The Potential Impacts of SMRs on Multinational Cooperation at the Back-end of the Fuel Cycle

Charles McCombie* Neil Chapman*

Jake Kinghorn-Mills * *

*Secretariat ERDO Association

* * MCM Environmental

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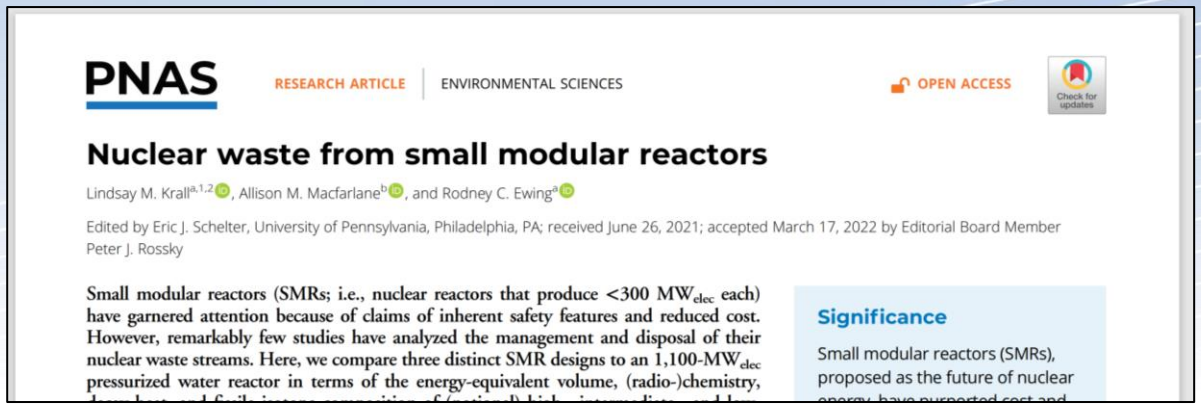
SMRs: key questions

- What are the pros and cons?
  - –Safety, Financing, Implementation times, Costs
- Are the potential advantages proven?
- Are they a “game changer” for the future of nuclear power?
- Are there too many competitors?
- **How might they affect back-end challenges *(“the unsolved waste disposal problem”*)?

Some controversy on waste generation in SMRs



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Nuclear waste from small modular reactors

Lindsay M. Krall[a,1,2], Allison M. Macfarlane[b], and Rodney C. Ewing[a]

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Small modular reactors (SMRs; i.e., nuclear reactors that produce <300 MW_{elec} each) have garnered attention because of claims of inherent safety features and reduced cost. However, remarkably few studies have analyzed the management and disposal of their nuclear waste streams. Here, we compare three distinct SMR designs to an 1,100-MW_{elec} pressurized water reactor in terms of the energy-equivalent volume, (radio-)chemistry,

Significance

Small modular reactors (SMRs), proposed as the future of nuclear

NOTE: more or less spent fuel to be disposed of makes little difference to policy – but NO need for SF disposal is a major change

But other issues more crucial in determining SMR prospects

SMRs: a big game changer?

Could small modular reactors be a game changer in nuclear energy's contribution to tackling climate change? **Charles McCombie, Robert Budnitz, Noura Mansouri, H-Holger Rogner, Robert Schock** and **Adnan Shihab-Eldin** examine the market, barriers to deployment and what is needed to overcome them

International and national interest in SMRs is WIDE

European SMR pre-Partnership

- Organised by the European Commission's DG ENER in response to the call of the European nuclear industry; 110 participants from 22 Member States
  - WS1 Market analysis
  - WS2 Licencing
  - WS3 Financing
  - WS4 Supply chain adaptation

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IAEA: Intensive activities related to SMRs

- IAEA Platform on Small Modular Reactors (SMRs) and their Applications
  - SCORPION: SMR Coordination and Resource Portal for Information Exchange, Outreach and Networking
- New TC Interregional Project: Supporting Member States' Capacity Building on Small Modular Reactors and Microreactors and their Technology and Applications; Period: 2022 – 2025
- Small Modular Reactor (SMR) Regulators' Forum
- Technical Working Group for Small and Medium sized or Modular Reactors (TWG SMR)

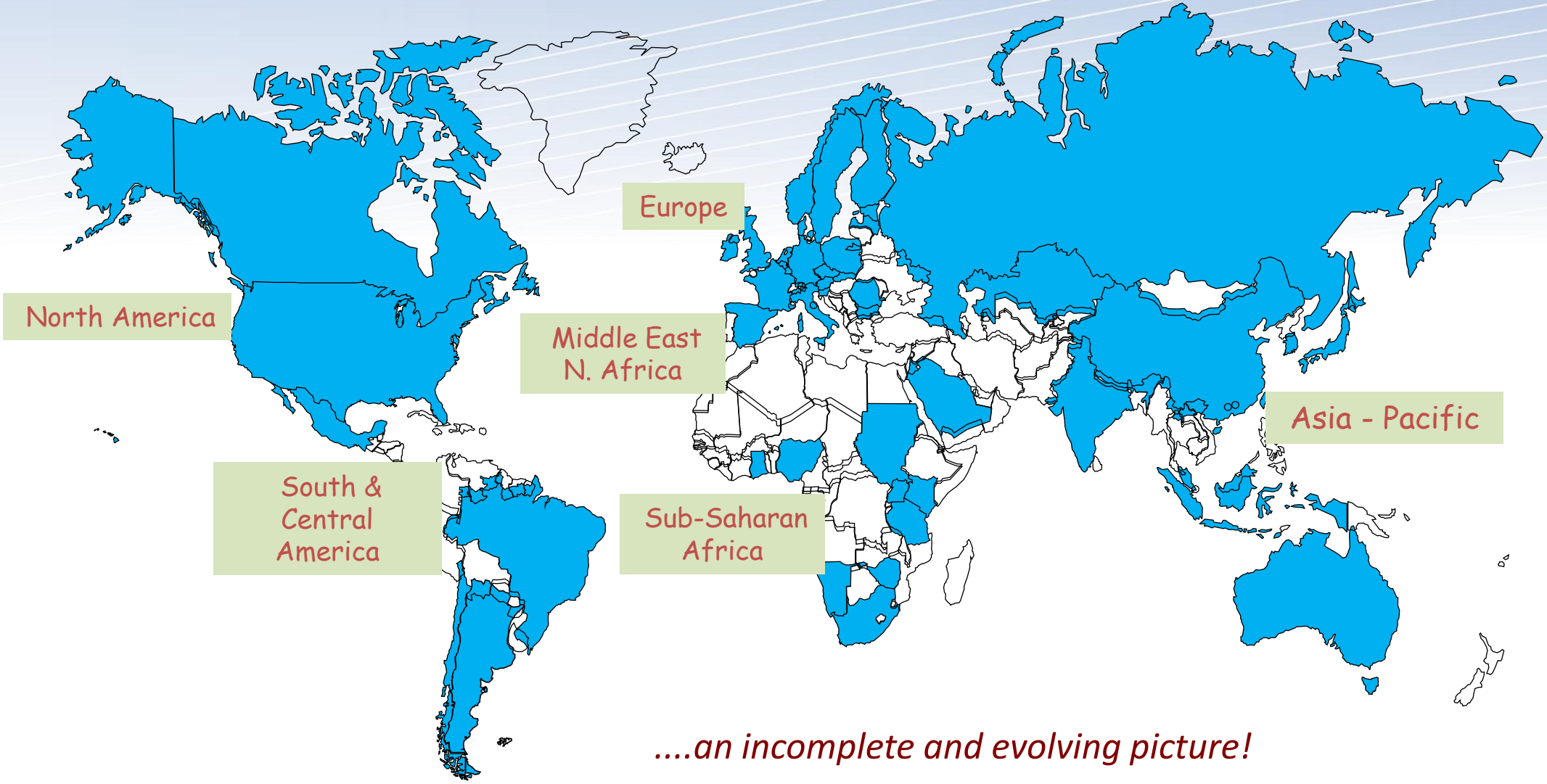
WHY DO WE NEED ANOTHER PROJECT?

Country	Current Interest in SMRs
All ERDO countries	Interest in the implications for multinational cooperation at the back-end if SMRs are widely adopted
Poland	A Polish company has signed an agreement with US startup for the potential construction of 10 small nuclear reactors with a total capacity of 200 MW
Denmark	A Danish nuclear technology company is developing floating nuclear power plants based on its compact molten salt reactor (CMSR).
Belgium	The SCK-CEN nuclear research centre will receive funding from the federal government to conduct research into SMRs..
Netherlands	Minister announced that more nuclear power may join solar and wind in the Dutch energy mix after 2030, in particular SMRs. Rolls-Royce SMR has signed an agreement with Dutch company to deploy SMRs in the Netherlands.
Norway	The Institute for Energy Technology has awarded a contract for the development and supply of a simulator based on SMRs
Italy	Participates in the EU project “innovative approach to the safety and licensing of SMRs”. UK-based developer has agreement with ENEA to cooperate on the development of small, lead-cooled fast reactors.
Slovenia	Currently no specific official national plans for SMR. Permit for Krško Nuclear Power Plant 2 (1100 MWe)
Croatia	

European SMR Interest also in:

Czech Repiblic
Estonia
France
Bulgaria
Romania
Sweden
Turkey
United Kingdom
…….

Potential SMR end-user nations and potential regional back-end groupings



....an incomplete and evolving picture!

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USDOE-ERDO SMR Project Drivers

- Lots of work on reactor design, fuels etc. for SMRs; relatively little work on back-end
- BUT, acceptance of nuclear is/has been strongly affected by disposal issues
- ERDO focuses on where/how/when multinational cooperation could ease back-end challenges
- USDOE International Programme has long supported multinational cooperation: INPRO, IFNEC, Study on Jordan Dual Track Policy, Arius, ERDO
- New Project: The potential impacts of SMRs on multinational cooperation at the back-end of the fuel cycle.

USDOE-ERDO Project Phase 1: Technical Issues

- SMR technologies and suppliers: focus on current and likely near-future deployable SMR technologies.
- SMR fuel characteristics: evaluation of the characteristics of the spent fuel produced by the numerous proposed SMR designs
- SMR fuel disposability: comparison of SMR fuel characteristics relevant to their disposability.
- SMR operational and decommissioning wastes: a scoping assessment of the types and amounts of fuel and wastes generated
- SMR impacts on management of a national nuclear fleet

USDOE-ERDO Project Phase 2: Strategic Issues

- Strategic aspects of the international SMR market: evaluation of potential supply and demand
- Costs of SMR fuel waste management: preliminary evaluation of the likely cost implications of disposal of SMR fuels.
- **Impact of SMRs on MNR planning**: assessment of how a shared or a commercial MNR project could be impacted in terms of concept/design, economics and scheduling if a number of users were to require disposal of SMR fuels and wastes.

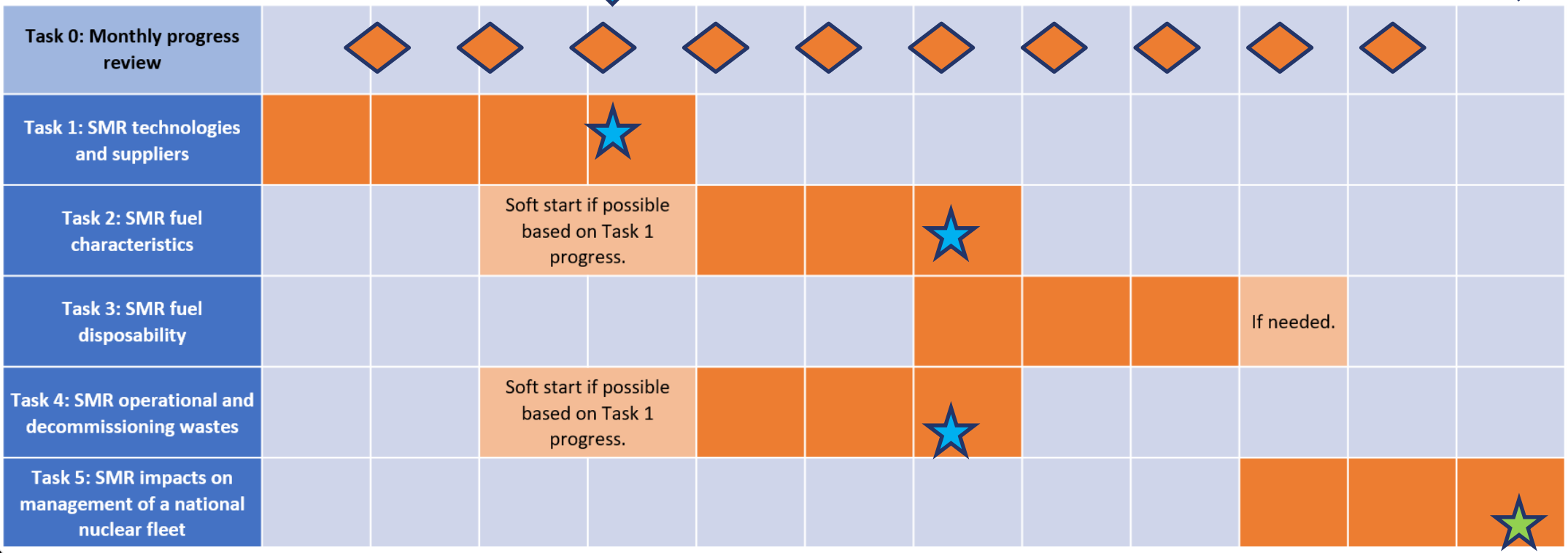
Stage 1 – SCHEDULE

Formal Deliverable
- Fully QA'd written report suitable for peer review and publication
- Outputs from other Stage 1 Tasks

Informal Deliverable

Informal Deliverable.

Start Sept 2022



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POTENTIAL IMPACTS OF WIDESPREAD SMR ADOPTION 1/2

- Pressure by vendors and customers may make spent fuel “take-back” of spent fuel become more probable
- Renewed interest in the commercial service provider approach – in a SMR producer country, a user country or even a non-nuclear country
- The security issues associated with numerous countries possessing one or a few SMRs may strengthen international support for implementation of a large and secure multinational repository.
- Note: Existing nuclear countries with small programs could benefit from the “take back” option only if the spent fuel from their existing plant(s) could also be exported.

POTENTIAL IMPACTS OF WIDESPREAD SMR ADOPTION 2/2

- Multiple SMR customers of the same design may cooperate on developing SNF conditioning and packaging approaches
- Suppliers of SMRs – especially those with novel fuel cycles – may be interested in building multinational “user groups”
- Major established disposal programmes may see opportunities in accepting relatively modest amounts of SF from new SMR countries
- Take back: new nuclear countries are more likely to order an SMR if the supplier takes back the module or the SNF
- Suppliers of SMRs may exert pressure on their home countries to accept return of core modules or of SNF elements

Impact of SMRs on Global Nuclear Policies?

- National nuclear policies may also be affected.
- Existing nuclear countries may complement their fleets by introducing distributed SMRs fulfilling various functions (process heat, district heating, etc.)
- SMRs may enhance the “image” and the acceptability of nuclear power so that large NPPs also become more acceptable
- If the “waste disposal problem” is removed by a take-away offer, then non-nuclear countries might reconsider the nuclear option. (Examples are Singapore, Philippines, Baltic States, Indonesia,…..)

Conclusions

- Enthusiasm for SMRs is high and global – in existing and newcomer nuclear countries
- Many of the potential advantages have yet to be demonstrated
- Impacts on spent fuel management and disposal are barely explored
- Concentrating these tasks at fewer sites can improve safety, security and economics
- The established drivers for multinational repositories (MNRs) are becoming stronger

The End

TWG-SMR established in Q1/2018

Argentina Comisión Nacional de Energía Atómica (CNEA)	**Australia** Australian Nuclear Science and Technology Organisation (ANSTO)	**Canada** Canada's National Nuclear Laboratory (CNL)	**China** Tsinghua University
Finland VTT Technical Research Centre	**France** Commissariat à l'énergie atomique et aux énergies alternatives (CEA)	**India** Bhabha Atomic Research Centre (BARC)	**Indonesia** National Nuclear Energy Agency (BATAN)
Iran Atomic Energy Organization of Iran AEOI	**Italy** Politecnico di Milano POLIMI *(The Chair for 2018 – 2021)*	**Japan** Japan Atomic Energy Agency (JAEA)	**Jordan** Jordan Atomic Energy Commission (JAEC)
Kenya Kenya Nuclear Energy Board (KNEB)	**Republic of Korea** Korea Atomic Energy Research Institute (KAERI)	**Pakistan** Pakistan Atomic Energy Commission (PAEC)	**Russian Federation** OKBM Afrikantov
Saudi Arabia King Abdullah City of Atomic and Renewable Energy (K.A.CARE)	**South Africa** Department of Energy	**Ukraine** Energoatom	**United Kingdom** Department for Business, Energy and Industrial Strategy (BEIS)
United States of America, Department of Energy (DOE)	**Morocco** *Office National de l'Electricité et de l'Eau Potable (ONEE) - Observer*	**EC-JRC** *Observer*	**OECD-NEA** *Observer*

Members: 21 countries = 15 countries with nuclear power + 6 countries without nuclear power including embarking countries;
Observers: 1 country (Morocco), 2 international organizations (EC-JRC, OECD-NEA)