organisations.

POCO builds on existing workforce with their knowledge, experience and skills. At the same time, decommissioning needs a change of mind-set. How do we deal with this with the existing operators?

Outage people can be used for the decommissioning of NPP, they are used to working to a budget and motivating people. Outage mentality is in accordance with outage, as for the operators tend to mind breaking things dues to the emotional attachment; thus are not always suitable for decommissioning work. The key is to know your people, because some people cannot be let go due to their knowledge and experience.

How do we ensure that these goals (change of mind-set of operators, aimed POCO end state) can be reached at the end of POCO?

The end state depends on the technologies. POCO is built on a defined end state. Discussions with the regulator need to be done.

How does the international community build experience?

Experiences can be shared; but there needs to be an understanding of where you are sharing experience. The goal is to find a way that all parties will benefit from the sharing of experience.

There are two levels on which experience can be shared; on the dismantling level and on the business level. Co-operation between states can benefit from the sharing of experience.

Previously, experience, good or bad, was not shared so easily between nations. Companies had a tendency to keep things internal. Today, the amount of collaboration and sharing of experiences is becoming more important. Sharing experience has become a standard and an expectation. The goal is to share in order to prevent repetition of failures and to improve.

It is important to create a knowledge centre, but ensure there is still competition between companies in the decommissioning market.

Sharing information is important, but we must be careful not to have too much information creating an information overload and all the disadvantages that come with that.

What is the best way to capture the knowledge of the operators?

The first thing to do is to determine the kind of knowledge that you want to gather and retain. From this, you will be able to adapt the method to gain that knowledge. A way to obtain and retrieve the knowledge from operators is by interviews or to get them shadowed during operations. But the problem is that once you obtain the information it has to be stored and managed.

No matter the method, the opinion of the people will also be provided. There is a need to determine what information is factual and what information is only opinion. Before a worker retires, they should write a testament of their experience and knowledge.

When is the best time to change the management process and go from operation to decommissioning?

It is recommendable to make the change from operating to decommissioning as soon as possible, with the existing operational workers. However, we need to be careful to explain to operators that the shutting down process is not the end, as they will tend to react negatively to the shutdown. The best time also depends on the final strategy chosen for the decommissioning project and whether it was decided to use current operational workers or use new workers.

The planning horizon should be one or two fuel cycles before the shutdown or about 2 - 3 years. This is important because the culture developed in operation needs to be replaced for the decommissioning project as soon as possible after permanent shutdown. There is a need to retain the key operating professionals.

An example from France: there is the concept of zoning in operation, but in decommissioning the zoning is different, it needs to be limited to have the least amount of waste possible. Operators with their comprehensive technical plant knowledge are predestined to change the zoning for decommissioning, but they are less suitable to carry out the decommissioning.

Session 4 – Important parameters for efficient and cost-effective waste management

Session on "Important Parameters for efficient and cost-effective waste management" covered activities in the preparation phase that support an efficient and cost-effective waste management; and how different decisions affect the preparatory activities. Examples of such decisions:

- Clearance or disposal as VLLW and its implication on the preparation for decommissioning activities;
- Optimisation of waste treatment and management of large masses and volumes (balancing On-Site and Off-Site waste treatment, capabilities in local waste treatment center, etc.)
- Radiation protection and sustainability considerations in the planning of the decommissioning.

This session was chaired by Mr Arne LARSSON (Studsvik, Sweden) and Ms Christine GEORGES (CEA, France).

Taking into account dismantling and decommissioning waste in conception and operation phases – Philippe PONCET (AREVA, France)

The characteristics and quantities of waste to be managed during Decommissioning and Dismantling (D&D) phases are highly dependent on the way the facility was designed and how it was operated during its lifetime. Taking future D&D into consideration already in the early design phase of new nuclear power plants as well as during operation becomes mandatory.

There are two aspects that drive the cost and complexity of future D&D operations: waste volumes by categories and occupational exposure while performing the work. In order to reduce such impacts, operators should focus on the following:

- maintain radiological cleanliness of areas;
- segregate the waste by types and waste management routes; and
- provide appropriate plant design provisions for decommissioning and dismantling .

A reduction in occupational exposure has been obtained by a careful selection of specific materials to avoid activation and thus prevent the creation of additional radioactive waste; and by the using screens to reduce exposure.

A specific design and waste zoning concept has led to less than 3 % of the plant area being classified as "nuclear" in the Georges BESSE 2 uranium enrichment plant. In MELOX, innovative nuclear waste management techniques have been implemented to reduce the activity of radioactive waste and shift the category from higher activity to lower activity leading to a reduction in management and disposal costs.

Finally, in the Jules HOROWITZ reactor (research reactor), a specific underwater management for all activated tools and materials has been performed.

Links: paper, presentation

Best practices for preparing vessel internals segmentation projects – Joseph BOUCAU (Westinghouse, Belgium)

In 2015, Westinghouse completed the segmentation of the reactor vessel and reactor vessel internals at the José Cabrera nuclear power plant in Spain. A similar project is ongoing at Chooz A reactor in France. For all segmentation projects, it is essential that all activities are thoroughly planned and a good radiological characterisation is considered to be an important component of the plan.

It is recommendable to start the planning of these dismantling activities at the end of the process by evaluating what type and size of containers are available for the different disposal options and working backwards to select a cutting method and finally the cut geometry required. Segments were made using under water mechanical cutting techniques. In both cases, and especially for old plants, to enable the completion of segmentation, significant plant modifications needed to be considered and implemented for meeting the project goals, including civil work modifications (demolition of an existing wall), new water filtration system, new power supply and new HVAC system (Heating, Ventilation and Air Conditioning).

Before going to the site, testing and qualification are performed on full-scale mock-ups in a specially designed pool. The mock-up testing is an important step in order to verify the function of the equipment and minimise risk on site of a fault or difficulties in using the equipment. Furthermore, operational waste has to be removed and a risk mitigation strategy has to be developed before dismantling operations commence.

Links: paper, presentation

Chooz A steam generators characterisation – Laurie AITAMMAR (EDF, France)

The Chooz A steam generators (SG) were disposed of in a Very Low Level Waste (VLLW) management facility as whole component. This strategy allowed EDF to save time and money by avoiding size reduction and packaging activities.

The SG had been out of use for 20 years. In order to reach the VLLW classification, the SG was characterised and decontaminated. After decontamination, final total activity levels were 2 GBq with the main radionuclide in the steam generators being Cobalt-60. The characterisation was done by external gamma spectrometry measurements, using Sodium Iodide (NaI) scintillation counters. Innertube measurements were taken using a Cadmium Zinc Telluride (CZT) semiconductor probe, which showed different activity levels in the tube bundles compared to the other subsections.

A MERCURAD simulation was used to calculate the transfer functions of each source, detector, and position. The channel head, transition cone, and upper shell had contamination uniformly spread so a simple model was used. The tube bundle required a specific model due to the different activity levels. Uncertainties in measurement, calibration, and within the simulation had to be taken into account; most specifically in the tube bundle. The VLLW category was proven from the combination of characterisation methods used. The results allowed the SG to be disposed of as a single component in the VLLW disposal site.

Links: paper, presentation

Options for Steam Generator Decommissioning – Joe ROBINSON (Studsvik, Sweden)

There are hundreds of retired steam generators (SG) in Europe, all of which must be treated or disposed of in the future. The challenges associated with steam generators include minimising collective dose, handling of such a large item, decontamination, dealing with the tube bundle and minimising the disposal volume.

Five options for decommissioning of SGs have been studied:

- treatment in containment;
- treatment in on-site treatment centre;
- direct disposal of entire component;
- segmentation for disposal; and;
- off-site treatment for recycling.

Mr Joe ROBINSON concluded that all options have pros and cons but considering the circular economy and the waste hierarchy there is a preference for the methods maximising material recycling.

Links: paper, presentation

An optimised cask technology for conditioning transportation, storage up to final disposal of end of life nuclear waste – Gilles CLEMENT, Florence LEFORT-MARY (AREVA, France)

Mr Gilles CLEMENT introduced a new cask for the conditioning, transportation and long-term interim storage of nuclear waste, developed and signed by AREVA. The motivation to design such a flask came from customer concerns surrounding the complexity and cost of current waste management strategies. Customers are required to manage the waste from diverse areas across sites resulting in diversity in the type, volume and activity level of the nuclear waste generated.

Currently there are two approaches for waste management, which are dependent on the country's regulations. The comprehensive strategy for waste conditioning, packaging, and storage may minimise future costs and avoid handling the waste multiple times but leaves an uncertainty in the package being accepted for final disposal. The second approach is to containerise the waste in an interim form until final disposal criteria are defined. This reduces the risk a package will not be suitable for final disposal, leaves a greater range of packaging options open and reduces initial costs. But it leaves uncertainties with the final cost and risks of future repackaging requirements.

This is why AREVA designed the TN MW Cask, a high integrity waste packaging solution for long-term interim storage and transportation that is suitable for a wide range of wastes and allows conditioning at an early stage in the decommissioning process. It allows the customer to avoid multiple handling and reconditioning steps while minimising the risk of the package not being suitable for final disposal.

Links: paper, presentation

Round table – Session 4

Was abrasive water jet technology considered instead of mechanical cutting?

Water jet cutting creates large volumes of secondary waste and require significant preparation. Previous experience at SONG 1 demonstrated it was costly. Common water abrasive cutting method leads to air bubbles and higher pressure leads to particles. Water suspension slicing works well and reduces the amount of secondary waste. A full assessment of segregation techniques was carried out and the use of diamond wire cutting selected.

José Cabrera was shut down in 2006 and the segmentation started in 2010 similar to SONGS 2 and 3. A detailed characterisation and comprehensive knowledge contributed that the challenges of this dismantling activity ahead were well-understood and assessed and in particular how internals needed to be packaged.

Public acceptance on treating foreign waste

Sweden is a licensed facility able to treat waste from outside of Sweden and the radioactivity is then sent back to the country of origin. This is routinely practised.

Where is the interest of decontamination vs not decontaminating?

The disposal capacities are limited and should only be used for that waste which cannot be treated to reduce the volume/activity further. Cost should not be the only driver for preferring direct disposal instead of decontamination. Issues of circular economy and government policy need also to be taken into consideration.

What can be done to speed up waste management and lower its costs?

It depends on the country, but it is recommendable to proceed by dismantling large components as complete units first and treat them in a separate area, if possible.

The waste volume is a big cost driver in terms of waste treatment and disposal. Time and risk are of secondary importance. Many off-site routes would allow programme completion quicker than using on-site treatment routes.

For any decommissioning project, it is important to identify what is driving cost and schedule: Logistics (including bottlenecks), resources, availability of disposition routes, technical problems or other aspects. This makes the choice for a waste management strategy easier.

40% of a decommissioning plan is cost of being at the site, maintaining site operation. 30% is waste and the remaining 30% is cost of dismantling activities. U.S. used to dismantle surgically and now prefer the "rip and ship" method. Decommissioning is expensive with no revenue generated.

Package planning optimised to reduce cost and volume

For activated waste, there is only a low number of canisters available. For cost reasons, the number of containers should be minimised. 3D simulations can help to optimise package use and ensure acceptable for transport and final disposal.

However, a better packaging often involves more segmentation. This is not always purposeful and larger packages should be preferred.

Transport costs are usually not a huge factor. For an optimised result, a transport of large components, such as steam generators or heat exchangers, as a whole may be better since it allows (additional) decontamination in a specialised facility.

Impact of characterisation

Characterisation is important as it influence and drives decisions how material and waste may treated aiming at maximising the recycling of material. Characterisation provides the information needed at the end of process to know what radionuclides are still present. For the transport of items detailed knowledge of the radionuclide inventory is required.

The initial characterisation does not necessarily have to be very accurate. The more important is to implement in line sampling while doing the dismantling work.

In the United Kingdom, the environment safety case and non-radiological characteristics are areas of increasing interest.

At the José Cabrera NPP a database has been established for recording and preserving characterisation data that are also needed to document the contents of each canister. Those data are provided to and used by El Cabril.

Session 5 – Regulatory framework and industry needs

The regulatory framework is one of the most important factors in a decommissioning project. It is vital that the industrial experience and needs are communicated and considered in the development of the regulatory frameworks and in the application of regulatory processes. The overall objective for all parties is to perform the decommissioning phases as efficiently as possible while maintaining a high level of safety. This session 5 on "Regulatory framework and industry needs" was intended to address

- Regulator and licensee views on how the decommissioning process can become more efficient;
- Which activities should be possible to perform after final shutdown and before the decommissioning licence is granted.

The session was chaired by Ms Inge WEBER (NEA) and Mr Henrik EFRAIMSSON (SSM, Sweden).

Characterisation challenges and opportunities – A UK perspective – Matthew EMPTAGE (Environment Agency, United Kingdom)

In 2005, the government of the United Kingdom recognised that there was a significant liability in the nuclear sector as it was managing its radioactive waste but not reducing the hazard associated with it. The scale and nature of the legacy was poorly understood and there was high uncertainty in the knowledge and information that was available. Characterisation plays a key role in the understanding of this legacy, the development of the decommissioning plan, waste management strategy and project cost planning as well as in reducing the risks of the decommissioning projects. Characterisation is also necessary to ensure worker and public safety from radiation and contamination release.

For this reason, the Nuclear Decommissioning Authority (NDA) and the British regulators have decided to undertake a review of characterisation techniques utilised throughout the UK nuclear industry. The review consisted of understanding current characterisation guidance and standards to establish risks and opportunities in the characterisation field. Interviewing industry characterisation experts and academics developing new characterisation techniques allowed the review panel to understand further the challenges and opportunities in characterisation.

In 2015 an industry workshop was organised. During this workshop, the following questions and issues were studied:

- What are the main challenges and opportunities of characterisation?
- How should the opportunities be prioritised?
- What are the needs in terms of resources and workforce?

The results of the workshop are summed up in a table with traffic light colours demonstrating priorities. Sharing and learning is undertaken with the UK involved in international working groups on characterisation topics. Communication between working groups and site operators needs to improve. There is an increased reliance and demand on the supply chain to undertake characterisation work where resources are limited. New techniques need to be developed to enable successful implementation of the waste hierarchy and take into account non-radiological characteristics of the waste that also affect the disposal route. Quality assurance surrounding characterisation is robust with internal audits and inspections completed as well as third party regulator audits. Mr Matthew EMPTAGE ended his presentation pointing out that the characterisation practice review is almost completed in the UK.

Links: paper, presentation

Decommissioning licensing process of nuclear installations in Spain – Cristina CORREA SAINZ (Enresa, Spain)

In Spain, once a facility is shutdown, the licence is transferred from the operator to Enresa; a company whose only activity is decommissioning of nuclear installations. Enresa already has experience in decommissioning having finished dismantling of Vandellòs 1 up to safe store status in 2003 and the current plan is to complete decommissioning of Jose Cabrera in 2018. Enresa is in charge of preparing the decommissioning plan during the transition period but the removal of spent fuel as well as the conditioning of operational radioactive waste is the responsibility of the operator. Once the decommissioning project is finished, the license is handed back to the operator.

The lifetime of a nuclear power plant in Spain is divided into three phases: the operational period (about 40 years), the transition period (3 to 5 years) and the dismantling period (7 to 10 years). The Spanish dismantling strategy is immediate dismantling. During transition the workforce undergoes restructuring resulting in a mix of operators and decommissioning experts. During decommissioning, the safety barriers are significantly reduced and specifically trained workers only should be on site.

The decommissioning licence is made up of a series of documents. A safety analysis report and operating instructions, nuclear safety and surveillance programmes, emergency and security plans need updating. The waste management plan needs to be developed as well as site restoration plans. All of these documents need to be submitted to obtain the decommissioning licence.

Decommissioning and demolition moves from the operating company to Enresa as the risk and work to be completed are significantly different to the experience of the operating company. The people need to adapt to the different lifecycle phase and there needs to be changes to the licence and documents. Co-operation between operations and Enresa is vital and good communication with regulators is important.

Links: paper, presentation

Decommissioning of NPPs with spent nuclear fuel present – efforts to amend the German regulatory framework to cope with this situation – Boris BRENDEBACH (GRS, Germany)

After the Fukushima Daiichi accident, the German Atomic Energy Act was amended: it was decided to stop using nuclear power plants to produce electricity by July 2021. Due to this a large decommissioning program awaits the German nuclear industry and it has been decided by all but two sites that dismantling activities should start with the fuel assemblies still in the cooling ponds and to apply the immediate dismantling strategy. This is not a standard situation and for this reason the regulatory framework needs to be updated. The dismantling and defueling will take place in a phased approach.

- Stage A is to move fuel assemblies into the cooling ponds.
- Stage B is to remove fuel from site but leave behind any defect fuel.
- Stage C is to remove the defective fuel and declare a fuel free site.

Updated decommissioning guidelines have been published in 2015 to take into account the early shutdown of the NPPs as well as the dismantling scenario with fuel in the cooling ponds. In addition, training programmes and education of the staff will be implemented to ensure experience and knowledge of required safety systems stays up to date. The decommissioning guidance links with guidance currently available to manage the transition between operations and decommissioning with no fuel on site. There is no legal hindrance for decommissioning with fuel elements on site but operators should endeavour to remove fuel as soon as possible and ensure that dismantling operations undertaken do not impact safety relevant systems.

Links: paper, presentation

The regulatory framework improvement for safe decommissioning of nuclear power plants in Korea – Sangmyeon AHN (KINS, Korea)

The regulatory body of Korea is comprised of the regulatory authority NSSC (Nuclear Safety and Security Commission) and two regulatory expert organisations underneath, the Korea Institute of Nuclear Safety (KINS) and the Korea Institute of Nuclear Nonproliferation & Control (KINAC). KINS deals with licences, inspections and the development of guides whereas KINAC focuses on safeguard and physical protection activities.

As decommissioning preparations in Korea have started only recently, a focus of the regulatory authorities' since 2015 is on developing and improving a regulatory framework dedicated to decommissioning is being developed and improved. This framework will be very necessary in the future because the first nuclear power plants are due to stop generating in 2017 (KORI 1). In addition, KINS is currently developing guidelines to help the operators preparing their decommissioning project. The NSSC, KINAC and KINS are strongly relying on the IAEA standards to guide the production of the new regulatory framework and guides and they are producing.

Links: paper, presentation

Lessons learnt from application of the Swedish regulations for decommissioning of nuclear facilities – The regulator's perspective – Henrik EFRAIMSSON (SSM, Sweden)

In 2011, the Swedish Radiation Safety Authority (SSM) issued new Swedish regulations concerning decommissioning of nuclear facilities. Major decommissioning activities have been prepared and initiated at three nuclear sites. Several lessons have been learnt by SSM from the application of the regulations and these now serve as input for a revision of the regulations.

Examples of lessons learnt include importance of radiological characterisation, importance of waste management plans, impacts of conventional legislation and international treaties on the decommissioning process and importance of pre-planning by the regulator and continuous dialogue between regulators and those undertaking the decommissioning project.

The current experiences of decommissioning in Sweden have shown that it is difficult to foresee the impact of regulations changes when they are first written. Sweden will be going through an intense period of decommissioning over the next 10 – 15 years. There will be a development of the guidelines and processes as decommissioning is undertaken.

Links: paper, presentation

Legal and regulatory frameworks for decommissioning and waste management – Jonathan LEECH (Dentons UKMEA, United Kingdom)

The NDA (Nuclear Decommissioning Authority) was created and defined in the Energy Act of 2004 for being responsible for the dismantling of the large nuclear legacy that exists in the United Kingdom. A GBP 115 billion fund is available to undertake this decommissioning project that is planned to last for 120 years. An additional GBP 20 billion will be available for the decommissioning of Advanced Gas-Cooled Reactors (AGR). The role of the NDA is as neither an operator nor a regulatory body, but its goal is to give advice and guidance on decommissioning of existing UK nuclear sites. It has control over decommissioning activities and the funds available through a contractual relationship with the licensee.

There are three models for operating nuclear licensed sites within the UK. The parent body organisation utilises a private sector company to manage the decommissioning programme. The private company obtain a fee for the work completed, provide leadership to the site and take on any allocated costs. The market enhanced model utilises partnerships to complete work and finally there is asset sale where the NDA has sold the site and has no further dealings in its running.

Links: paper, presentation

Round table – Session 5

In the context of the development of the Korean framework, in what issues will the framework deviate from the IAEA standards?

The Korean situation and approach takes into account the development of the framework. For example, according to IAEA, a decommissioning plan shall be updated every 5 years. In Korea, an update is planned every 10 years.

Is the cost estimate considered a safety related document and is it reviewed by the regulator?

In Sweden, the cost estimation is reviewed by the regulator but it is not a part of the decommissioning plan.

In the UK, no cost analysis is requested by the regulator. The lifetime plan is updated every year with cost analysis. The regulator's interest is mainly to ensure that funding is sufficient.

In Spain, Ministry of industry and energy reviews the cost analysis.

In Germany, the Federal Ministry or Economic Affairs and Energy reviews cost analysis but it is not a safety related document.

In Korea, the cost analysis is described in the decommissioning plan and thus is reviewed by the regulatory body.

How much flexibility should be allowed in the regulatory framework, to take feedback into account?

Deregulation with respect to decommissioning should be considered as radioactivity being removed. This involves the question what level of regulation is (still) required? Perfect stability of the regulatory framework is not recommended as there needs to be flexibility to respond to different risk levels during the different stages of decommissioning. Demonstration of reduced risk needs to be made by operators to enable reduction in regulatory involvement.

A flexible framework is needed as strict regulation is a problem during decommissioning as the risks in decommissioning projects continually evolve. Need rules but not too many. The regulator should not be too restrictive to enable flexibility in decommissioning projects. Good communication between the regulator and operator is considered as essential in this context.

Session 6 – Good examples and lessons learnt in preparation for decommissioning

Session 6 on "Good examples and lessons learnt in preparation for decommissioning" focused on feedback from decommissioning preparation activities including experiences of transition between the operating phase and the start of dismantling.

The session was chaired by Mr Vladimir MICHAL (IAEA) and Mr Michael KNAACK (TÜV Nord, Germany).

Decommissioning planning for the Oskarshamn Site – Niklas BERGH (Westinghouse, Sweden)

The Oskarshamn site (OKG), located on the south-east coast of Sweden, has 3 operating Boiling Water Reactors (BWRs). In October 2015, it was decided by the majority owner E.ON to shutdown OKG unit 1 and 2 earlier than initially planned (2016 and 2017). One of the challenges that this unplanned shutdown entails is to obtain the regulatory approval of the necessary documents within short time frame which allows defueling, shutdown and decommissioning operations to commence.

In order to start the pre-decommissioning planning immediately, a decommissioning project with focus on preparatory activities has been initiated. Strategic decisions have to be taken and prioritised. The organisational model needs to be defined in order to select staff that will remain for decommissioning operations and contractors required. The pre-decommissioning planning also considers the waste management strategy as this will drive dismantling and characterisation activities. The final repository for decommissioning wastes in Sweden is under construction and foreseen to be ready by no sooner than 2027. The lack of final disposal site constitutes a challenge for OKG as interim storage capacities for the decommissioning wastes generated need to be made available. Finally, OKG is also facing the challenges of managing a site with two units in decommissioning and one unit still in power operation as the risks and nuclear safety of the plants are considerably different.

Links: paper, presentation

Influence of decontamination – Michael KNAACK (TÜV NORD, Germany)

Decontamination is performed in order to reduce radiation exposure, to remove contamination from the site allowing for release from regulations and to decrease the amount of radioactive waste generated during decommissioning. All decontamination methods and techniques remove contamination from materials and concentrate the activity in a smaller volume. The secondary waste requires disposal as radioactive waste but the decontaminated material may be suitable for unrestricted or restricted release or be of a lesser radiological waste category than before decontamination. Experience from German decommissioning projects has shown that the costs for decontamination for clearance of material are less than for treatment and disposal as radioactive waste.

The largest masses of materials arising from decommissioning projects are concrete and building rubbles. For concrete after clearance, there are several options available and possible in Germany:

- landfill (conventional waste site);
- road construction;
- new buildings constructions.

Full System Decontamination (FSD) plays a major role in every NPP decommissioning project and is a very powerful kind of decontamination. Typical decontamination factors (dose rate prior to decontamination vs. dose rate after decontamination) are between 10 and 75 (in some cases up to 100). But the number of influence factors is various, for example FSD operation, the material, the surface, the decontamination fluid flow. Because of the high cleanout effect of FSD, the radiological characterisation activities for waste management and clearance is to be started after the FSD. The possibility of shifting the nuclide vector must be considered.

However, in general, radiological characterisation should start as early as possible as it is necessary for the planning of the dismantling and decontamination activities. Characterisation data inform planners about the amount and type of contamination present. Any kind of decontamination will influence the nuclide distribution and the isotope vector. This will affect the estimation coefficient for nuclides present but not easily detectable. It is necessary to have a concept of radiological characterisation that includes facility history and the waste management aims that also takes into account the risks of shifts in the isotope vector because of the decontamination method chosen.

Links: paper, presentation

Feedback from D&D projects – Improvement through preparation – Alexandra SYKORA and Uwe ARNOLD (AREVA, Germany)

AREVA's learning from experiences at all stage of decommissioning projects can be summarised into four main points:

1. Build a strong and specific decommissioning team: To achieve this, collaboration is needed between existing operatives and new decommissioning team members. In the decommissioning team, the knowledge of the former operators is essential in order to understand the plants history. This also provides perspectives for the former operating staff. But also strong alliance of customer, contractor and (local) sub-contractors is needed from the very beginning.
2. Prepare a thorough radiological characterisation concept covering a complete initial characterisation but also a real time characterisation. Characterisation is a key activity of the post-operation phase. The characterisation of the plant should be completed at an early stage but verified repeatedly during all dismantling operations by the taking samples and completion of surveys.
3. Develop a tailored decommissioning manual streamlined from the operation manual but taking advantage of source term and risk reduction. The decommissioning manual shall be written in an open and flexible way, address simplifications, standardise as far as practical (same degree of details, high level) and ensure that the decommissioning project is prepared for the unexpected. It is intended to replace the plant operation manual.
4. Replace existing operation support systems with module and lighter system to accelerate the decommissioning.

Links: paper, presentation

Benefits from R&D for D&D preparation – Christine GEORGES (CEA, France)

The Commissariat à l'Énergie atomique et aux énergies alternatives (CEA) is both an operator and a research organisation. As an operator, CEA is in charge for the decommissioning of currently 22 facilities that are diverse in size and in type without a series effect.

CEA's R&D programme has two main purposes: optimising R&D activities in support of clean-up and dismantling programmes in order to reduce the cost, duration of the work, the doses incurred, and the amount of waste produced; and developing and promoting R&D and expertise by sharing R&D developments, providing expertise and developing industrial partnerships.

Innovative solutions and expertise are being developed in six main areas:

- Work in hostile environment: in some extreme conditions with a very high dose rate innovative solutions have to be found to be able to complete the decommissioning safely. Techniques such as robots and tele-operated equipment, remote cutting processes by laser, 3D cartography and development of virtual reality to validate and optimise scenarios have all been used in order to reduce the dose absorbed by the workers.
- Overall facility characterisation: Sampling operations and in situ characterisation are necessary to assess the initial radiological state. This crucial step also helps to anticipate the needs for R&D in D&D projects and so reduce the cost of the dismantling in the end as possible difficulties are discovered at an early stage. The development of gamma cameras to avoid sampling increases the safety of the workers in high dose rate areas.
- For waste characterisation, the CEA has developed neutronic measurement (non-destructive analysis).
- Structure and soil decontamination: CEA has also developed new technologies for decontamination to adapt to complex geometries and materials and to reduce effluents generated.
- Methods and IT tools, for example for project and waste management.
- Waste treatment and conditioning solutions such as developing efficient treatments for complex radioactive wastes (mercurial, sodics, Mg from cladding sludges, graphite, other legacy waste, etc.).

In her conclusions, Ms Christine GEORGES underlined that R&D needs to be involved from the very beginning of a decommissioning project in order to optimise the efficiency of R&D and not only when a project is already faced by an issue discovered during dismantling.

Links: paper, presentation

Round table – Session 6

What was the impact of the anticipation of shutdown date of OKG on the funding?

This is still being evaluated. The Swedish authority might propose increase of funding.

It is important that we share knowledge: how can small companies learn about recent or ongoing research and development activities?

PREDEC2016, as a medium-sized conference, serves the direct exchange of knowledge and lessons learnt. There is a broad understanding of the important role of the IAEA and NEA to offer and organise opportunities for international experience exchanges, information sharing and co-operations in R&D for decommissioning.

All interested vendors, companies and organisations, either small or of large size, are invited and encouraged to participate these exchanges.

Should we collaborate in advance before sharing experiences once decommissioning is complete? Identifying the needs for learning and sharing in advance.

Financial people manage the fund and engineers develop the necessary systems and equipment. There is poor connection between people who are managing the money and the ones who use it.

Some companies are reluctant to share information and experience with competitors. In particular regarding to decommissioning cost estimation, companies do not want to publish data as they may contain commercially sensitive information.

To enable sharing, small contractors need to be invited and represented at events like PREDEC2016.

What are the areas of improvements of the decommissioning field in R&D?

In general, R&D activities and improvements can be observed in all areas of decommissioning a waste management. R&D topics included, for example, waste inventory measurements, characterisation or developing faster decommissioning tools, such as simple, safe and reliable cutting devices.

How is a graded approach applicable to nuclear facilities; regulator view point?

In the Slovak Republic, a graded approach was effectively used for small (historical) experimental waste management facilities at the Bohunice site in comparison with the major decommissioning project of Bohunice A1 NPP.

How much of the decommissioning budget should be dedicated to post-operation activities?

It depends on facility and country but also strongly on the availability of waste routes and may be about 10 to 15 % of the decommissioning budget. In any case it is considered as very important to ensure that sufficient budget is available to be spent on planning and preparation for dismantling, a main prerequisite for a smooth decommissioning implementation phase.

For example at the UP1 reprocessing plant in Marcoule, completed characterisation was performed during dismantling instead of before. This led to a late discovery of plutonium inside the facility what caused a delay of 10 years in the decommissioning project. This illustrates the importance of early plant characterisation as one major preparatory activity.

However, it was also noted that safety of workers and environment has always the highest priority and any cost issues are of subordinate importance.

Session 7 – Best practices in characterisation of material and waste

There are many good examples in radiological characterisation of material and waste. In session 7 on "Best practices in characterisation of material and waste", leading experts shared their experiences in characterisation including the benefits the conducted characterisation activities have resulted in.

This session was chaired by Mr Yvon DESNOYERS (Geovariances France) and Ms Hélène DENIAU (Studsvik, France).

How digital autoradiography technique can be useful for D&D projects? – Pascal FICHET (CEA, France)

Radiological characterisation is essential in order to determine the type, quantity and allocation of contamination. Different techniques including destructive and in situ methods have been developed to enable radiological characterisation. Methods for measurements of radionuclides that are difficult to detect, such as C-14, H-3 or I-129 in decommissioning projects, have been developed.

Mr Pascal FICHET introduced the Digital Autoradiography (DA) technique which enables high and low energy radiations to be detected visually and two-dimensionally. The camera is a scintillator-based radiation detection system that images and identifies charged-particles. It employs high-performance computing software for real-time imaging and activity quantification. Single-particle digital autoradiography of alpha emitters has advantages over classical sampling techniques in terms of sensitivity, spatial resolution as well as capability of activity quantification. This technique allows measuring of the radionuclides emitting alpha and beta, which are hard to observe and characterise accurately in materials and waste. Only 20 % of the measurements of the material or waste are required to obtain a classification of the contamination level on the totality of the surface with a minimum risk of incorrect classification.

Links: paper, presentation

Best practice on facility characterisation from a material and waste end-state perspective – Matthew EMPTAGE (member of TGRCD, Environment Agency, United Kingdom)

The Task Group on Radiological Characterisation and Decommissioning within the Nuclear Energy Agency (NEA) aims to understand best practice in relation to facility characterisation during decommissioning activities. Furthermore, it emphasises the importance of international co-operation and co-ordination in this subject area in order to lead improvements in radiological characterisation for decommissioning projects. In order to draw on the wide practical experience of international experts and understand characterisation good practice, the survey gathered knowledge and experience from operators and regulators. The survey was is in the form of a questionnaire, which gathered knowledge of characterisation.

The sections of the questionnaire to gather views on best practice included questions on the objectives in overall characterisation plans, use of archives and historical radiological inventories of the facility, implementation, data evaluation, using judgement and probabilistic approaches, how these are selected on case by case, quality assurance using independent expert review of results and the storage of records.

34 responses from operators and 19 responses from regulators were received from 12 different countries including Europe, Asia and North America. The survey report "Radiological Characterisation from a Material and Waste End-state Perspective: Evaluation of the Questionnaire by the NEA Task Group on Radiological Characterisation and Decommissioning Intermediary Report" is available on NEA public webpage.

Links: paper, presentation

FIR 1 TRIGA activity inventories for decommissioning planning – Antti RÄTY and Petri KOTILUOTO (VTT Technical Research Centre, Finland)

For the decommissioning plan, it is essential to estimate the activation level of a structure for planning the interim storage and the final disposal of waste requirements as well as packaging systems needed. The TRIGA Mark II type research FiR 1 reactor has been in operation in Finland since 1962. During its history FiR 1 has been used for training, scientific purposes, and isotope production. The reactor was permanently shut down in summer 2015 and will be decommissioned in following few years.

Neutron flux distributions were modelled in detail and calculated with Monte Carlo code MCNP (Monte-Carlo-N-Particle) which is routinely used for determining criticality and uses geometry of a defined cell and calculates flux of neutrons. When neutron flux rate distribution is calculated by MCNP, activity inventories of different materials such as concrete, graphite, steel, aluminium, and Fluental have been calculated by ORIGEN-S point depletion code. This code considers the irradiation history based on actual use of the reactor: Activation of concrete has occurred around the core and beam tubes whereas steel and aluminium were used as a material of irradiation ring and thus been activated differently. Fluental is a neutron moderator that causes the production of H-3 due the reaction of Li-6 with neutrons.

Calculated total activities are Co-60 dominated for concrete, steel and aluminium and H-3 for the moderator. Total activity is estimated at approximately 39.5 TBq. The results of the calculations include uncertainties due to assumptions on material compositions and possible diffusion of gaseous nuclides. The main uncertainties are due to activation of small impurities in the materials used and the operational history of the beam tubes.

Links: paper

Characterisation and clearance of M/S SIGYN – Jonatan JISELMARK (Studsvik, Sweden)

M/S SIGYN was operated by SKB of Sweden for transport of nuclear fuel and radioactive waste for nearly 30 years. The ship has now been replaced. M/S SIGYN weighs 2 044 tonnes. In order to estimate the activity and determine the clearance level on characterisation steps had to be completed prior to decommissioning activities taking place. The materials transported through the years were analysed and the likely nuclide distribution derived from this information.

Detector effectiveness for scintillation detectors was calculated using the nuclide distribution. Hotspot detection is considered a risk during decommissioning of a structure. A hotspot value was calculated and used to scan the ship. Once hotspots had been eliminated, surfaces and components on-board the ship were categorised by risk for contamination being present. The number of measurements taken was correlated against the risk; the higher the risk of contamination being present the more samples were taken. Random measurements verified that contamination had a Gaussian distribution and an upper credibility level for the contamination present of 95 % was given using Bayesian statistics. The calculated activity at 95 % confidence level was used for every proven homogenous unit and compared to clearance levels. The result was that the entire ship was cleared as is.

Links: paper, presentation

Round table – Session 7

There can be a big impact of averaging over areas when applying geostatistics. How was the issue of resolution tackled?

Thirty screens used in each area to enable statistics to be applied once results are generated. The issue of resolution and how to resolve it depends on what the objectives of the characterisation are. The results can be used to show fine geo-statistical detail or average screen results to show hotspot location.

Poster Session

Poster No. 1. The strategic challenge of capacity for German decommissioning – Barry MOLONEY (NSE international nuclear safety engineering, Germany)

After the Fukushima accident, Germany has taken the political decision to reduce and eventually to stop its nuclear power plant operations. This means that 22 nuclear power plants will undergo decommissioning operations in the near future. The strategy chosen is immediate dismantling and the operations will begin in 2017. The decommissioning programme is expected to go on for 25 years, with peak decommissioning in the mid-2020s. The decommissioning costs are expected to create a EUR 30 billion market.

From these figures it is clear that this market has a lot of potential for service providers to provide cost efficient and effective decommissioning methods to reduce waste volumes, dose uptake to workers and decommissioning time scales and there is great potential in term of employment and the subsequent benefits that brings to an area. Germany faces strategic constraints and challenges, the main one being law suits against the government over the decision to shut down all plants. There are challenges in waste disposal, cash flow of the operator, licensing, procedures, and self-performance of decommissioning.

Links: abstract

Poster No. 2. Releases at EDF nuclear sites undergoing decommissioning – Benoît CLAVEL (EDF, France)

Currently, EDF owns 9 shut down reactors that need to be dismantled. They are of 4 different designs; natural uranium graphite gas, fast breeder, heavy water reactor and pressurised water reactor. In order to be able to decommission these facilities, EDF has to ask for the authorisation of the Nuclear Safety Authority (NSA), by sending an application which contains a large number of documents and data. Among these documents is the Environmental Impact Assessment (EIA) which describes the procedures that will be applied to monitor the waste and determine the environmental impact from the decommissioning. The impact on the environment is limited due to the application of Best Available Techniques (BAT) and controlled via the use of discharge limits (gaseous and aqueous) by the regulator. These discharge limits enable EDF to release only very small quantities of radionuclides into the environment near the facilities. A number of specific radionuclides are taken into account in the studies for the discharge limits. The radionuclides which are of concern include C-14, noble gases and alpha emitters. The discharge of radionuclides depends on the dismantling step and the required authorisations are requested for the dismantling scenario. The most recent authorisation was released in 2015 for Saint-Laurent A NPP.

Links: abstract

Poster No. 3. LIBS probe for in situ material characterisation – Nadine COULON (CEA, France)

Characterisation is one of the most important but one of the more difficult aspects of the planning phase for decommissioning. This team has created a portable probe to perform in situ material characterisation. The LIBS (Laser Induced Breakdown Spectroscopy) technology is the spectroscopic analysis of the plasma emission produced by a laser focused on the surface to be characterised. The device consists of a laser and spectrometer that are connected by two optical fibres. The spectrum of the chemical element and the concentration measurement can be recognised as each material has its own spectrum. By this principle all chemical elements in any physical state (solid, liquid, gas) can be detected. Other advantages in using LIBS include no sample preparation being required and it gives real time measurements. It can also be operated remotely which will allow material characterisation in areas of the nuclear facility with limited access. Tests were successfully performed to detect surface contamination at CEA Cadarache during the decommissioning of a building.

Links: abstract

Poster No. 4. Applying Freeze Technology for characterisation of liquids, sludge and sediments – Jens ERIKSSON (Studsvik, Sweden)

During a decommissioning project an activity is to perform characterisation of a contamination area to meet the objectives of the decommissioning plan. Accurate characterisation can have a positive impact on the cost and the schedule of the decommissioning project going forward. For radiological characterisation a sampling technique is used, but this can result in some disturbance or spreading of the contamination.

Studsvik's Freeze Technology has been used for environmental characterisation and remediation applications. The technique has been developed so that the radioactivity is contained and to limit the risk for cross contamination. This technique is used to develop a 3-D map of the physical, chemical and radiological characteristics of the contaminated area.

For many projects, this type of information will allow for a large reduction in the dredging/remediation activities required, having a positive impact by reducing the overall amount of material that must be disposed. The same technology can be used across a variety of scales to accurately remove contaminated fractions with essentially no cross contamination to surrounding material.

Links: abstract

Poster No. 5. Decontamination with wet blasting of components in nuclear power station for service or free release – Per FAGERSTRÖM (Fagerström Industrikonsult AB, Sweden)

It is important to understand how contamination bonds to surfaces in order to choose an effective method for decontamination. The principle of decontamination of components is to enable conditional or free releases of materials.

A protective oxide layer is formed on steel surfaces in contact with the reactor water. This oxide layer is constantly growing in thickness which makes it more likely for radioactive particles to become part of the surface. Contamination is lower on cold system surfaces than on the hot surfaces because of the slower corrosion rate. An effective method to decontaminate components is wet blasting with glass beads or aluminium oxide for more effective peeling. This method has been compared to other methods and it has been concluded that it is a fast way to decontaminate components. The oxide on the metal surface is removed by the pressure shock of the water-cushions around the beads. The contaminated waste from wet blasting is collected either in the water treatment plant or in the blasting media. Wet blasting is an effective tool in order to decontaminate steel surfaces, with a low volume of secondary waste produced.

Links: abstract

Poster No. 6. Behaviour of C-14 in irradiated nuclear graphite waste: consequences for inventory, decontamination and disposal – Nicolas GALY (Université de Lyon – EDF, France)

The poster described the behaviour of C-14 and N-14 (one of C-14´s precursors). Transmutation and activation are the two main C-14 productions paths; the predominance of one reaction over another depends on the nitrogen content in the graphite.

Analysis was made by implanting C-13 into virgin nuclear graphite issued from SLA2 reactor and in some cases into model graphite such as HOPG. N-14 implantation was also carried out to simulate its presence. The different parameters studied were the effect of temperature and irradiation on mobility; the effects of radiolytic corrosion on N-14, and C-14 release at the graphite/gas interface.

During the research it was concluded that thermal annealing does not induce any migration of C-13 up to 1 600°C. Moderate electronic excitations and ionisations do not promote C-14 release. Finally, they found that in absence of methane, when the free radicals formed through gas radiolysis are produced at the gas/heated graphite interface, the radiolytic corrosion of the graphite surface proceeds, leading to a loss of the C-13 or N-14 implanted close to the interface. The results were extrapolated to the behaviour of C-14 showing that nor UNGG reactor temperatures nor irradiation seem to favour C-14 migration release.

Links: abstract

Poster No. 7. Nuclear measurement device: Piloting aid for highly radioactive deposit retrieval operations – Florence GOUTELARD (CEA, France)

In nuclear decommissioning, it is essential that the waste obtained and packed from retrieval operations satisfies the transport specifications and the waste acceptance criteria of the facility it is destined for.

In order to check compliance two characterisation steps were put in place using a nuclear measuring device. The first step concerns the deposits in the metallic container, measurements with two STTC probes (gamma equivalent dose rate measurement), one at the top and one at the bottom of the package, were performed to determine the isotropic nature of the container and to make sure that the value for each isotope did not exceed a threshold. The second step was to perform three in situ gamma spectrometry measurements. This way a transfer function was obtained by digital modelling and simulations to know the number of photons detected in the waste.

With this measurement device, waste was retrieved and packaged in accordance with the ANDRA waste acceptance criteria and transport regulations.

Links: abstract

Poster No. 8. Preliminary identification of contaminating; α- and β-emitting radionuclides in nuclear installations to be decommissioned through digital autoradiography – Raphael HAUDEBOURG and Pascal FICHET (CEA, France)

Digital Autoradiography is a non-destructive characterisation technique sensitive to all types of radioactivity. This technique is particularly efficient with alpha and beta-emitting radionuclides (including alpha and H-3 or C-14 emitted beta). It is composed of flexible sensitive phosphorescent screens that are put in contact with a radioactive sample or area and a detector to read the sample. Various nuclear samples can be analysed (wastes, blocks, rubbles) to preliminary check for contamination, evaluate contamination location, homogeneity and activity. Digital Autoradiography technique efficiency in real world situations has a precision of approximately 10 %. It does not involve nuclear material transportation, nor requires operators' presence during signal acquisition. Screens can be reused around 100 times so the analysis produces very small volumes of waste. Recent studies show the technique can provide identification of the radionuclides in a sample by analysing the decreasing signal coming from a stacking of several screens. A method has been developed to scan all the screens in a stack in only one run to shorten analysis duration.

Links: abstract

Poster No. 9. Validation of numerical simulations of activation by neutron flux – Sylvain JANSKY (EDF, France)

EDF DP2D (Direction de Projets Déconstruction et Déchets) has developed a calculation scheme to calculate radioactive inventories using MCNP (Monte-Carlo-N-Particle), which solves the Boltzmann equation. The nuclear database which takes into account the cross sectional areas. In the code-file the geometry is defined, the chemical composition and neutron sources. The output obtained is the neutron flux. DP2D then uses Darwin's code to solve the equation and provide a history of irradiation. These codes calculate the radioactive inventory; allowing an estimation of waste classification to be provided. The calculated code can be compared and validated using measured values.

The DP2D team made a comparison between Chooz A (300MWe Pressurised Water Reactor) calculated and measured values on the site. The results showed that the calculation scheme slightly overestimates the radioactive inventories, in particular of Fe-55 and Ni-63. The results linked with minor chemical elements or impurities allowed to validate the use of the average measured compositions. The overestimation is deemed acceptable as it did not change the waste classification. The calculated codes are important to provide an estimate of the waste classification. This tool will be able to quickly and efficiently give the radioactive inventories and allow for fewer samples to be required therefore cutting down time, cost and dose uptake.

Links: abstract

POSTER No. 10. Footprint reduction: Strategy and feedback of the Dutch historical waste management programme – Gaël MÉNARD (Nuclear Research and consultancy group, The Netherlands)

There is a volume of historical waste within the nuclear industry where information regarding the provenance and radiotoxicity of the waste is not known.

In 2007, in order to tackle the historical waste issue, the Dutch launched "the historical waste programme", in order to remove this waste stream from Petten to the Dutch central radioactive waste storage facility, COVRA. Within this project, 1 700 legacy drums shall be treated, sorted and sent to the repository.

The goal of this project is to characterise the drums and deduce the quantity of radioactivity in order to determine the waste category. For that, a tool called "Nuclide vectors" is used, which helps for sorting and characterising waste.

Links: abstract

Poster No. 11. Waste handling in SVAFO's hot cell – Jennifer MÖLLER (Vattenfall AB, Sweden)

SVAFO is responsible for the decommissioning of nuclear facilities in Sweden and providing interim storage until the final repository for long-lived wastes is available. The HM facility is a small waste treatment plant for liquid and solid waste, owned and operated by SVAFO. The facility includes a hot cell equipped with tools for the handling and packaging of the wastes with high dose rate. As with most hot cells there is an accumulation of surface contamination. The wastes passing through the hot cell will be classified as long-lived wastes, even if the activity consists solely of short-lived nuclides because of the contamination residing in the cells.

In order to optimise the use of the final repositories and decrease the cost of waste storage, it is important that the waste be sent to the optimal repository; that is, that waste containing short-lived radionuclides only not be designated as containing long-lived radionuclides. Adequate characterisation of the hot cell environment, to allow short-lived waste brought into the hot cell to be classified as short-lived wastes, needs to be completed. A method was developed to collect surface contamination samples inside the hot cell and tests to be carried out in order to determine the cross contamination between the cells and objects. These results indicate that it may be possible to establish a method to justify the classification of certain waste as short lived, even after handling in the HM hot cell.

Links: abstract

Poster No. 12. Contaminated land remediation on decommissioned nuclear facilities: an optimised approach – Emilie SAUER (EDF, France)

EDF is in charge of the decommissioning of a former heavy water reactor and the effluent treatment facility is currently being dismantling. The building platform and the soil underneath have been contaminated due to various incidents and during the decontamination phase in 2004/2005 it was realised that the contamination went deeper than expected. After characterisation it was established that the contamination of the soil was due to low, predominately Cs-137 (0.26 Bq/g) activity diffused in the zone surrounded by two layers that had higher activity levels. The first layer is 50 cm below the platform (0.69 Bq/g) and the second at 3 - 3.5 m (0.58 Bq/g). 80 % of the source term comes from the platform. An optimised approach has been proposed with an impact on the soil activity of 8.10 – 3 µSv/y. It consists of optimising the soil excavations to only the first 50 cm which will reduce the dose. It takes into account technical difficulties, worker's safety, sustainable management and the quantity of low level waste produced following the ALARA principle (As Low As Reasonably Achievable). If accepted this optimised method will set a precedent for radiological waste production.

Links: abstract

Poster No. 13. Global solutions through simulations for better decommissioning – Vincent TESTARD (Oreka Solutions, France)

During preparation for decommissioning of a nuclear facility, many interdependent complex factors have to been taken into account including radiological data, history of the facility and any radiological events that may have occurred. Oreka Solutions has developed software which combines all the available data and process it in a way to allow engineers to optimise decommissioning scenarios. ALARA approach is fully implemented to protect workers from radiation. Many strategies can be tested, analysed and compared. Risk analysis is completed and contingencies can be planned for by testing an infinite number of situations. It helps to manage dismantling operations through a 3D model of the system with detailed dimensions of the cells, tools and equipment, showing what is possible.

Links: abstract

Poster No. 14. 3D based integrated support concept for improving safety and cost-efficiency of nuclear decommissioning projects – István SZÖKE (IFE, Norway)

This project focuses on 3D simulation and virtual reality. It aims to re-create the nuclear facilities' environments and one of its current goals is to facilitate decommissioning projects through the testing of dismantling scenarios and the training of decommissioning specialists. This project could enhance safety and reduce the decommissioning cost through good preparation of the decommissioning project. The software has been used to re-create the environment of Chernobyl and other nuclear facilities where accidents have occurred. It can also simulate the propagation of radionuclides in the atmosphere after a leak due to an accident. The dosimetry map of a facility can be simulated as well, either using data that was collected in the facility or from radiation mobilisation equations. All these functions are connected to one another so that the simulated facility is close to reality. This system could be a useful tool to record facilities' data and information throughout its lifetime, making a complete historical data set available when the decommissioning planning starts.

Links: abstract

Poster No. 15. Safety enclosure management strategies at three Canadian prototype power reactors – Meggan VICKERD (Canadian Nuclear Laboratories, Canada)

Lesson learnt by Canadian Nuclear Laboratories (CNL, former AECL) in preparation for decommissioning of three prototype reactors is a result of various strategies used for each site. The preferred decommissioning strategy is deferred dismantling allowing for the decay of radionuclides. The strategies chosen for each reactor were based on the location, configuration, and intended designation of site.

The Nuclear Power Demonstration Generating Station (NPDNGS) was constructed in the 1950s and was shut down to a “Cold, Dark, and Quiet” state. Remote management of fire detection and security surveillance, and an active ventilation system allowing for periodic inspections maintain this state. The Douglas Point Nuclear Power Generating Station from the 1960s was a CANDU reactor and put into a semi custodial state after shutdown. This is an active safety enclosure meaning continued occupancy, repurposing of some buildings, and continued operation of building services. The Gentilly 1 Nuclear Generating Station was a CANDU-BWR experimental reactor. Commissioned in 1972 it was permanently shut down in 1982. The safe enclosure strategy is “Cold and Dark” as all ventilation and heating systems are shutoff but there is continued use of a dehumidifier to manage moisture levels. There are costs and benefits to all of these deferred dismantling methods including operating costs, lifetime management strategies, and regulatory implications for the final decommissioning phase.

Links: abstract

Poster No. 16. Identification and sorting of materials with portable LIBS before decommissioning – Evelyne VORS (CEA, France)

The portable Laser Induced Breakdown Spectroscopy (LIBS) demonstrates ability to perform on-site identification for waste sorting and inventory management before decommissioning with a high efficiency, rapidity and reliability on the analysis. The principle of LIBS is based on analysing the surface of a sample with a focused laser beam. This creates a plasma formed by the atomised compounds. The light emitted by the plasma is detected and analysed by an optical spectrometer. The methodology of LIBS is based on database spectra and was built with a commercial instrument, called “IVEA SAS Easylibs”, with reference samples of four categories for industrial interest waste sorting: alloys, plastics, concrete and glasses. LIBS analysis can be applied to the identification of materials using multivariate analysis, in order to direct them to the correct waste stream. Such a method has already been applied to determine the origin of yellow cakes and for the identification of alloys, and gives accurate results.

Links: abstract

Poster No. 17. Concrete waste reduction of 50 % – Renate DE VOS (NRG, The Netherlands)

During the decommissioning phase of nuclear facilities concrete waste is produced. To overcome this, there are currently different methods to manage concrete waste including: segregation, re-use, conditional release, release according to their degree of activation and disposal. In the future smart materials will be used in the construction of new facilities to reduce the volume of concrete waste. Moreover, much research is being conducted to increase the reducing coefficient of concrete waste. In this context, the Dutch group Nuclear Research and consultancy Group (NRG) has performed research on distinctive waste management processes to reduce the volume of concrete waste under the current Dutch's regulatory framework. Among the available management of concrete waste, the NRG has conducted further research into the separation processes. Following these researches, the NRG have started a patented process on pilot tests for a new method of separation that would achieve a reduction in concrete waste by approximatively 50 % of their initial volume due to their release or re-use in nuclear facilities or conventional industries.

Links: abstract

Poster No. 18. 3D Liquid and solid waste reduction by using reverse osmosis (RO) – Renate DE VOS, T.T. TOMASBERGER and J.M. REIJ (NRG, The Netherlands)

This poster outlines the reverse osmosis technique used to treat radioactive water produced at the NRG site in Petten (Holland). The waste water treatment facility used membrane filtration and a flocculent to reduce the amount of liquid waste; however the use of flocculent produced secondary wastes solid (like sludge). The original idea was to reduce this secondary solid waste with reverse osmosis. During the experiments with different types of waste waters the effect of reverse osmosis was tested. The tests were carried out on waters with different concentrations of heavy metals and the chemical oxygen demand. The results show that the radionuclide concentration in the waste water, was reduced between 90 – 100 % and the reduction of nitrogen and oxygen in the range of 65 – 100 %. The reverse osmosis has many advantages, such as the amount of flocculent required can be reduce up to 50 %, and the quality of the water which is released is improved. The waste water can be reused in other cleaning processes.

Links: abstract

Closing Session

The closing session was led by the two chairs of the symposium, Ivo TRIPPUTI and Jonathan LEECH. Each session was summed up by the corresponding chair focusing their views and summaries on main messages for the future:

Session 1 on *Preparation for decommissioning – Strategic Issues* was closed with the conclusion that characterisation is one of the most important topics that has to be improved in the coming years.

Session 2 on *Early Characterisation Challenges* was also closed by emphasising the importance of characterisation during decommissioning projects.

Session 3 on *Workforce transition, flexibility and knowledge management* indicated that the financial aspect of decommissioning is a key area. The dialogues between the financial controllers and the technical experts must be enhanced. Solutions for decommissioning where a funding shortfall may become apparent should be considered. In order to optimise costs, the fleet of nuclear power plants globally should be seen as a one global system where learning and solutions can be applied across all areas. The difference between the technical and the strategic planning and goals needs to be managed and then the plans aligned.

Session 4 on *Key aspects for efficient and cost-effective waste management* intensively discussed questions like “What can be done to reduce the total waste management cost including disposal in decommissioning?” and “How to speed up the process to reach end-state conditions?”

The views can be summarised as follows:

- Outline a full characterisation plan in the planning phase. Revisit and update as necessary throughout the process as it develops. Secure traceability of the results and a good quality of analysis.
- Reduce the waste for disposal by segregation, waste treatment for volume reduction and implement clearance for recycling outside the nuclear sector.
- Ship waste off-site as soon as possible by implementing a “rip and ship” strategy where available.
- Industrialise the processes.

Session 5 on *Regulatory framework and industry needs* showed the importance of communication between different stakeholders before, during and a after decommissioning project in order for it to be successful. It was concluded that a stable regulatory framework is essential for a robust decommissioning programme. It was also underlined that a decommissioning project needs to remain flexible to react more efficiently on changing regulatory framework and to unexpected situations.

Session 6 on *Good examples and lessons learnt in preparation for decommissioning* was closed with the emphasis on the importance of considering all lessons learnt from different countries in decommissioning projects.

Session 7 on *Best practices in characterisation of material and waste* outlined a wide variety of materials and objects that require characterisation. The characterisation objectives can be diverse. Characterisation allows for categorisation and optimisation of the management of waste and materials in each category. The dose rate can be calculated before major works begin to secure the right level of protection of the workers and the probability of reaching the clearance level through on or off-site treatment methods can be assessed.

After the session summaries, the floor was given to two students of the Master Nuclear Energy – Decommissioning and Waste Management (École des Ponts et Chaussées/ParisTech; École Centrale-Supélec et INSTN) who supported the symposium. On behalf of their entire group the two students presented a valuable view of what they learnt in the conference and, more important, how they see their future in this business sector.

Finally, Mr Tripputi and Mr Leech presented some closing remarks based on their perceptions of the main messages from the conference. In particular, the following points were mentioned:

- Decommissioning is a complex project management activity that should be based on a timely preparation and clear strategies and objectives.
- "Immediate dismantling" and "Safestore" strategies are only the two extreme decommissioning strategy options; while fixed costs for care and maintenance will go up with the increased project duration, other intermediate decommissioning strategy options may prove to be preferable and more cost-effective depending on the specific circumstances of a nuclear facility.
- The plant operation licensee shall decide during operation about the make-or-buy options, acting consequently with the plant staff, including an appropriate training programme and safety culture monitoring process.
- Knowledge management is a key challenge to decommissioning projects; type and amount of relevant information shall be defined during plant operation and collected accordingly. Information shall be kept for some time after the completion of the project also as part of a knowledge basis.
- Decommissioning projects in general are considerably more affected by uncertainties than construction projects; minimising uncertainties shall be a firm objective that should be based, among other things, on a detailed (as necessary) initial plant characterisation. In addition, the use of a proven, mature technology should be accompanied by careful integration of technical innovations.
- Technical uncertainties are frequently connected with cost uncertainties making the project management even more risky. Better project cost assessment and cost controls should be introduced to minimise financial risks.
- Decommissioning projects have often a social impact; the effects of this impact should be anticipated and mitigation measures should be agreed timely with all stakeholders and the workers involved in the project.
- International experience and knowledge exchange is an important element for decommissioning projects. Currently the final balances of fully completed relevant decommissioning projects are scarce. Benchmarking with similar projects is important, but, to be effective, should be based on standardised bases to the extent possible. NEA and IAEA work on the decommissioning cost structure is a good example.
- The conference confirmed the importance of timely preparation for decommissioning as soon as possible during plant operation and for new reactors even on the drawing tables.

APPENDIX A – Symposium programme

Tuesday, 16 February 2016	**13:00**	**SYMPOSIUM OPENING AND INTRODUCTORY SESSION** *Chair*: Ivo TRIPPUTI (Sogin, Italy) *Co-chair*: Jonathan LEECH (Dentons UKMEA, UK) **Invited presentations and round table:** • Sylvain Granger (EDF, Head of decommissioning and waste management) • Vladimir Michal (IAEA, Decommissioning and Environmental Remediation Team leader) • Michael Siemannn (NEA, Head of Division of Radiological Protection and Radioactive Waste Management) • Michael Mononen (Studsvik AB President and CEO) • Guillaume Dureau (AREVA, Senior Executive Vice President, Back-End Business Group) • Laurence Piketty (CEA-DEN, Director of Nuclear Cleanup and Dismantling Division) **Focus on NEA task groups:** • Preparation for Decommissioning during Operation and after Final Shutdown (Boris Brendebach) • Strategies for radiological characterisation for decommissioning of nuclear installations (Arne Larsson)
	15:45	**SESSION 1 Preparation for decommissioning – strategic issues** *Chair:* Konrad SCHAUER (AREVA, Germany) *Co-chair:* Jean-Marie RONDEAU (EDF, France)
	18:00	Evening cocktail

Wednesday, 17 February 2016	**8:30**	**SESSION 2 Early Characterisation Challenges** *Chair*: Sue AGGARWAL (NMNT International, USA) *Co-chair*: Thierry VARET (AREVA, France) **SESSION 3 Workforce transition, flexibility and knowledge management** *Chair*: Gilles GIRON (EDF, France) *Co-chair*: Leo LESSARD (AREVA, USA)

	13:00	**SESSION 4 Important parameters for efficient and cost-effective waste management** *Chair*: Arne LARSSON (Studsvik, Sweden) *Co-chair*: Christine GEORGES (CEA, France) **SESSION 5 Regulatory framework and industry needs** *Chair*: Inge WEBER (NEA) *Co-chair*: Henrik EFRAIMSSON (SSM, Sweden)
	15:30	**POSTER SESSION INTRODUCTION** Chaired by Gilles CLEMENT (AREVA, France)
	16:30	POSTER SESSION
	19:00	Dinner reception – Abbaye de Collonges

Thursday, 18 February 2016	**08:30**	**SESSION 6 Good examples and lessons learnt in preparation for decommissioning** *Chair*: Vladimir MICHAL (IAEA) *Co-chair*: Michael KNAACK (TÜV, Germany) **SESSION 7 Best practices in characterisation of material and waste** *Chair*: Yvon DESNOYERS (Geovariances, France) *Co-chair*: Hélène DENIAU (Studsvik, France)
	11:00	**Summing-up and closure of the symposium (all chairs)**
	13:00	Departure for guided site tour to ICEDA
	18:00	Arrival to Lyon after the guided site tour