Potential Impacts of SMRs on Multinational Cooperation at the Back End of the Fuel Cycle

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Context & Purpose

<u>Why was the study initiated?</u>

- Significant effort has been made to develop SMR technologies, but…
  …there has been relatively little focus on SMR back end / global RWM impacts and challenges.

- **<u>ERDO</u>** aims to address common RWM challenges collaboratively, including disposal in an MNR.
  - Widespread adoption of SMRs could present new common RWM challenges.
  - SMR waste would require disposal, potentially in an MNR.

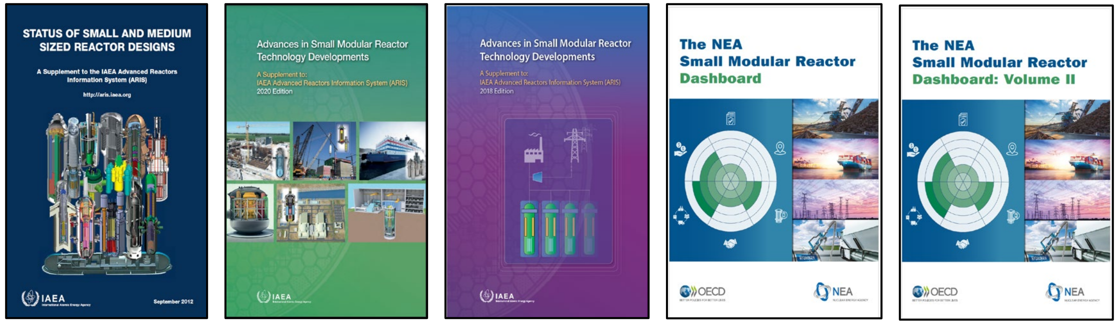
- **<u>(Inter-)governmental and policy organisations</u>** are interested in global RWM safety and security.
  - Widespread adoption of SMRs could present safety and security challenges.
  - Multinational disposal solutions are seen as a potential mitigation to such challenges.

<u>What was the purpose of the study?</u>

- To consider the multinational aspects of the potential technical and strategic, political and commercial impacts of SMR commercialisation (adoption / deployment) on the back end of the nuclear fuel cycle, including deep geological disposal and MNR projects.

Approach

- Many SMR designs in the open literature…



- We review publications / news articles to determine global interest in SMR designs
- We identify 22 credible designs across 5 generic reactor types
- We down-select 1 SMR design per reactor type, based primarily on data availability:

Reference Large PWR	**Pressurised Water SMR**	**High Temperature Gas-cooled SMR**
Sodium Fast SMR	**Molten Salt SMR**	**Heat Pipe-cooled SMR**

- We define **national** scenarios based on:
  - Disposal programme plans & inventory diversity
  - Nuclear fuel cycle facilities & expertise
  - Installed & desired nuclear capacity (GWe)
- We define **MNR** scenarios based on:
  - MNR by partnership
  - MNR as a commercial venture
  - Variation of nation types (nuclear / non-nuclear)
  - Reactors (all same SMRs / mix of SMRs / etc.)
- For **national** & **multinational** scenarios, we consider SMR deployment implications on:
  - Disposal feasibility
  - Upstream complexities & opportunities
  - Research, development & demonstration

Impact on RWM

We assess SMR vendor plans for once through **upstream (pre-disposal)** activities.

When compared with conventional reactor RWM, common requirements for SMR designs include:

- Regulatory engagement to licence a 'new' activity e.g. transporting HEU fuels.
- Addition of steps e.g. SFR sodium cleansing.
- Adaptation of steps e.g. transport of irradiated reactors to central facilities avoids on site RWM activity, but introduces challenges and/or concerns for transport regulation, safeguards, etc.

Many required activities are established. Others are complex, but precedent exists e.g. sodium coolant, salt fuel-coolant, but likely require much RD&D to upscale for commercialisation.

Increased distribution of reactors will add logistics infrastructure complexity (facilities, throughput, skills) & add security and/or safeguards challenges.

We assess the impact of SMR designs on **disposal**:

- Activated metals will require geological disposal. LWR & SFR wastes likely won't require changes to DGR scale, concept or approach.
- Large volumes of activated graphite e.g. in HTGR TRISO particle fuels would increase the need for disposal-related RD&D.
- Significant uncertainty around MSR fuel-coolant.
- We define topics to specifically assess SNF disposability and use this in our scenarios:

	SMR Reactor Type				
	PWR	HTGR	SFR	MSR	HPR
Volume					
Decay Heat					
Fissile Content					
Waste Packaging					

Least challenging
In between
Most challenging

Impact on National Programmes

Countries with medium / large NP programmes:

- Most likely to have large inventories / mature DGR programmes, and therefore most likely to be able to 'absorb' SMR SNF.
- Likely disposal cost efficient to align SMRs with existing technologies (similar reactor types).

Countries without / with small NP programmes:

- Implementing identical / similar SMR designs being deployed in other similar countries could be an incentive for enhancing cooperation on pre-disposal and disposal activities.

Non-nuclear nations with minimal NP plans likely strongly motivated to look at MNRs, avoiding DGRs.

- Most likely to be benefit from market-led solutions, e.g., SNF take back.
- Likely to benefit most from deep borehole disposal (if suitable) given flexibility over MNRs.

Non-nuclear nations with ambitious NP plans are well placed to become SMR / MNR leaders, as a large investment / need for a DGR are a given:

- Less conventional SMRs may be more viable if drivers exist.
- Better placed to host a commercial MNR, as can build into DGR plans / boundary conditions.

Impact on Multinational Collaboration

- Widespread SMR deployment is likely to result in more nations with small inventories of waste requiring geological disposal.
  - This is likely to increase interest in MNR implementation given economics involved.
- DGR & MNR technical constraints are mostly the same, but scheduling of MNR waste arrivals will need careful management / planning:
  - e.g. significant storage facility to accommodate varied waste arisings.
- Complexities could be mitigated if MNR participants extend collaboration upstream.
  - But extra regional / global transport needs added for upstream collaboration.
- Widespread SMR deployment and the transport infrastructure required for an MNR heighten security and safeguards concerns.
- An MNR is more likely to need to be able to dispose of SNF from multiple different SMRs.
  - This adds complexity / cost over an DGR (or MNR) disposing of one SNF type.
- Cross-national legal & regulatory compliance would add complexity in each case.
- Interest in SMRs could potentially help with public engagement for MNR implementation.

Impact on Multinational Collaboration

MNR development as a commercial venture

- Commercial MNRs would benefit from designing systems able to handle a range of SMR wastes.
- Additional up-front costs expected when compared to adopting existing DGR design / safety case / operational procedures.

MNR development through partnership

- Countries involved likely motivated to align SMR technology selection & SMR deployment / scheduling.
- Establishing regional ERDO-like organisations could be an enabler to partnerships

Overall Conclusions

- SMR deployment could make MNR development more likely and could help with public engagement and acceptance.
- Technical / security / safeguards concerns will need to be dealt with for SMR deployment, so not unique challenges to MNRs.
- Biggest MNR challenges likely to be upstream alignment, scheduling of waste transports, varied regulatory regimes and the legal status of exporting radioactive waste for disposal.

Outlook

There is primarily benefit in more & closer collaboration between SMR vendors & disposal solution development organisations.

Specific boundary conditions and scenarios would help to improve on generic conclusions made using generic boundary conditions and example scenarios.

This would enable a full understanding of the back-end impact of SMR designs and potential collaboration in MNR projects.

Potential for Follow-on Activities

- Systematic assessment of MNR upstream collaboration implications, involving SMR vendors and WMOs as part of the process.
  - Disposal containers able to accept various wastes could aid MNR collaboration.
  - An LCA focused on collaborative scenarios could highlight unique challenges of upstream RWM collaboration.
- Exploration of potential mechanisms through which an MNR implementation organisation could emerge.
- Establishing global communities for regional consideration of RWM / MNR collaboration.
  - ERDO is the only active organisation dedicated specifically to collaboratively addressing common RWM challenges.
  - Other regions increasingly interested in NP e.g. ASEAN, African Union.

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