

Overall Objectives

Technical Meeting on Back End of the Fuel Cycle Considerations for Small Modular Reactors

Vienna, 20-23 September 2022

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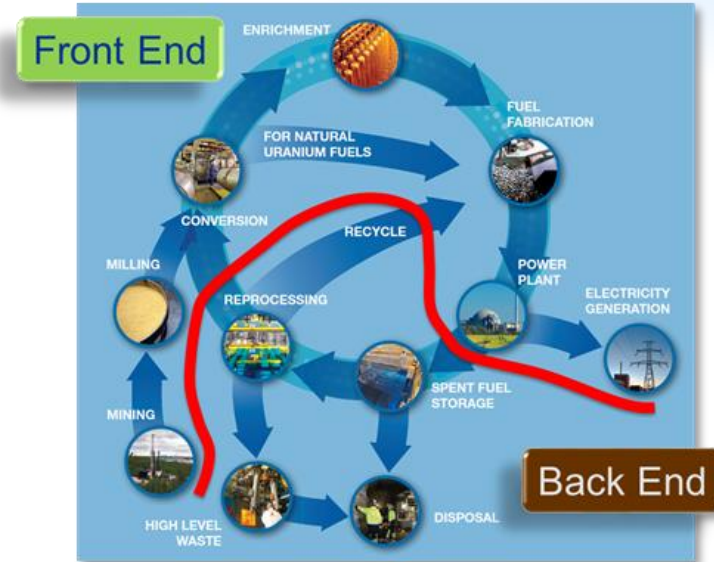
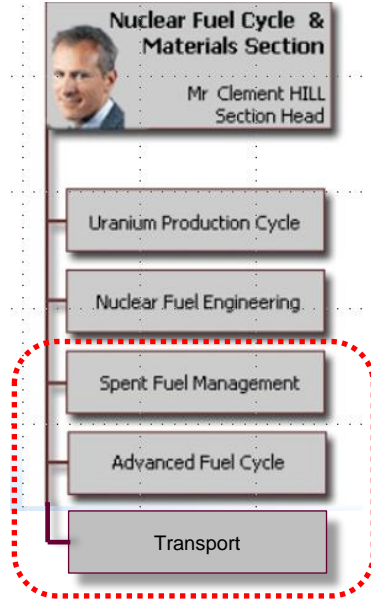
Team Leader Spent Fuel Management

Nuclear Fuel Cycle and Materials Section (NEFW-NFCMS)

IAEA Nuclear Energy Department



Scope of the Spent Fuel Management Team



Each Type of Reactor has an Associated Nuclear Fuel Cycle

Technical Working Group on Nuclear Fuel Cycle Options and Spent Fuel Management (TWG-NFCO)



20 Member States (Belgium, Canada, China, Finland, France, Hungary, India, Japan, RoK, Mexico, Netherlands, Romania, Russia, Spain, Sweden, Slovakia, UK, UAE, Ukraine, USA) and **Three International Organizations** (EC, OECD/NEA and WNA)

TWG-NFCO focuses on nuclear fuel cycle options with an emphasis on:

- Spent fuel management (storage, recycling and transportation)
- Innovative fuel cycles (multirecycling, minor actinides management and P&T of long-lived fission products)
- Nuclear materials management



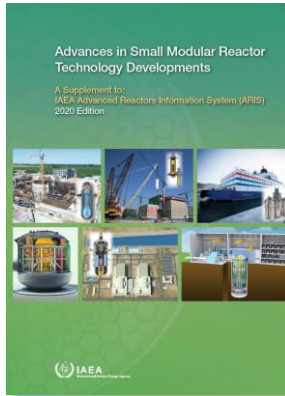
May 2022

Conclusions from the TWG-NFCO Session on SMRs Meeting in 2019



- *“There is very good potential that small modular reactors (<300 MW) could be deployed over the next decade and the IAEA has several Sections looking into several different aspects of SMR deployment, including reactor concepts, engineering, economics, infrastructure, safety, etc.*
- *However, fuel cycle and in particular spent fuel management from SMRs does not appear to be a topic of investigation.*
- *While SMRs that are of similar design and use similar fuels as reactors that are in operation today (for example LWRs) would be able to leverage on lessons learned and experience already gained, other designs of reactors using different fuel types may face challenges.*
- *The next update of the Advances in Small Modular Reactor Technology Developments Report should consider technologies for managing SNF from SMRs including the back-end infrastructure that would be needed to support SMRs (e.g. transportation, storage, recycling, and disposal technologies)*
- *Nuclear fuel cycle aspects, in particular the back-end, should be integrated into all IAEA working groups that are looking at SMRs.*
- *The fuel cycle costs should be considered into economic investigations of SMRs.”*

IAEA on Booklet SMRs Designs



IAEA SMR Booklet, 2020 Edition	
Number of reactor designs:	72 (16 more than in the 2018-edition)
Member states involved:	18 countries
Reactor types included:	<ul style="list-style-type: none"> Water-cooled Land Based Water-cooled Marine Based High Temperature Gas cooled Fast Neutron Spectrum Molten Salt Microreactors Test Reactors (HTGR only)
Distinguishing features	<ul style="list-style-type: none"> Special coverage for the first time on fuel cycle approach, waste management and disposal plan Insightful annexes with various charts and tables Microreactors
Status	Published, limited hardcopies available
Downloadable version	https://aris.iaea.org/Publications/SMR_Book_2020.pdf

Fuel Cycle Approach Categories	SMR designs by type of coolants and technology characteristics				
	Water-cooled Reactors	HTGRs	Liquid-metal cooled and Fast Reactors	Molten Salt Reactors	Microreactors
Open Fuel Cycle	CAREM, ACP100, SMART, NuScale, CANDU-SMR	HTR-PM, GTHTR300, PBMR, GT-MHR, Xe-100, SC-HTGR	EM ²	Integral MSR, SmTMSR-400	All designs
Close Fuel Cycle	SHELF		BREST-300-OD, 4S, SVBR-100	FUJI, LFTR, CA Waste Burner (later generation), and MCSFR	eVinci®, MoveluX
Longer Refuelling Cycle > 24 months	SMART, HAPPY200, ABV-6M, RITM-200, SHELF	HTR-PM (online refuelling), GTHTR300	MicroURANUS, W-LFR, SEALER and EM ²	CA Waste Burner	
Enrichment < 5%	CAREM, NuScale, VBER, NUWARD and ACPRS05			Integral SMR Stable Salt Reactor	MoveluX
5% ≤ Enrichment ≤ 15%		HTR-PM, PBMR, GTHTR300	BREST-300-OD, 4S, EM ² , ARC100, Superstar	ThorCon	Energy Well
Enrichment > 15%	KLT-40S, RITM, SHELF, ABV-6M	MHR-T, MHR-100, GT-MHR, SC-HTGR, Xe-100,	SVBR, SEALER, LFR-TL-X, W-LFR	ThorCon	eVinci®, Aurora, MMR
Spent Fuel Processing and Conditioning			BREST-300-OF, 4S, SVBR	SmTMSR-400	
Use of Thorium-cycle and/or Plutonium Disposition		HTMR-100, GTHTR300, GT-MHR, SC-HTGR, and possibly for all	LFR-AS-200, Superstar	FUJI, LFTR, Integral MSR, CA Waste Burner, ThorCon, Moltex SSR and SmTMSR-400	
Use of Spent Fuel as Fuel		GTHTR300	BREST-300-OD	Moltex SSR and CA Waste Burner	

Consultancy Meeting on Backend of the Fuel Cycle Considerations for Small Modular Reactors



IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Consultancy Meeting to Develop Programmatic Activities on the Back End Technological Options for the Fuel Cycles of Small and Modular Reactors

Virtual Event

9 – 11 March 2022

Ref. No.: EVT2002185

Information Sheet

17 experts from

- Canada
- China
- Denmark
- France
- India
- JRC (EC)
- Japan
- Romania
- Russia
- UK
- USA

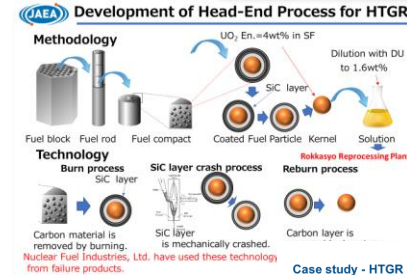
Small Modular Reactors in Canada

- SMR Roadmap and Action Plan by NRCan.
- Significant to off-grid energy applications – remote communities, mining operations, etc.
- Technologies under development by private vendors.
- SMRs – Once through cycle (near term), partially or fully closed fuel cycle (long term) that would require reprocessing.
- Requirements of enriched fissile materials, such as LEU and HALEU instead of natural U.
- Technology selections influenced/driven by market pull.



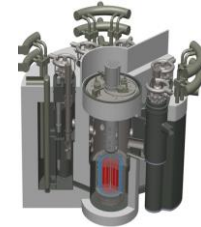
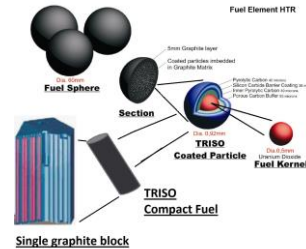
Canadian Nuclear Laboratories

2022-03-02



Identified Spent Fuels from SMR Types

- LWR-type SMRs (Land based): Enrichment levels of below 5% are similar to conventional PWRs
- LWR-type SMRs (Marine based): Enrichment levels up to 20% (HALEU)
- HTGR-type SMRs: Pebble Beds/Prismatic Limited Backend Experiences
- Advanced Reactors (Fast Neutron SMRs): New fuel types introducing a new spent fuel characteristics/multirecycling processes
- Molten Salt SMRs: Nuclear fuel dissolved in melted chloride/fluoride fuel salts. Recycling of fissile material and managing salt mixtures containing all fission products is a challenge



Technical Meeting on Backend of the Fuel Cycle Considerations for Small Modular Reactors



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International Atomic Energy Agency
Atoms for Peace and Development

Technical Meeting on Back End of the Fuel Cycle Considerations for Small Modular Reactors

IAEA Headquarters, Vienna, Austria
and virtual participation via Cisco Webex

20–23 September 2022

Ref. No.: EVT2105850

Information Sheet

~ 120 Nominated Experts from
36 Member States and 2
International Org. (EC and
OECD/NEA)

~ 40 Presentations and
Extended Abstracts

Overall Objectives of the TM

- To share technical information on the management of spent nuclear fuel from the operation of SMRs
- To anticipate related opportunities/challenges/issues
- To identify infrastructures and knowledge gaps
- To identify the potential ways to move forward in addressing them in the near, medium, and long term

Expected Outputs

- To prepare a report compiling **extended abstracts/technical papers** capturing the state of the art, discussions during the event, and recommendations for future activities on SMR nuclear fuel cycles from a spent fuel management perspective
- Focused on:
 - potential synergies among different SMRs' fuel cycle options
 - gaps with the current technologies in place
 - opportunities/challenges for the different stages of the back end of the fuel cycle
 - enablers for implementation
 - new infrastructures and R&D needs

Extended abstracts/full papers guidance



1. Foreseen options for SFM for the SMR type(s) of interest in the country
2. Integration of the foreseen SMRs nuclear fuel cycle strategy in the current nuclear fuel cycle strategy for LWRs with the focus on spent fuel management (for countries with a nuclear power programme; and for countries thinking of developing different SMR technologies, integration of various systems will be required)
3. Gaps and opportunities between the foreseen strategy for SMRs and the current one for LWRs and how might fuel cycle strategy be modified by the adoption of SMRs
4. Needs and enablers for developing and implementing the foreseen strategy for managing SMRs spent fuel, including needs in infrastructures (at national and/or international level)
5. R&D needed to support the development and implementation of the foreseen strategy for managing SMRs spent fuel
6. Challenges and issues for SMRs spent fuel transportation

Discussion Points for the Break Out Sessions on Thursday

Sessions in the Agenda



- Tuesday 20: International perspective
 - IAEA setting the scene with activities in different related fields (SMR designs, spent fuel management, safety, security, economics, safeguards, transport, etc)
 - OECD/NEA
- Wednesday 21: Member States Approaches (*continuing Thursday morning*)
- Thursday 22: Three break out sessions by technologies LWRs (land and marine), HTGRs, ARs + MSRs
 - to identify and discuss gaps/challenges/opportunities for implementing Back End of the Fuel Cycle of SMR Technologies
- Friday 23: General discussions on
 - Conclusions from Break Out Sessions
 - General Discussion on cross-cutting issues
 - Potential future IAEA activities, collaborations and path to move forward

Chairperson and Co-Chairs/Reporters



- Chairperson: Ms Cecile Evans (France)
- Co-Chairs/Reporters:
 - ❖ Mr Suren Bznuni (Armenia): Session on Tuesday after lunch break with IAEA information and International Perspectives
 - ❖ Mr Andrea Salvatores (France): Session on Wednesday morning until lunch-break
 - ❖ Mr David Hambley (UK): Session on Wednesday afternoon from lunch-break to adjourn
 - ❖ Ms Fatmah AlMomani (Jordan): Session on Thursday morning until the breakout sessions
 - ❖ Mr Jorge Narvaez (USA): Session on Thursday afternoon after the coffee break, when we all will gather after the break out sessions



Thank you!