



IAEA

International Atomic Energy Agency
Atoms for Peace and Development

Spent Fuel Management Activities at the IAEA

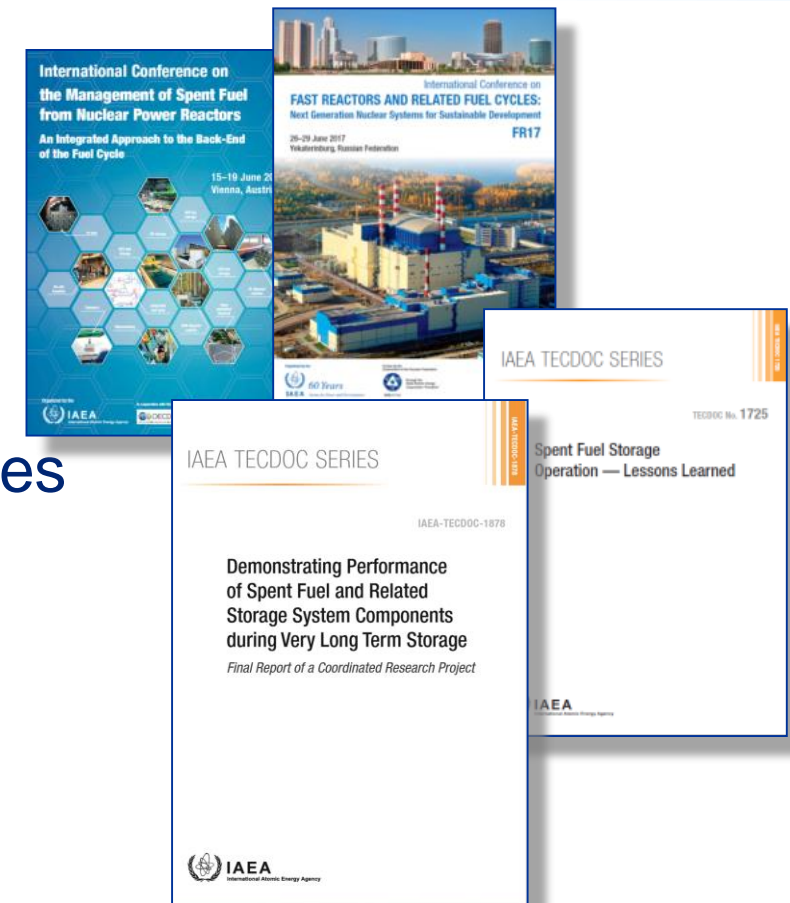
Laura McManniman

NFCMS-NEFW

November 2019

IAEA actively supports the sustainable, safe, secure, reliable and economic management of SF from nuclear power reactors by providing MSs with relevant technical information (guidance) based on operational experience and best practices about the SF management options

- Through:
 - International conferences and workshops
 - Publication of technical documents and reports
 - The coordination of international research activities through Coordinated Research Projects (CRPs)
 - The management of specific databases



Multiannual Programmes considering MSs recommendations/requests expressed through:



- Yearly adopted resolutions: **GC(63)/RES/10**
- Standing Advisory Group on Nuclear Energy, (**SAGNE**) is an internally-focused IAEA group that advises the **Director General** on nuclear power, fuel cycle and nuclear science issues
- Technical Working Groups (TWGs):
 - TWG on Nuclear Fuel Cycle Options and Spent Fuel Management (TWG-NFCO) which focuses on nuclear fuel cycle options with an emphasis on spent fuel management (storage and reprocessing and recycling), innovative fuel cycles and nuclear materials management

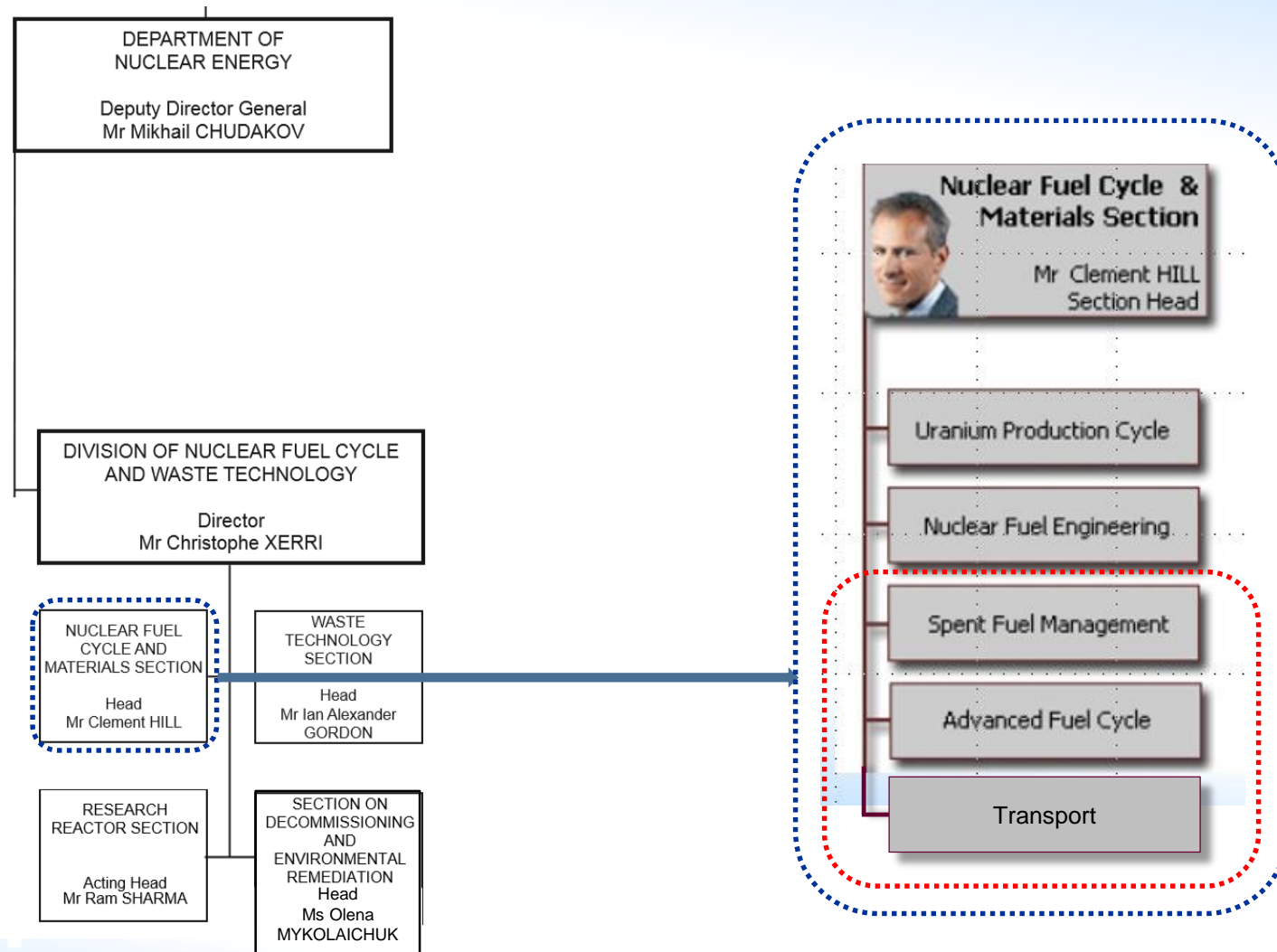


Vienna, April 2019



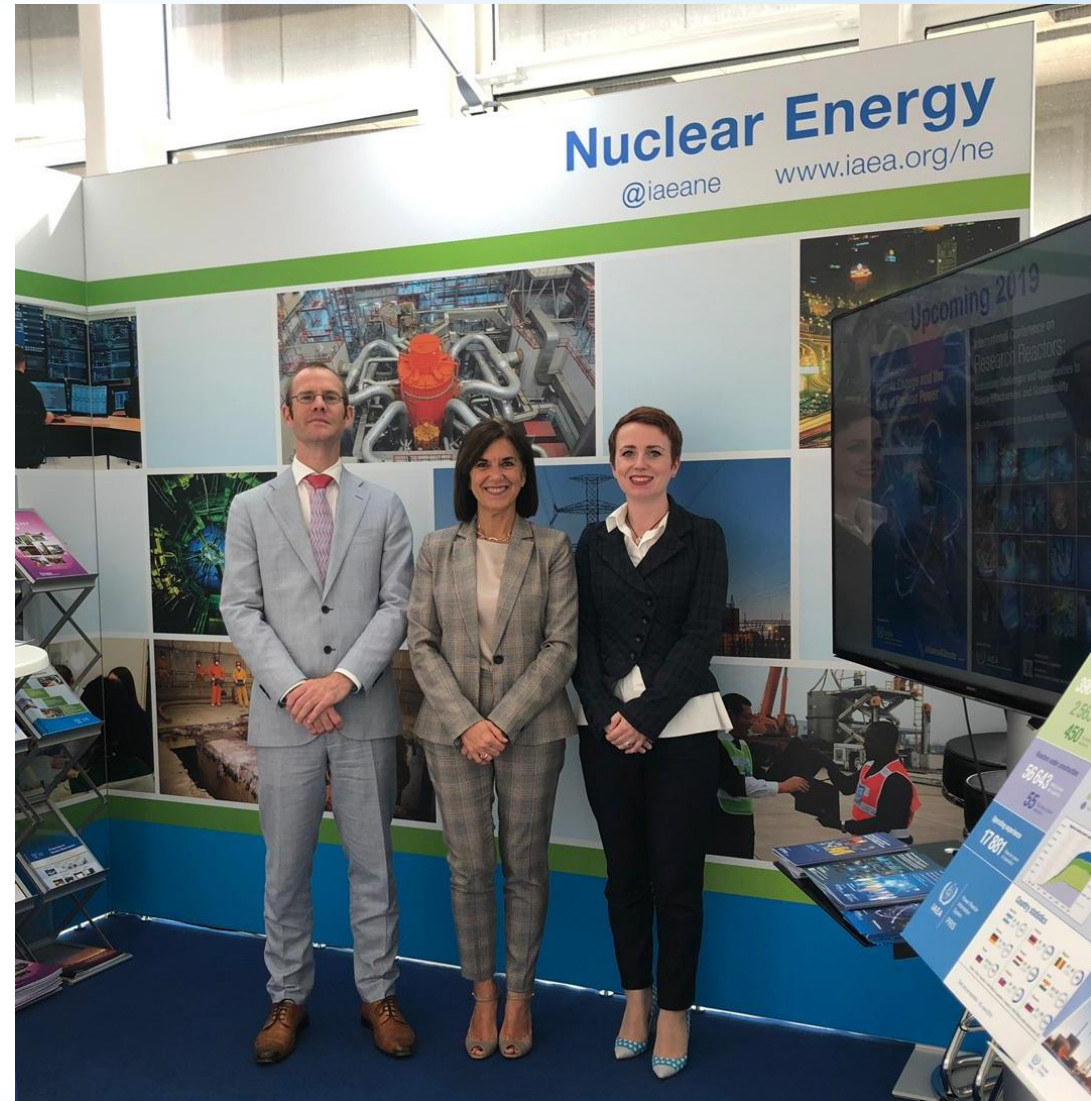
General Conference

Nuclear Fuel Cycle & Materials Section



Scope of work SFM Team

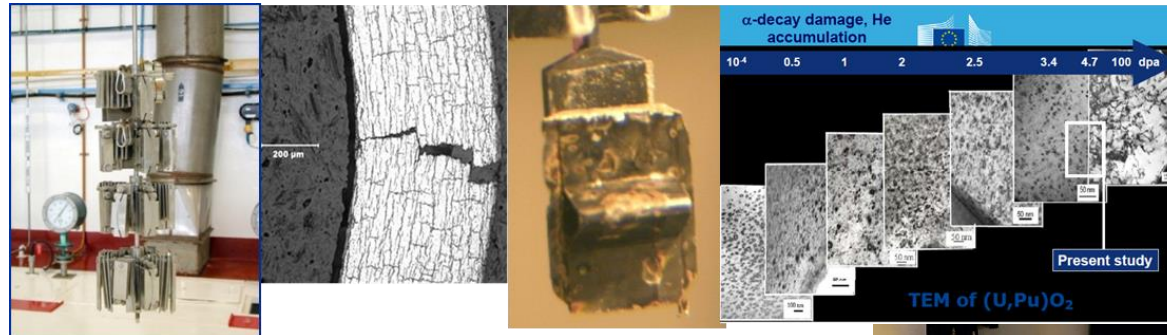
- Storage (until ultimate disposition)
- Reprocessing and recycling current fleet
- Advanced Fuel Cycles for Gen-IV
- Transportation of spent fuel



CURRENT ACTIVITIES

Activities on SF storage

- IAEA CRP (T13016) 2016-2020 on “*Spent fuel Performance Assessment and Research (SPAR IV)*”
 - Covering all power reactor fuels:
 - MAGNOX, RBMK, WWER, AGR, BWR, PWR, HWR, PHWR
 - Wet and Dry storage systems

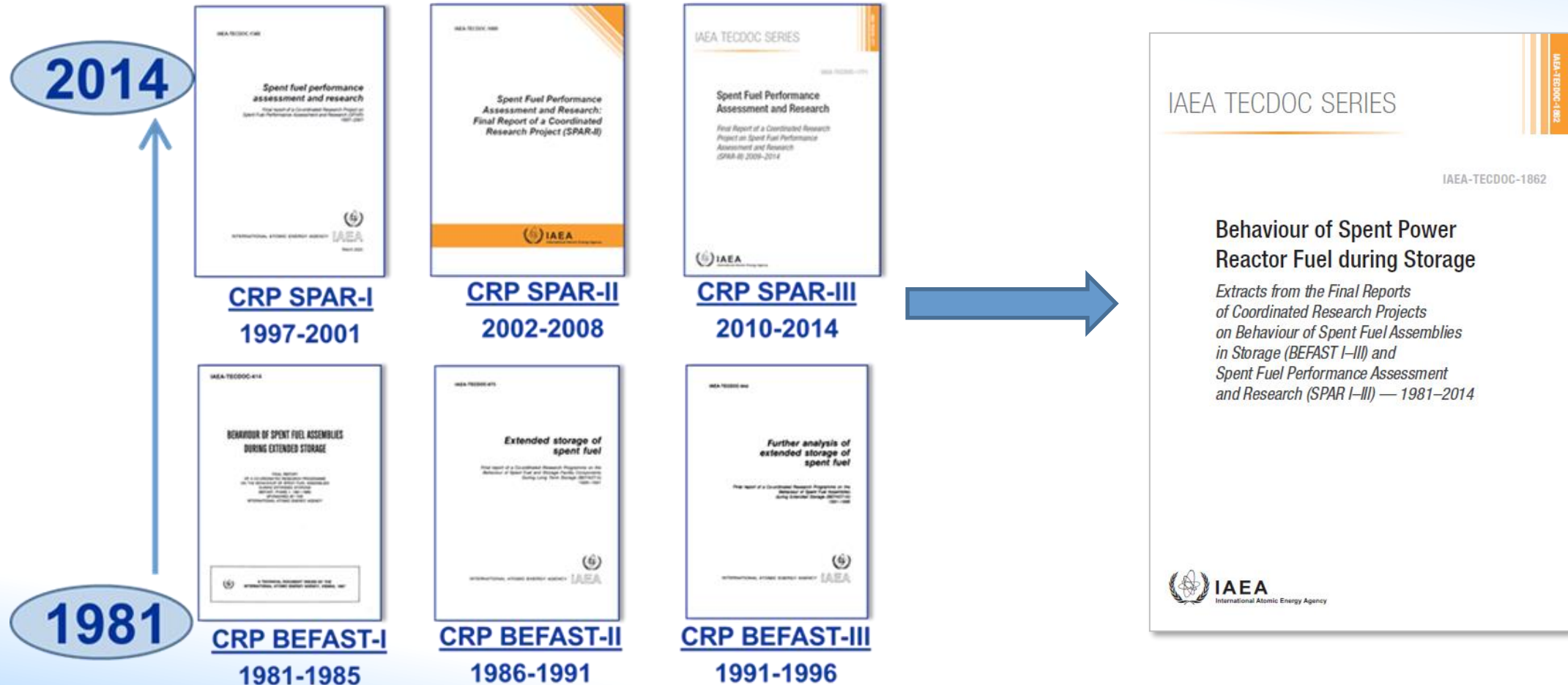


- 9 RA and 4 RC from 10 MSs
- RCM-1, Vienna (10-14 October, 2016)
- RCM-2, Seoul (RoK) (9-13 April, 2018)
- RCM-3, Buenos Aires (Argentina) (7-11 October 2019)
- The younger participants voiced their appreciation of the peer comments & mentoring offered by the more senior experienced members



Activities on SF storage

BEFAST/SPAR: 30+ years of operational experience and R&D



Activities on SF storage

- **IAEA CRP (T21028) on “Ageing Management Programmes for Spent Fuel Dry Storage Systems”**
 - Overall Objective is to develop the technical basis and methodology to enable guidance to be provided to Member States on how to generate an ageing management programme for spent fuel dry storage systems
 - October 2016 until December 2020
 - RCM-1 held in Vienna, October 2017, 5 RA and 2 RC from 5 Member States
 - RCM-2 held at ANL (Chicago, USA, April 2019)
 - RCM-3 to be held in France (October 2020)



Vienna 2017



Chicago 2019

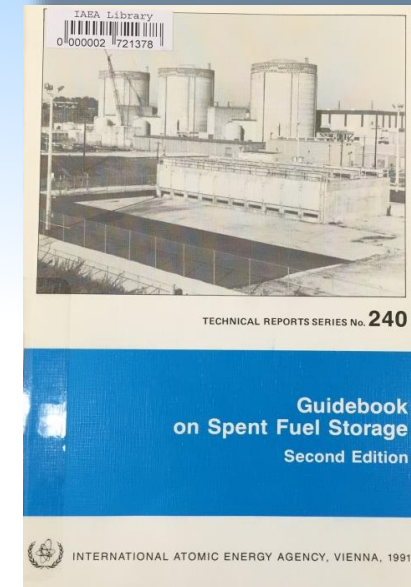
Activities on SF storage

▪ Spent Fuel Storage Guide

- Guidebook on Spent Fuel Storage (IAEA TRS 240, 1991)
 - Covers all aspects of storage
 - Will highlight the evolution of SF storage and the fact that storage lifetimes are much longer than anticipated in 1991

▪ Management of SF at Shutdown Reactors

- Covers planned and unplanned reactor shut downs
 - E.g. for phase out of nuclear energy or economical reasons
- Technical Meeting on premature shutdown of nuclear power plants held June 2018
- Site visit to Oyster Creek NPP with DOE May 2019
- TECDOC currently in production



Activities on Advanced Fuel Cycles

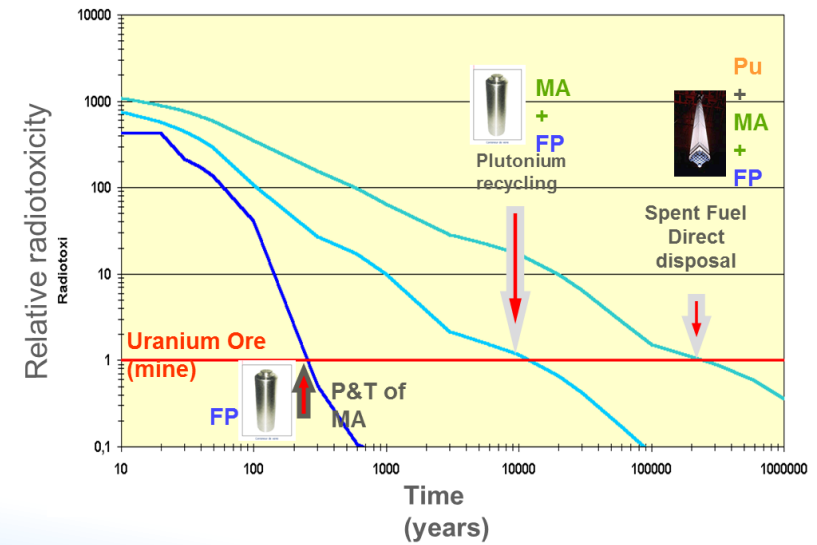
▪ New CRP on Advanced Recycling Technologies

- To identify fuel cycle options for aqueous and pyro processes and factors that influence technology choice to be deployed (cooling time, burn-up, etc.)
- Impact of new developments in fuel fabrication (accident tolerant fuels, new cladding materials, etc) in the BEFC
- Comparison of different cycle options against different criteria (wastes produced, non-proliferation aspects, TRL, scale up)
- Different approaches for recycling valuable FPs



▪ Nuclear Energy Series on fuel cycle options for waste burden minimisation

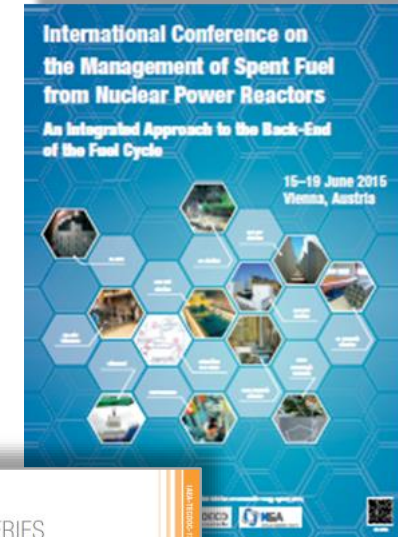
- Drafting a concise report aimed at reviewing an updating technological developments in current and advanced fuel cycles to provide policy and decision makers with information on how adopting different fuel cycle options can minimise the burden of generated waste



Activities on Integrated Approaches

■ Integrated approaches to the back end of the fuel cycle

- There is a need to look at the back end of the fuel cycle in a fully integrated manner including items such as retrievability, transportation, storage, recycling and disposal;
- Publication IAEA-TECDOC-1774, based on material gathered prior to 2011;
- TM held July 2018 and updated TECDOC now in preparation.



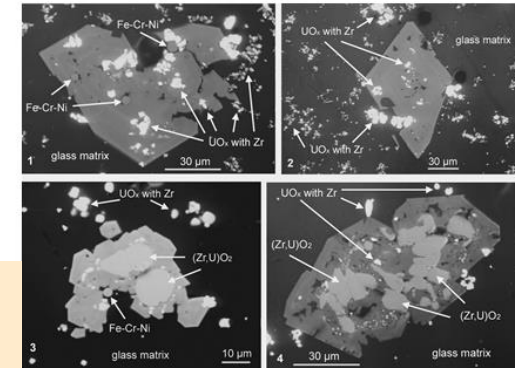
Activities related to Fukushima accident

- IAEA CRP (T13015) initiated February 2016 on “Management of Severely Damaged Spent Fuel and Corium”
- Overall objective
 - To expand the existing knowledge base and identify optimal approaches for managing severely damaged spent fuel
- 2016 to 2019
- 7 RA and 2 RC from 6 MSs
- RCM-1, Vienna (13-16 February 2017)
- RCM-2, Japan (5-9 November, 2018)

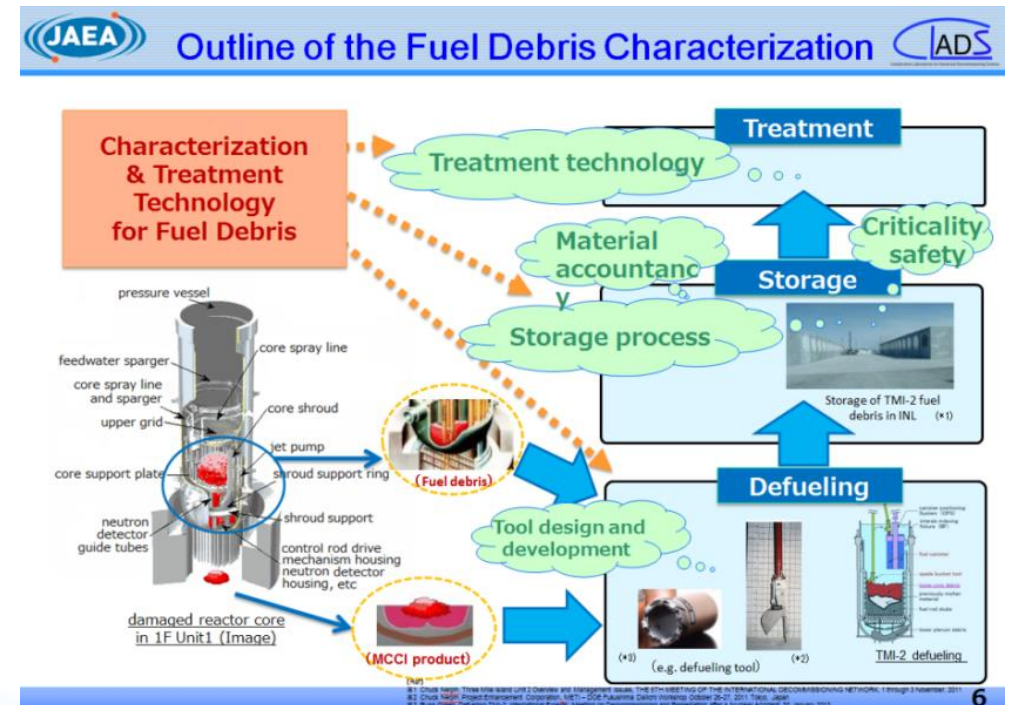
Value

Sharing experiences and knowledge
TMI, Chernobyl and Fukushima,
damaged fuel management strategies

Inclusions in black and brown “lava” matrices
(from steam discharge corridor)
SEM-BSE
1,2 – brown “lava”; 3,4 – black “lava”



KRI-samples

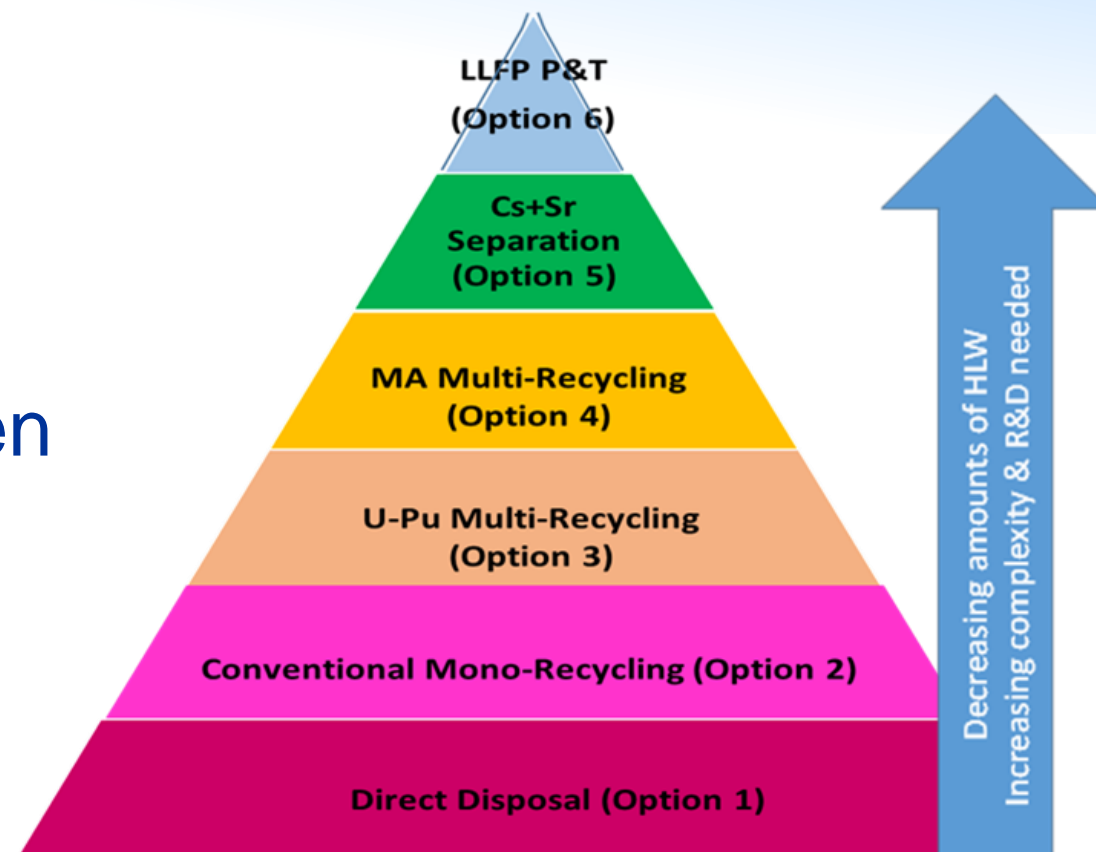


UPCOMING TECHNICAL MEETINGS

TM on Strategies and Opportunities for Spent Fuel Management in the Longer Timeframe, 25-29 November 2019

Objectives:

- Consolidate the content of the document on “Existing and Advanced Nuclear Fuel Cycle Technical Options for Waste Burden Minimisation”
- Discuss current and potential innovative recycling approaches
- Frame the CRP on Advanced Recycling Technologies



Contact:

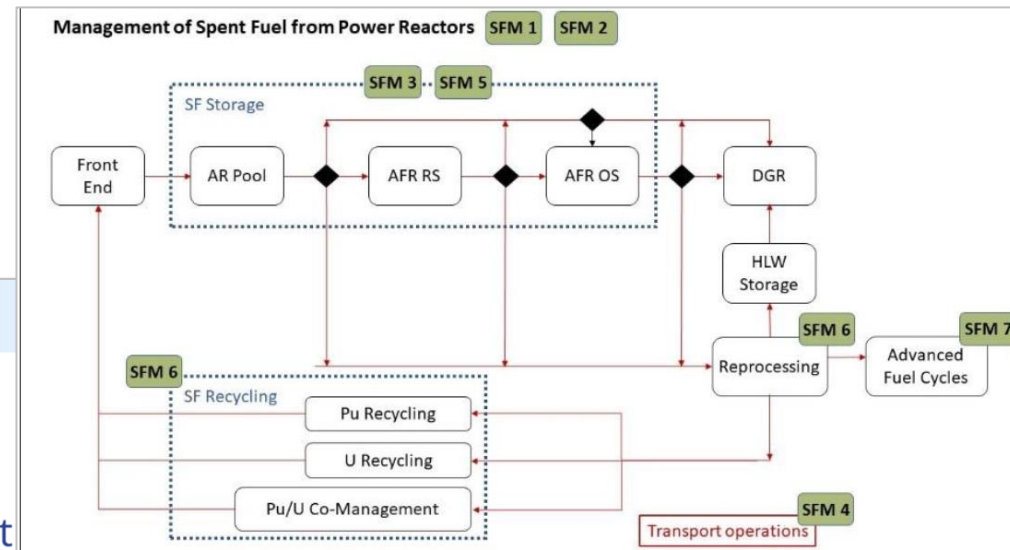
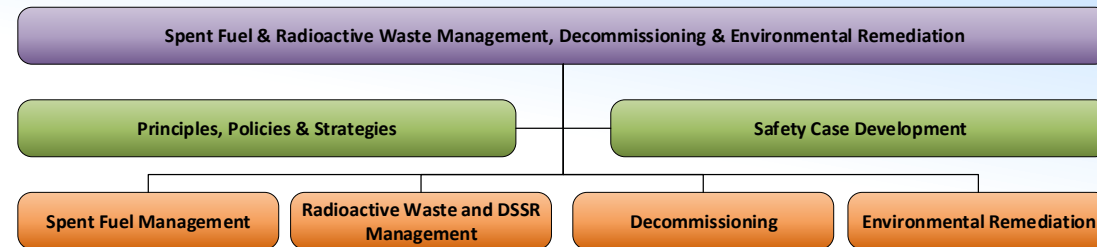
A.G.Espartero@iaea.org

E-LEARNING MATERIAL

E-Learning Overview

7 Modules planned to cover all aspects of spent fuel management

Modules 1 & 5 now available!



IAEA

Spent Nuclear Fuel Management

START

Sponsored by:  MEXT
MINISTRY OF EDUCATION,
CULTURE, SPORTS,
SCIENCE AND TECHNOLOGY/JAPAN

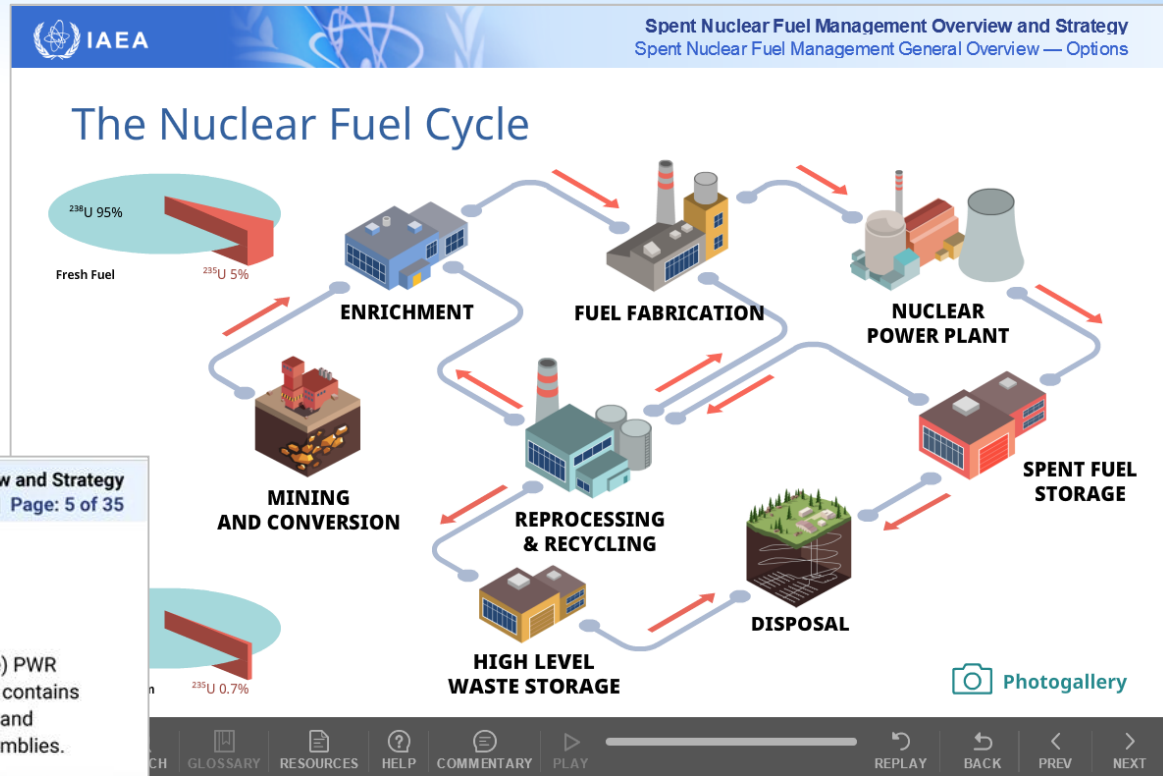
Version 1.0 January 2018

CONTENT SEARCH GLOSSARY RESOURCES HELP COMMENTARY PLAY REPLAY BACK PREV NEXT

<https://nucleus.iaea.org/sites/connect-members/LMS/Pages/Welcome-to-the-learning-materials-section.aspx>

Module 1 – Policy & Strategy for SFM

Designed to give an overview of what spent fuel is and the different options for its management

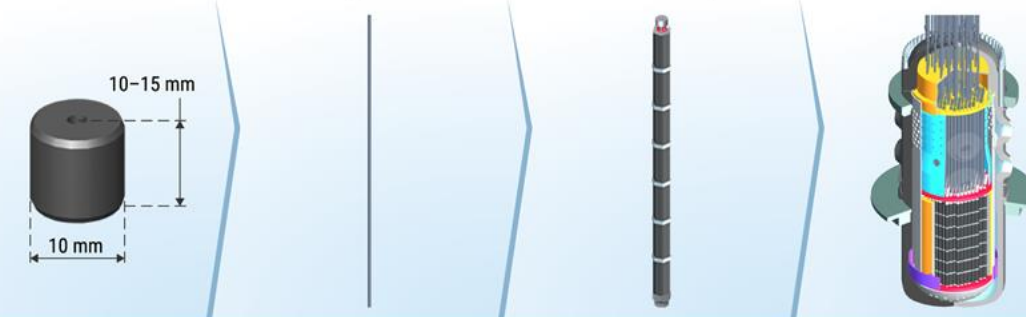


Module: SNF Overview and Strategy
Lecture: General Overview – Options | Page: 5 of 35

Nuclear Fuel Components

Nuclear fuel is composed of:

- Ceramic pellets of UO_2 enriched in ^{235}U about 10 mm in diameter and 10–15 mm height.
- The pellets are stacked in fuel rods made from Zircaloy that are about 4 m long.
- The fuel rods are assembled together in a fuel assembly can be handled as an entity.
- A 1000 MW(e) PWR core typically contains between 200 and 250 fuel assemblies.



Approximately 40 SNF assemblies containing about 20 tonnes of uranium are discharged as SNF every year.

Navigation: CONTENT, SEARCH, GLOSSARY, RESOURCES, HELP, COMMENTARY, PLAY, REPLAY, BACK, PREV, NEXT

Material aimed at professionals new to nuclear or university students

Module 5 – Spent Fuel Storage

Lecture 5.1 covers the different strategies in use for spent fuel storage

IAEA Spent Nuclear Fuel Storage Fuel Storage Facility Design and Operation

Wet Storage Safety

Fuel rod cladding provides primary containment.



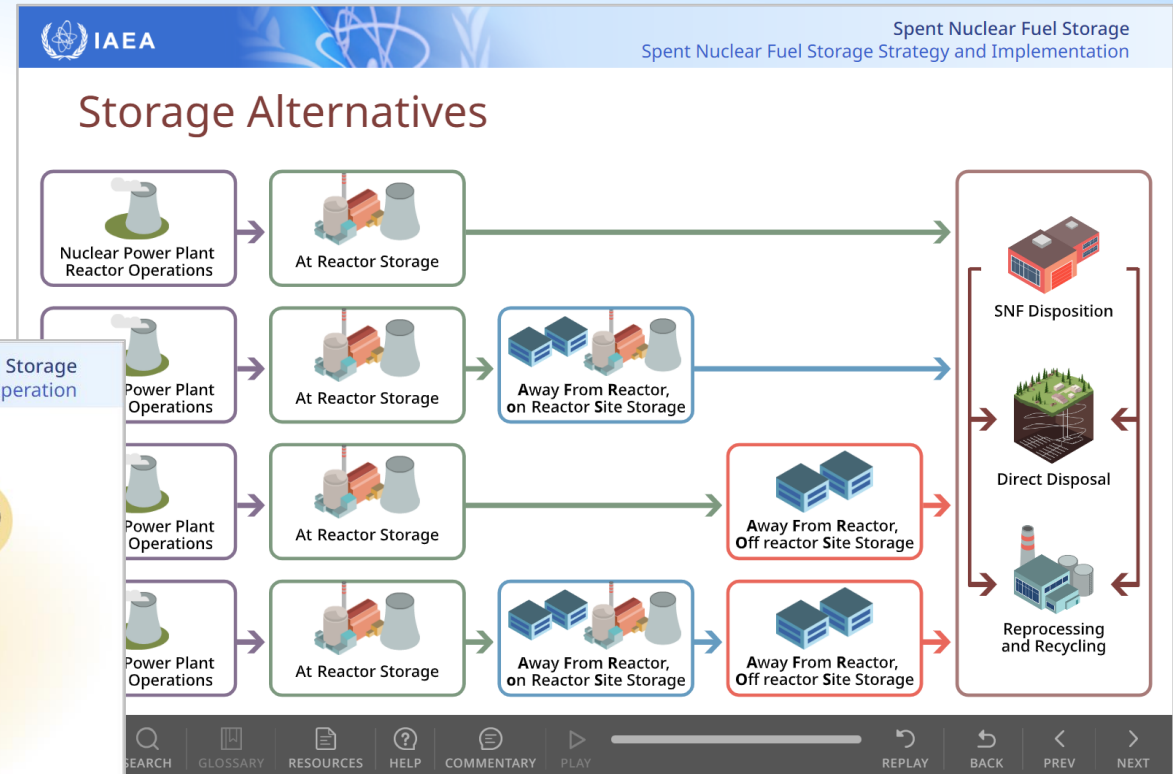
- WATER LOSS PROTECTION**
- SAFETY ALERT INSTRUMENTS**
- COOLING SYSTEM**
- STRUCTURAL INTEGRITY**

Water provides shielding, provides heat removal and keeps the fuel cool.

Continuous water clean-up removes any activity from surface contamination on the fuel and from any leaking fuel rods.

Maintaining good water chemistry prevents fuel degradation.

SEARCH GLOSSARY RESOURCES HELP COMMENTARY PLAY REPLAY BACK PREV NEXT

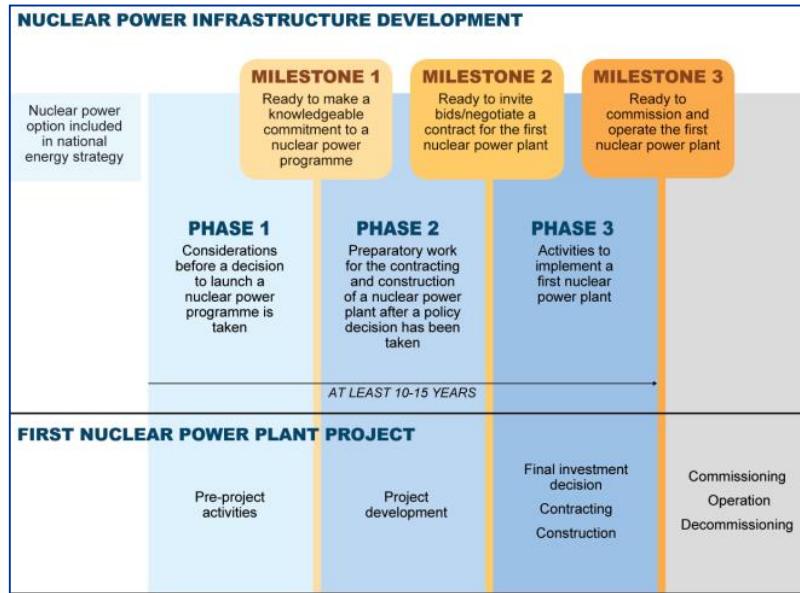


Lecture 5.2 describes the different designs of facilities and their operation

OTHER ACTIVITIES

Support to Newcomers

Provide support to newcomer countries developing nuclear programmes through NENP/NIDS



Training Activities

Participate in Workshops and Nuclear Schools and provide training materials

- Joint IAEA-Rosatom Meeting for Young Scientists, Moscow and Saint Petersburg (Russia)
- IAEA Nuclear Energy Management Schools



Nuclear Fuel Cycle, Radioactive Waste Management & Decommissioning

Laura McManniman
Spent Fuel Management Specialist, NFCMS
Division of Nuclear Fuel Cycle, Waste Technology & Research Reactors

Nuclear Energy Management School
St Petersburg, August 2019



Joint ICTP-IAEA School on Nuclear Energy Management



Seven years of successful cooperation in developing competence for Nuclear Energy Management



21 August - 1 September 2017
Trieste, Italy

Further Information:
Website: <http://www.iaea.org/NewsCenter/Events/2017/08>
Email: iaea@iaea.org

Spent Fuel Management Network



IAEA.org NUCLEUS

IAEA SFMNet

Search this site

Other Networks SFM Public CRPs Technical Meetings Publications Webinars Members' area

Not a member yet?

International Organizations

Current Highlights

New Publication: STIPUB/1850 Proceedings from IC on Management of Spent Fuel from Nuclear Power Reactors 2015

New IAEA e-Learning on Spent Fuel Management available on the IAEA on-Line Learning Platform

Welcome to the IAEA International Network on Spent Fuel Management - SFM Net

The spent fuel management (SFM) network is a forum for the sharing of practical experience and international developments on spent fuel management.

Its main objectives are to facilitate the efficient exchange of information, communication and cooperation amongst professionals working in the back end of the fuel cycle – from its removal from a reactor core to its final disposition (i.e. SNF wet and dry storage, transportation, handling and retrieval, reprocessing and recycling, economics of the back-end of nuclear fuel cycle, damaged SNF management, stakeholder involvement, communication issues, etc.)

The establishment of the SFM Net is aimed at fostering safe, sustainable and efficient spent nuclear fuel management practices across all IAEA Member States.

For further information or questions please contact SFM.Contact-Point@iaea.org.

Featured Publications

Events 2019

- Technical Meeting on the Phenomenology, Simulation and Modelling of Accidents in Spent Fuel Pools (2-5 September 2019, IAEA, Austria)
- Technical Meeting on Technical and Operational Issues Related to the Transportation of High Burnup and Irradiated Mixed Oxide Fuels and the Transportability of Long-Term Stored Spent Fuel (24-26 September 2019, IAEA, Austria)
- Technical Meeting on Cost Estimation Methodologies for Spent Fuel Management (21-24 October 2019, IAEA, Austria)
- Technical Meeting on Spent Fuel Characterization (12-14 November 2019, IAEA, Austria)
- Technical Meeting on Strategies and Opportunities for Spent Fuel Management in the Longer Timeframe (03-05 December 2019, IAEA, Austria)
- Second Research Coordination Meeting on Ageing Management Programmes for Spent Fuel Dry Storage Systems (29 April – 03 May 2019, Chicago, USA)
- Third Research Coordination Meeting on Spent Fuel Performance Assessment and Research (07-11 October 2019, Buenos Aires, Argentina)

Active CRPs

- Ageing Management Programmes for Dry New Storage Systems (AMP, T21028)
- Severely Damaged Fuel and Corium (CORIUM, T13015)
- Spent Fuel Performance Assessment and Research (SPAR-IV, T13016)

To join our ongoing CRPs click here

Related

<https://nucleus.iaea.org/sites/connect/SFMpublic/Pages/default.aspx>

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International Network on Spent Fuel Management (SFM) - Members Site

To see more information about the users click here

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Requestor	Company	Country	Email	Select keywords that apply to field of expertise
<input type="checkbox"/> ABOU-ALOU, Rowayda	Egyptian Atomic Energy Authority	Egypt	rowayda_mahmoud@yahoo.com	MCNFP, core modeling, core inventory, criticality safety, burn up calculations, radionuclides activities
<input type="checkbox"/> ADAMS, Lyndsey	U.S. Department of Energy/National Nuclear Security Administration	United States of America	lyndsey.adams@nnsa.doe.gov	
<input type="checkbox"/> ADJILE, MARC-AUREL	MINISTRY OF SUPERIOR EDUCATION AND SCIENTIFIC RESEARCH	Benin	adjilemarc@yahoo.fr	Un séjour sans faille
<input type="checkbox"/> AGARWAL, Kailash	Bhabha Atomic Research Centre	India	kagar@barc.gov.in	
<input type="checkbox"/> AGARWAL, Kailash	Bhabha atomic research centre	India	kagar@barc.gov.in	Nuclear Fuel cycle, Spent fuel management, Radioactive Waste Management
<input type="checkbox"/> AGARWAL, Kailash		India	kailashagarwal@yahoo.com	Spent fuel management and advance fuel cycle
<input type="checkbox"/> AL SHAHRANI, Rubaian	King Abdullah City for Atomic and Renewable Energy	Saudi Arabia	r.shahrani@energy.gov.sa	
<input type="checkbox"/> Alejano Monge, Maria Consuelo	Consejo de Seguridad Nuclear	Spain	cam@csn.es	
<input type="checkbox"/> ALQAHTANI, Mohammad	the King Abdullah City for Atomic and Renewable Energy	Saudi Arabia	m.qahtani@energy.gov.sa	Radioactive Waste Management, Health Physics, Spent Fuel Management, LILW,
<input type="checkbox"/> ALYOKHINA, Svitlana	A.M.Pidgorny Institute for Mechanical Engineering	Ukraine	svitlana.alyokhina@gmail.com	

Recent

SFM19 - Conference presentation upload

Jordan Expert Mission 2019

IC on SFM19

TWG-NFCO 2018

AMP-DSS



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International Atomic Energy Agency
Atoms for Peace and Development

Spent Fuel Characterization

Laura McManniman

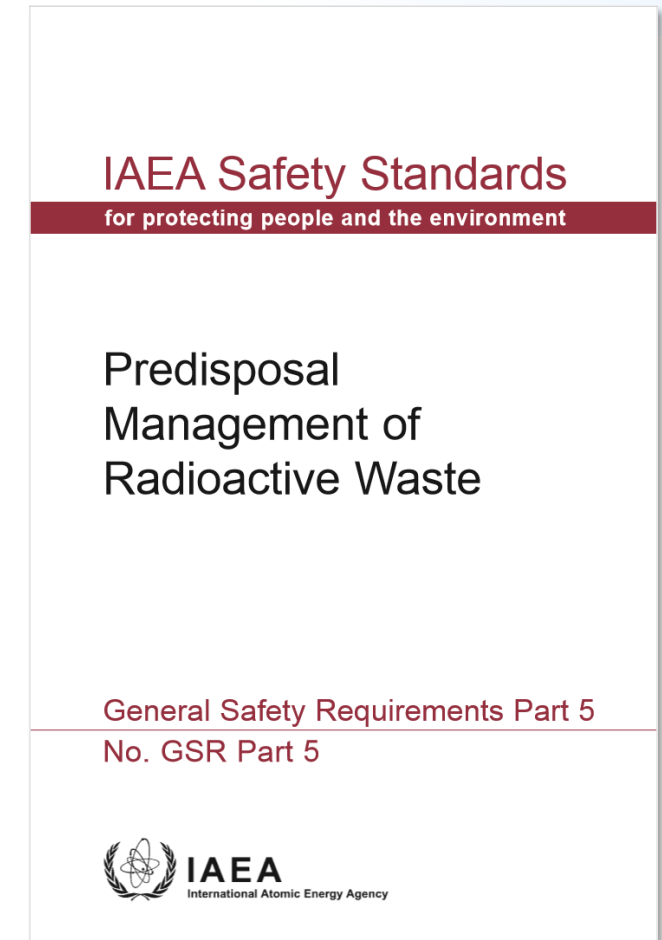
NFCMS-NEFW

November 2019

Spent Fuel Characterization

- Essential activity in the evaluation of the ability of the SF to meet specific acceptance criteria
- Forms part of Requirement 9 of GSR Part 5

“Characterization and classification of radioactive waste at various steps in predisposal management of radioactive waste, the radioactive waste shall be characterized and classified in accordance with requirements established or approved by the regulatory body.”



SF Characterization Activities at IAEA

- Has often been discussed as part of a wider range of issues
 - For example, as a conference topical session
- In recent times, not covered in a specific topic in its own right and no specific information collated and published by the IAEA to advise Member States on the range of approaches available and their validation

SF Characterization Activities at IAEA



- At 14th Technical Working Group on Nuclear Fuel Cycle Options & Spent Fuel Management (TWG-NFCO) (2016), it was recommended that an activity on Spent Fuel Characterization be included in 2018/2019 biennium planning
- Activity should identify:
 - Data needed to support safety and other analyses for storage, transportation and disposal
 - The methods and modelling codes that can be used

SF Characterization Activities at IAEA



- A session on the topic was included as part of the 16th TWG-NFCO (2018)
- The TWG observed that the characterization requirements for storage, disposal and safeguards should be integrated to avoid increasing the measurement and reporting burden
- The TWG also observed that the SG requirements for deep geologic disposal have yet to be fully established
 - During emplacement
 - Following repository closure
- Requirements could set a precedent for all MSs implementing direct disposal

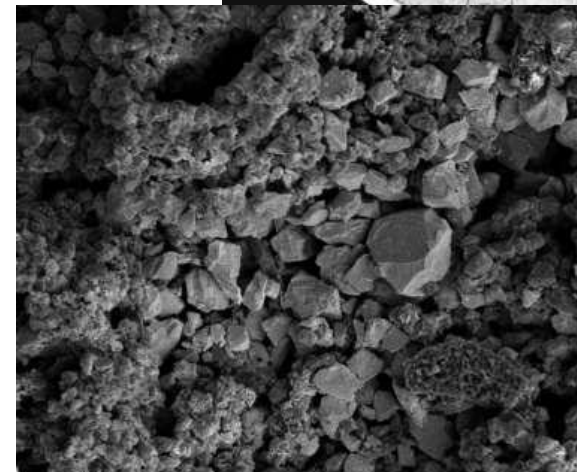
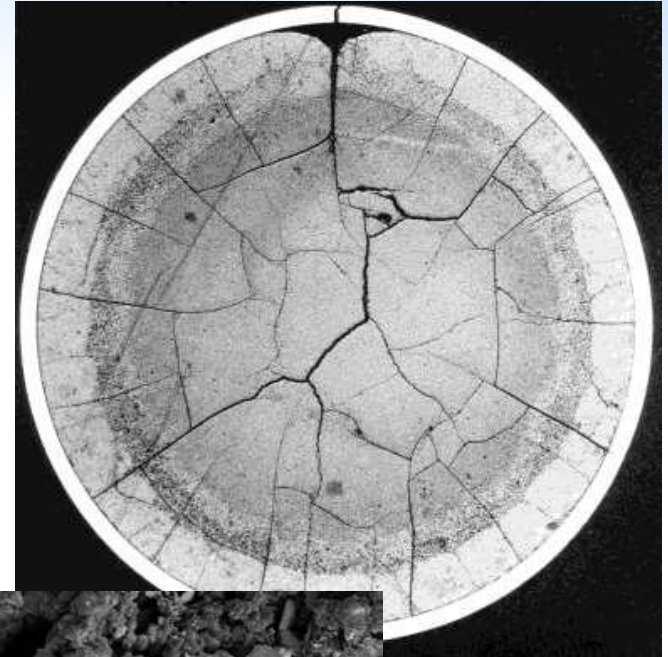
SF Characterization Activities at IAEA



- Consultancy meeting held 13-15 November 2018
- The objectives were to:
 - Identify appropriate content for a TECDOC on SF Characterization
 - Develop the foundations for this Technical Meeting
- Participants from CAN, FIN, SPA, SWE, UK, USA
- Each participant gave a presentation on the activities underway in their organization.

Canada

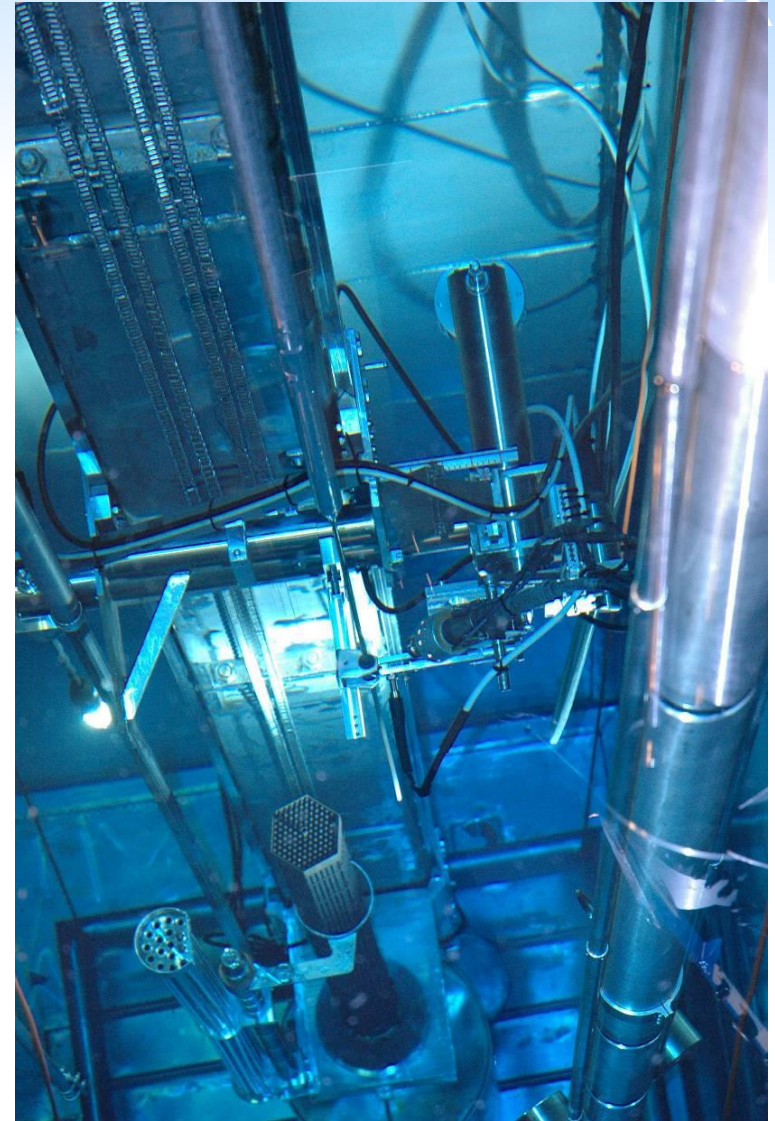
- Facilities at Chalk River Laboratory (CRL) can handle CANDU & experimental fuel, looking to enhance for LWR fuel
 - Range of NDA and DA capabilities
 - Developing Advanced Nuclear Materials Research Centre (ANMRC) which will have new hotcell and new Pu handling facilities.
- Modelling for CANDU completed with ELESTRES (normal op. conditions, legacy code) and FAST (NOC and transients, under development)



8µm
SE Region 2, 1500x

Finland

- Capabilities at utilities is limited to poolside NDA
- Fuel for destructive analysis is sent to Studsvik
 - Utilities do so for operational purposes
 - Posiva doing so for radiochemical characterization
- Issues with repeated inspections of the same BWR assemblies over time due to the mechanical effects of multiple removal and replacement of shrouds
 - Also issues with spares obsolescence of the ATULA inspection system
- Fuel data is collected by the utilities, but it is likely that Posiva will need more information



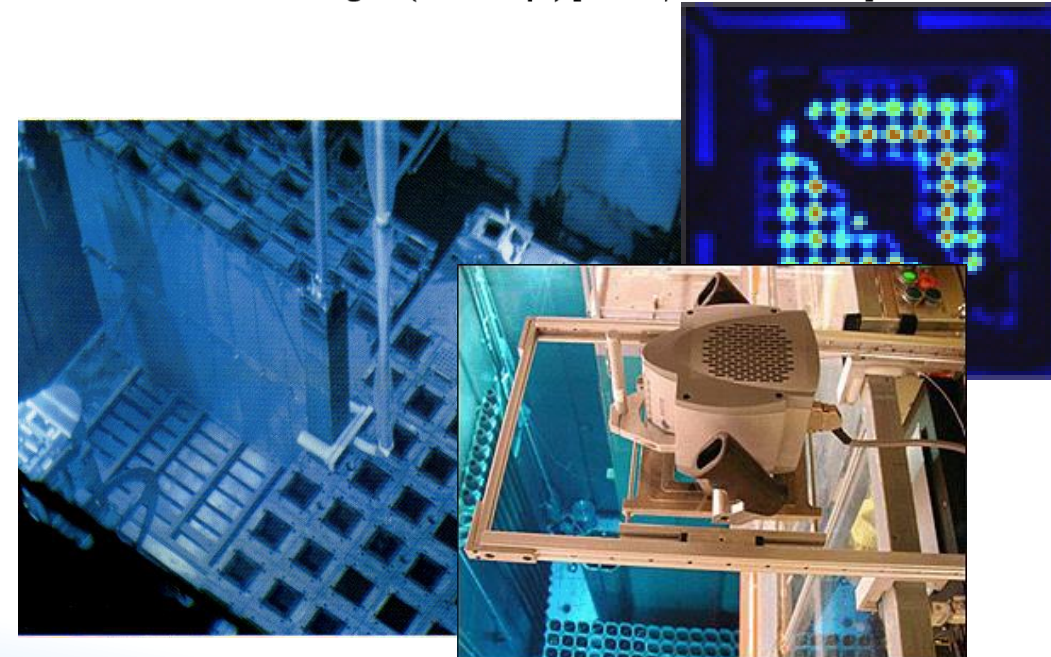
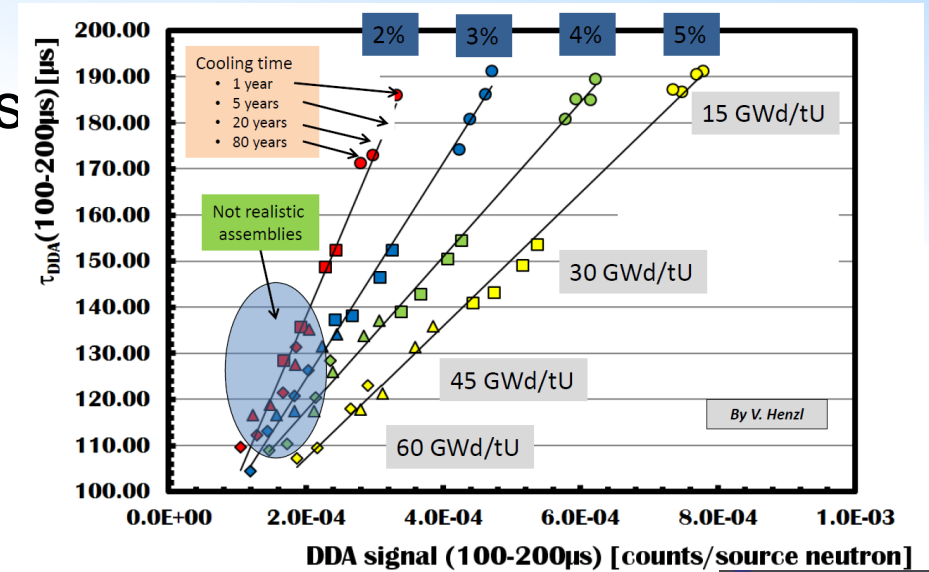
Spain

- No capability for destructive examination, but participate in international programmes for code validation
- Undertake some NDA, but expensive in terms of dose, time, economics etc.
- Calculation codes are very useful, but require validation and are subject to uncertainties
 - ENRESA & ENUSA doing a lot to develop models for oxide layer thickness and spalling
- One of the most important things is expert assessment of the techniques and results.



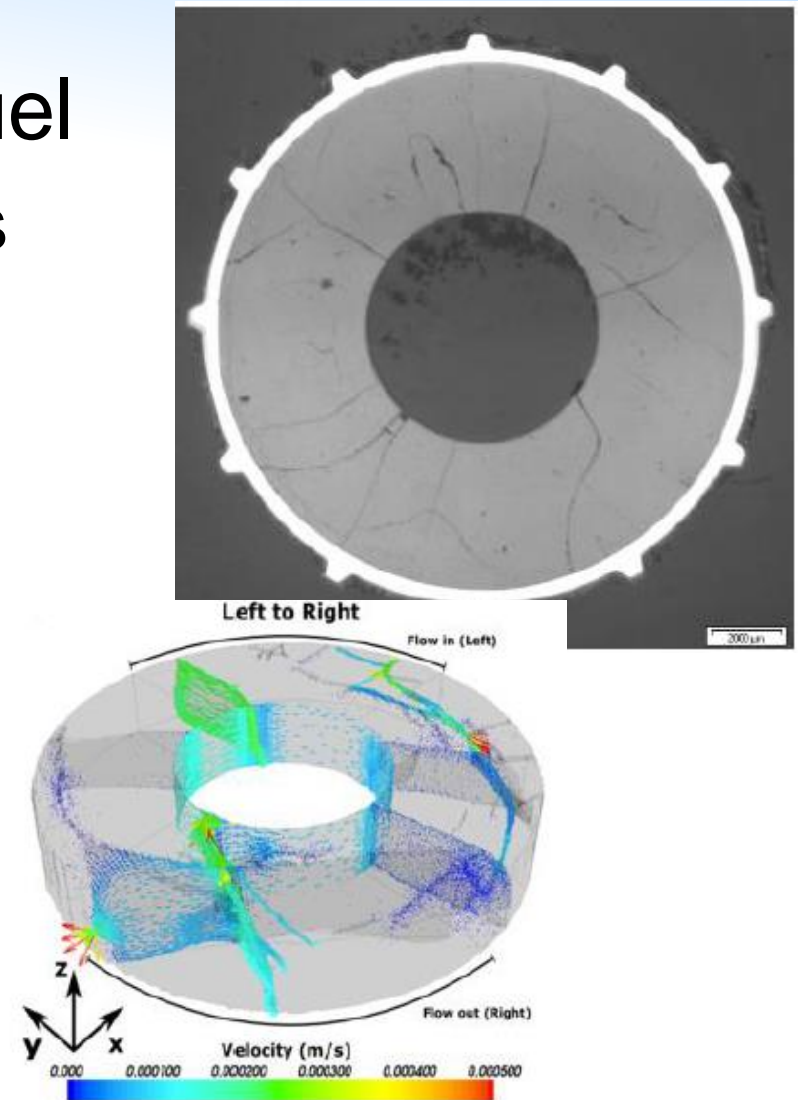
Sweden

- Once the CLINK encapsulation plant becomes operational, SKB will have to determine around 12 assemblies a day
 - Current calorimetry rig accurate to 2-3% but takes several days measurement to achieve this level of accuracy, so would need 100s...
 - Need an indirect method to obtain a reasonable level of accuracy
 - Data will cover both safeguards and disposal requirements
- Investing a lot of effort in development and use of NDA techniques
- Providing data for international collaboration, such as SKB-50 and Blind Test Exercise



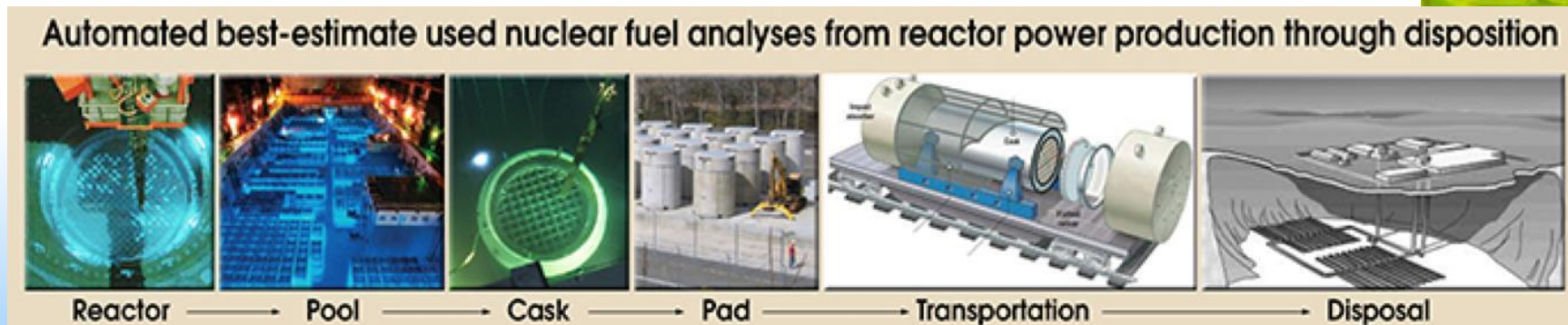
United Kingdom

- Extensive experience in PIE of AGR fuel
 - Looking at the evolution of characteristics with increasing burnup
 - Gathering data for model validation
 - Supporting long term storage
- Working towards disposal
 - Both NDA and modelling to support fuel drying
 - Characterisation for disposal



United States of America

- Sibling rod programme looking to find the information identified during the gap analysis exercise
 - Gaining data for modelling validation as DA on this scale will not be repeated
- Developing the UNF-ST&DARDS tool to provide a single comprehensive resource for SNF data that is sustainable in the long term



TECDOC Development



- A structure for the TECDOC has been drafted
- A draft of the more generic information will be available for TM participants in advance of the meeting
- A matrix has been developed to collect data from TM participants on what activities are underway in their country, and how information is determined
- The output will cover the what, why, how, use and who, as well as providing a reference for technique availability and development in Member States
- Anticipated that draft will be completed for mid-2020
 - Publication hopefully end 2020

What data do you need?

- First step to determine what data is required
- Data can either be:
 - Base
 - Intrinsic information that comes with the fuel post-irradiation
 - Derived
 - Calculated parameters (dose, criticality etc.)
 - Measured
 - Obtained from examination of the fuel

Why do you need the data?

- What has to be known for the different steps?
 - Storage
 - Transport
 - Disposal
- What data is essential?
- What data is 'nice to have'?
- Is the primary base data good enough?
- At what stage is it too late to obtain certain data?

How do you get the data?

- **Destructive analysis**

Can give definitive results, but such techniques are investment intensive and require specialist facilities not available to all Member States

- **Non-destructive analysis**

More widely available and depending upon the techniques, analysis can be undertaken at the fuel location

- **Performance modelling**

Enables analysis to be undertaken with no requirement to handle the fuel and incurs a much-reduced cost. However, the codes require validation through experimental means to ensure their reliability

How do you use the data?

- A population of spent fuel is not homogenous and its characteristics are dependent on several factors
- As such, the application of the analysis and modelling results have as much importance as the results themselves
- How do you ensure you can develop and maintain the capability and skills in the area, especially considering the length of time that may lapse between fuel cycle steps?

Who will use the data?

- Fuel vendors, utilities, waste management organizations may have different requirements for data at different times
- What may be surplus to requirement at one stage may be necessary at a future stage of spent fuel management
 - How do you ensure data is not lost?
 - How do you ensure data can be shared among stakeholders?

Coordinated Research Projects

- Bring together research institutes in MSs to collaborate on research topics of common interest
 - Usually around 10-15 institutes in a CRP
- Project duration is around 3-5 years
 - Output is a TECDOC to disseminate knowledge gathered
- Two types of participation available
 - Research agreements
 - Research contracts

See <https://www.iaea.org/services/coordinated-research-activities> for more information on CRPs and to apply

NFCMS-SFM CRPs



Spent Fuel storage activities usually conducted via CRPs:

- **DEMO:** Demonstrating Performance of Spent Fuel & Related Storage System Components during Very Long Term Storage (2013-2016)
- **SPAR-IV:** Spent Fuel Performance Assessment & Research Phase IV (2016-2020)
- **AMP-DSS:** Ageing Management Programmes for Dry Storage Systems (2016-2021)

CRP Development



- Other output from Technical Meeting is a proposal for a Coordinated Research Project on SF Characterization
- First RCM to be held to align with EURAD WP8 meeting 2021
 - Two further meetings will be held at 12 month intervals
- Aim is to complement EURAD WP8 scope and widen participation from non-EU Member States active in the area
 - E.g. Argentina, Canada, RoK, Russian Federation, USA....

Meetings could be structured as **International Workshops**

BEFAST/SPAR: 30+ years of operational experience and R&D

2014



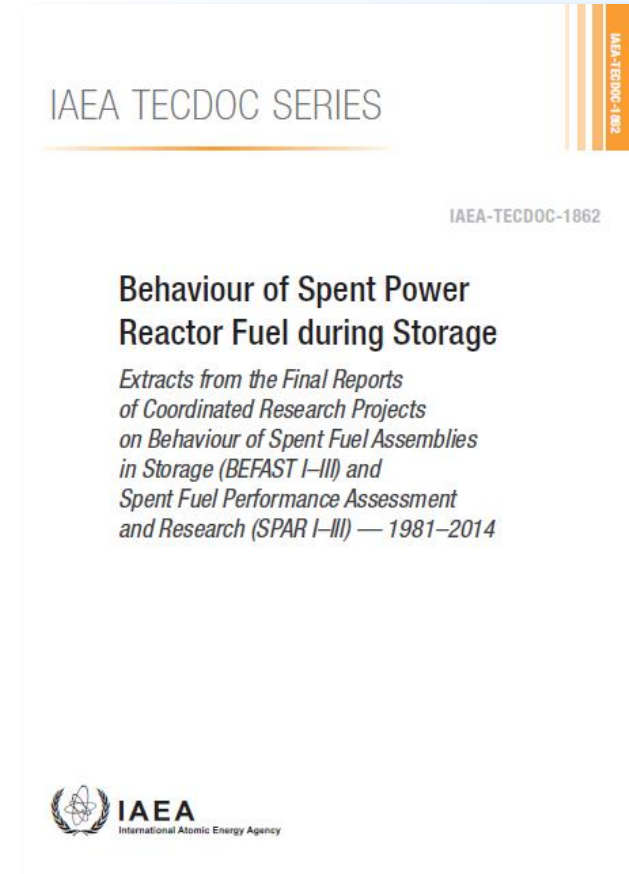
CRP SPAR-I
1997-2001



CRP SPAR-II
2002-2008



CRP SPAR-III
2010-2014



1981



CRP BEFAST-I
1981-1985

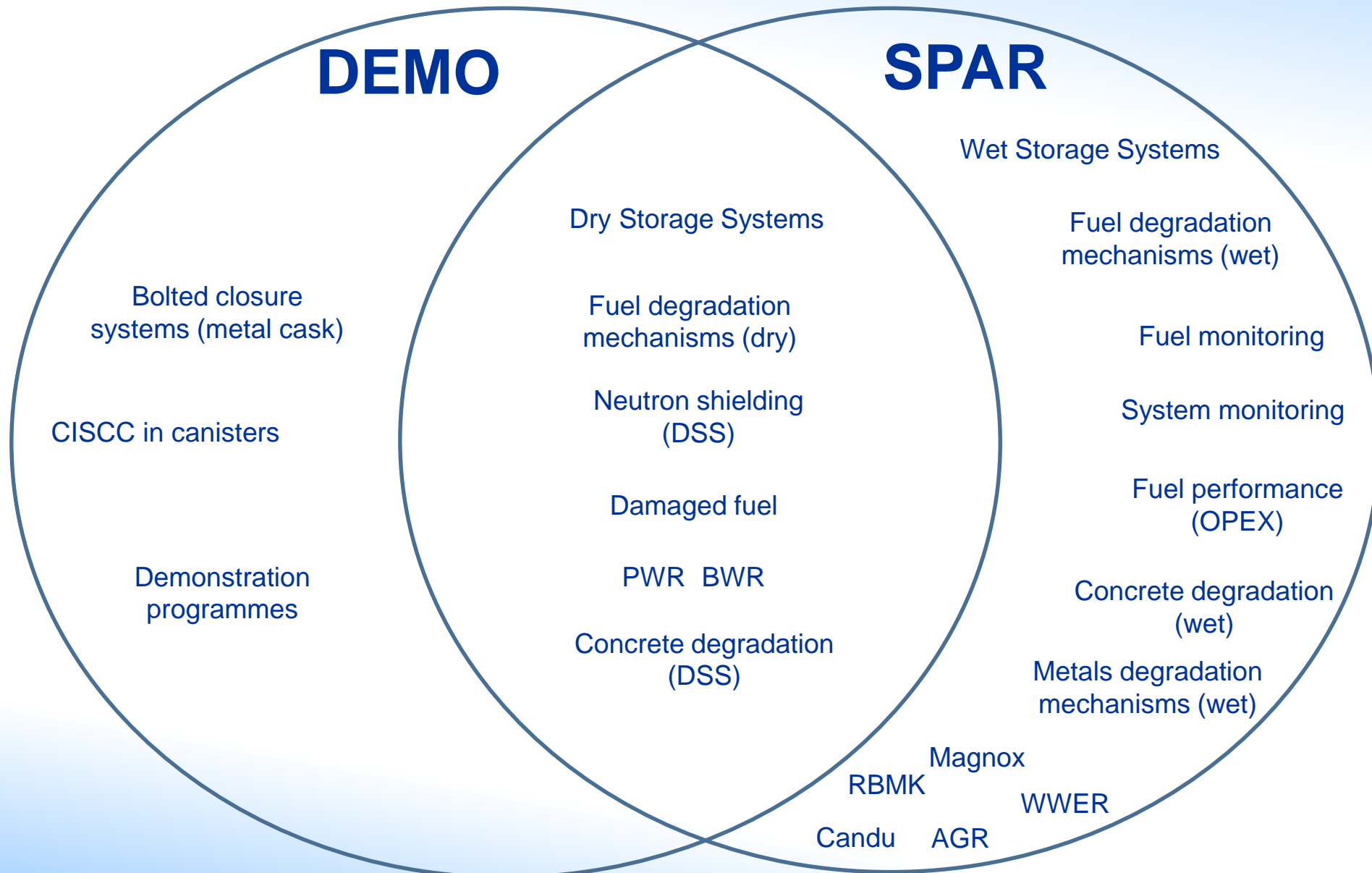


CRP BEFAST-II
1986-1991

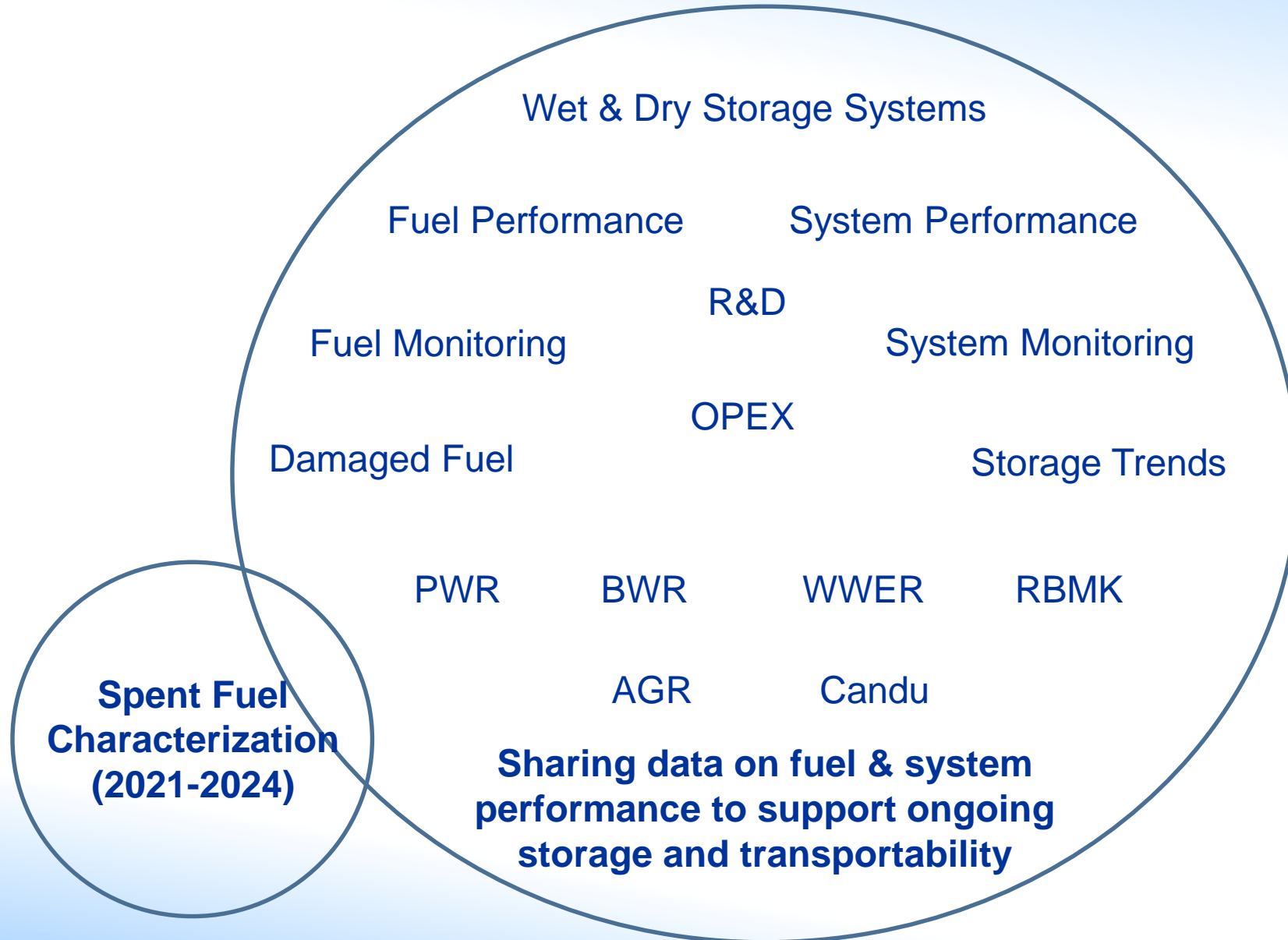


CRP BEFAST-III
1991-1996

DEMO vs SPAR



DEMO and SPAR hybrid (2021-25)





IAEA

International Atomic Energy Agency
Atoms for Peace and Development



Thank you!