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E-mail: asa.thelander@iko.lu.se, asa.ek@design.lth.se and henrik.rahm@kau.se**Keywords:** preparedness, sense making, small modular reactors, SMRs, actors, stakeholders**Abstract**

Small modular reactors (SMRs) are increasingly promoted as part of future fossil-free energy systems, yet they may introduce new types of risks and involve a broader set of actors compared to conventional nuclear power plants. The study examines how key actors in Sweden understand SMRs and interpret their roles in radiation emergency preparedness. This qualitative study is based on qualitative interviews with actors involved in emergency preparedness for potential SMR deployment, a context shaped by Sweden's recent policy shift toward expanded nuclear energy. Findings show that expectations of SMRs are generally high, and benefits tend to overshadow considerations of radiation risks. Among newcomer actors, emergency preparedness is widely perceived as an issue that can be addressed later in the SMR development process rather than as an integral part of early strategic planning. Among actors with previous experience of radiation risks, SMRs do not entail any major changes or challenges. As a result, a broad preparedness culture—including early engagement across organisational boundaries and systematic integration of radiation emergency preparedness—is not yet discernible. These gaps warrant continued attention as SMR initiatives advance.

1. Introduction

Global energy transitions have renewed interest in nuclear power as a low carbon solution. Among emerging technologies, small modular reactors (SMRs) are promoted for their flexibility, potential for lower costs, and enhanced built-in safety compared to traditional nuclear power plants. Several SMR projects are currently under development worldwide, reflecting high expectations for their potential to support fossil free energy systems. However, SMRs may also introduce distinct risks, which may vary across reactor designs and applications. Their flexibility—enabling deployment in remote regions, off-grid areas, and potentially closer to communities—raises questions about safety and radiation emergency preparedness.

In Sweden, 13 municipalities have expressed interest in hosting SMRs, as they have applied for funding for pre-evaluation from the Swedish Environmental Protection Agency. Some municipalities already have nuclear facilities, while others are newcomers with no prior experience in radiation safety or emergency planning. These developments involve a network of actors, including municipalities, energy producers, technology vendors, authorities, and civil society actors such as state rescue services (county administrative boards) and municipal rescue services. For newcomer municipalities and county administrative boards, radiation emergency preparedness, collaboration, and coordination within these networks can present challenges. Fraser Semenoff and Smith (2025) observe these challenges in Swedish newcomer municipalities, as well as a foregrounding of economic development while backgrounding risks and emergency preparedness.

In the report on milestones for developing nuclear energy, the International Atomic Energy Agency (IAEA) states that ‘an integral part of becoming ready to make a knowledgeable commitment to a nuclear power programme is the recognition of the importance and priority of safety’ (2024:17). Safety should be integrated from the beginning to the end of the process and include all organisations involved (p. 17). Actors need to make sense of the emergency preparedness process and understand risk issues and emerging risk events related to SMR technology and operations. Already in the early so-called consideration phase, actors need to understand and acknowledge their responsibility. A particular challenge for SMRs is that learning must proceed faster and organisations need to adapt more quickly due to the short construction time. Emergency preparedness extends beyond technical planning; it also involves a sociotechnical system and a mindset of preparedness. The sociotechnical system in which SMRs are embedded involves actors that in various ways will have a role in emergency preparedness. SMRs are ‘new’ in the sense that there is limited experience with planning, building, and operating them. In this early phase, it is essential to understand how the various involved actors make sense (Weick 1990) of the technology. This sensemaking is a ‘process through which individuals work to understand novel, unexpected or confusing events’ (Maitlis and Christianson 2014:58). Actors seek to clarify what the technology is, how it works, and its benefits and risks by interpreting cues from the environment. Sensemaking is based on a shared social reality grounded in common beliefs, values, and meanings. It shapes shared beliefs and informs action. Recent scholarship introduces the concept of readiness to capture this mindset in crisis management (Jin *et al* 2024), emphasising continuous, collaborative processes among diverse actors. Negotiations and the development of understanding regarding other organisations’ crisis management responsibilities, values, and ways of working are conducted in such collaborations. To date, sensemaking and preparedness among key actors in SMR deployment are underexplored.

This research study addresses this gap by examining the sensemaking of preparedness among actors involved in SMR development and use in Sweden. Specifically, it asks:

- How do the key actors make sense of SMRs?
- How do actors with and without previous experience of radiation emergency preparedness interpret their role in preparedness for SMRs?
- What are the current implications of the actors’ sensemaking for preparedness?

The study is conducted in the context of Sweden. After decades of decommissioning following the 1980 referendum, a policy shift toward nuclear energy—targeting 2500 MWe by 2035—is now in place. SMRs are part of this target. The state-owned energy producer has initiated SMR deployment plans at an existing nuclear site, shortlisting two vendors, while other producers and municipalities explore additional locations. A decision on the size of emergency planning zones is expected by 2026 or 2027. These developments involve both experienced and newcomer actors regarding radiation emergency preparedness; yet little is known about their preparedness and emergency planning.

2. Theoretical frame

The study takes a systems view on radiation safety and emergency preparedness. The system is a socio-technical system in which people, organisations, and technical artefacts are included as system elements. Sociotechnical systems are characterised by a network of complex interactions between human, technical, and organisational subsystems and across different levels within the system (Rasmussen 1997). The actors involved in the current system include authorities, state and municipal rescue services, energy producers, technology vendors, municipalities, and end users. These actors operate at various system levels and have divided responsibilities for emergency preparedness. A systems safety perspective considers safety—here, radiation safety—as an emergent property of the system. Thus, emergency preparedness is an active, continuous, and integrated process. As SMRs are still an evolving technology, the emergency preparedness discussion is in a very early preventive stage. Actors’ sensemaking of SMR emergency preparedness is central. This sensemaking is shaped by their knowledge, experience, interests, and responsibilities. Prevention and preparedness often involve coordination and cooperation between organisations. Negotiations and the development of understanding of other organisations’ preparedness responsibilities, as well as basic values and ways of working, occur in such collaborations.

Organisational radiation safety and emergency preparedness capability in safety-critical systems such as nuclear power production are related to concepts such as resilience and adaptability (Hollnagel *et al* 2011). Actors need to develop or enhance their organisational capability to act in a flexible, adaptive,

and safety-conscious manner under changing conditions. This also requires continuous learning. Aspects of resilience and adaptability relate to the concept of collective mindfulness (Weick and Sutcliffe 2007), in which ‘organisations continuously develop, refine and update a shared understanding of the situation they face, the problems defining it and what capabilities exist to ensure safe performance’ (Vogus and Sutcliffe 2007). Organisational mindfulness is a state of alertness and active awareness of reality, where problems and challenges are anticipated through openness to new information and awareness of multiple perspectives. In a sociotechnical system involving SMR operations, characteristics of mindful organisations may be both desirable and important for the planning and management of emergency preparedness. To study emergency preparedness means studying sensemaking and mental mindsets and linking them to what actors are expected to do and how to act in an emergency situation according to regulations. Perspectives on preparedness encompass emerging technology, governmental investigations of basic conditions, and actors’ orientation in a changing environment.

3. Method and empirical material

For this qualitative study, interviews were conducted with key actors engaged in preparedness for SMRs. The purpose was to develop an indepth understanding of the preparedness levels across a range of relevant organisations. The study includes actors from the nuclear industry—such as energy producers and technology vendors—as well as local and regional authorities, including municipalities, county administrative boards, and both state and local rescue services. These actors hold formal responsibilities for ensuring the safety of citizens and communities and for supporting municipalities in the potential deployment of SMRs within the Swedish context. To capture a broad spectrum of perspectives, the study included actors with and without prior experience of radiation emergency preparedness. This encompassed representatives from municipalities already hosting nuclear facilities as well as municipalities currently exploring the possibility of deploying SMRs. In all selected organisations, individuals with designated responsibility for SMR-related issues were interviewed.

The interviews were designed as semi structured conversations about SMRs (Brinkmann and Kvale 2015), guided by thematic areas including perceived benefits, risks, strengths and weaknesses of SMRs; conceptualisations of preparedness; the actors’ own roles in preparedness processes; and interorganisational collaboration. All interviews were audiorecorded and subsequently transcribed. The analytical process followed a phronetic iterative approach (Tracy 2018), with a focus on how actors engage in sensemaking regarding SMRs and emergency preparedness. To protect the anonymity and confidentiality of participants, no verbatim quotations are presented.

4. Results: actors’ sensemaking and preparedness for SMRs

From the analysis, actors make sense of SMRs in different ways. Energy producers primarily view SMRs as an additional energy source with characteristics that can strengthen their overall production portfolio. Flexibility in siting, shorter construction to operation timelines, and anticipated lower investment costs are considered key advantages. Producers with experience from conventional nuclear power mention similar advantages and are aware of associated risks, which they generally assess as lower for SMRs. They also recognise their responsibilities in future preparedness work.

Following the government’s approval of SMR deployment, new consulting firms have emerged to support companies and municipalities exploring the technology. Unlike energy producers, these companies’ business models are centred entirely on promoting SMR solutions. They emphasise flexibility and modular design while acknowledging that financing and regulatory processes remain major challenges. Preparedness issues are not yet a priority for these actors, and their role within the broader preparedness system is still undefined.

Newcomer municipalities exploring the deployment of SMRs express high expectations for the technology. SMRs are understood to secure a stable and predictable energy supply, which is expected to support regional development, attract new businesses, and enhance local competitiveness. For these municipalities, SMRs also carry symbolic value, signalling hope for economic development and population growth, as well as representing innovation and proactive engagement in national energy transitions. Risks and uncertainties are generally regarded as limited and not significantly different from those associated with other energy technologies, such as wind power. As a result, SMRs are increasingly regarded as a strategic asset and a potential branding opportunity. Municipalities with experience

highlight concerns about how to finance SMRs and whether the current Swedish repository for short-lived radioactive waste is sufficient for waste generated by future SMRs.

Even when municipal rescue services have no previous experience of radiation emergency preparedness, some clear strengths exist, including well-developed general emergency management systems that can be scaled up for larger events, and experience with hazardous activities such as chemical industries. A significant weakness is the lack of knowledge and experience regarding nuclear risks and the handling of radioactive substances—particularly in relation to radioactive releases. During the current SMR development phase, municipal rescue services highlight uncertainty regarding the required level of emergency preparedness and how it should be integrated into their operational planning. The SMR technology, with its passive safety systems, may reduce the need for extensive preparedness zones and thereby simplify tasks and resource requirements. This could create conditions for new forms of risk management where the SMR operator takes greater responsibility for radiation emergency preparedness.

Municipal rescue services without prior experience also express concerns that new preparedness requirements and tasks may arise with SMRs—without a corresponding increase in resources or compensation. Currently, there is limited dialogue between municipalities and rescue services regarding planning and establishment of new nuclear facilities. These rescue services highlight the importance of strong collaboration between municipalities, authorities, and producers. Early and well-planned dialogues during feasibility studies and planning stages is seen as essential to managing emerging challenges. They also anticipate significant complexity in coordination responsibilities and resources between municipal and state levels regarding radiation emergency preparedness.

State rescue services (county administrative boards) with previous radiation emergency preparedness experience have well-established preparedness structures supported by strong collaboration between county administrative boards, municipalities, municipal rescue services, police, the coast guard, and national authorities. Regular exercises further reinforce these structures. However, they identify uncertainties linked to SMR technology, particularly regarding environmental consequences, cooling needs, technology choices, and emergency preparedness categorisation, as well as a lack of local environmental expertise. They consider public knowledge about radiation to be low, noting the need for improved information to clarify risks. They also see a continued need for competence development and adaptation for future SMR solutions.

State rescue services without previous radiation emergency preparedness experience still regard SMRs as relatively abstract and long-term issues. Their sensemaking of SMR and emergency preparedness is characterised by uncertainty, conceptual confusion, a need for increased knowledge and coordination, and an understanding that many challenges remain before SMRs can become a viable solution for energy supply. The issue is complex and involves technical, organisational, and political aspects. Collaboration among actors is fragmented and dependent on individual initiatives, hindered by a lack of expertise and an unclear division of responsibilities.

5. Concluding discussion

The interviews consistently show high expectations for SMRs across actors. SMRs are largely viewed as solutions to a wide range of challenges, offering energy supply, economic benefits, long-term local development, and symbolic value tied to innovation and future progress. This optimistic framing tends to overshadow more critical reflections on uncertainties and potential risks. As a result, actors' understanding of SMRs is often one sided, which may hinder the development of a balanced risk awareness and, in turn, limit the conditions for organisational mindfulness (Weick and Sutcliffe 2007) and preparedness.

Actors already responsible for radiation emergency preparedness demonstrate awareness of radiation risks. For them, the introduction of SMRs is expected to require adjustments rather than substantial changes to current practices. In contrast, newcomer actors without prior experience tend to postpone addressing preparedness issues, expecting future guidance from authorities. Their limited knowledge of radiation emergency preparedness means that norms, routines, and sometimes resource needs are not yet considered. This contributes to a project-based approach in which preparedness is treated as a later stage activity rather than as a strategic concern integrated from the outset, as recommended by the IAEA (2024).

Overall, the fragmented interaction patterns and differing levels of experience do not currently support the emergence of a comprehensive emergency preparedness culture. SMRs in Sweden are still in an early development phase, with unclear requirements around emergency planning zones, regulatory processes, technology choices, and preparedness responsibilities. This uncertainty creates a natural limitation: sensemaking may shift significantly once concrete designs, sites, and guidelines emerge.

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Data availability statement

The data cannot be made publicly available upon publication because they contain sensitive personal information. The data that support the findings of this study are available upon reasonable request from the authors.

The qualitative interviews can not be shared due to promised anonymity, confidentiality and possible sensitive data not analysed.

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