Disclaimer: This draft represents the initial assembled version of the Strategic Research and Innovation Agenda (SRIA) for the PIANOFORTE Partnership. It is being shared at this early stage to gather feedback and insights from a broad range of stakeholders, with the aim of incorporating their input into the ongoing development of the SRIA. Please note that several sections are still missing, and the document as a whole remains a work in progress. It does not yet reflect a consolidated or official position of the PIANOFORTE Partnership.
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Radiation Protection Strategic Research and Innovation Agenda

Chapter 1 - Advancing radiation protection research for a competitive, safe, and sustainable Europe

"We are choosing to put research and innovation, science and technology, at the heart of our economy" – Ursula von der Leyen, President of the European Commission, 5 May 2025 [1]

This clear commitment made by President von der Leyen highlights the essential role that knowledge and cutting-edge technologies play in shaping Europe's future. As the European Union (EU) is confronted with a multitude of emerging, sometimes unprecedented challenges - ranging from the Russian Invasion of Ukraine, climate change, to scepticism towards or even disengagement from internationally established scientific consensus, as well as an anticipated rise in cancer cases[2] - investing in research and innovation has never been more critical. The radiation protection field exemplifies how science and technology can drive progress by safeguarding the health of the public, workers, patients, and the environment. This protection not only enhances well-being but also pushes European industrial and medical innovation, strengthening the EU's resilience, competitiveness, and sustainability.

Today, around half of all cancer patients undergo radiotherapy, which necessitates advanced expertise in radiation protection to maximise the benefits of the therapy for patients and minimize adverse effects to healthy tissues. Furthermore, a growing proportion of public exposure to ionising radiation comes from medical applications such as X-rays and CT scans, as well as nuclear medicine imaging techniques including scintigraphy and PET scans. Optimised protection of patients, practitioners and (family) caregivers, as well as justified medical practices, are therefore key. Similarly, exposure of the environment to ionising radiation (e.g. in post-accident situations or from historically contaminated areas) and the associated consequences for ecosystems and humans, as well as human exposure to ionising radiation through the environment through naturally occurring radioactive materials, call for robust radiation protection policies, regulations and practices, based on a scientifically sound quantification of the relevance of ionising radiation compared to other natural and anthropogenic stressors. These benefit the overall quality of life in Europe and beyond and need to continue to be rooted in state-of-the-art scientific knowledge.

The ongoing war on the European continent, fought in a nuclear energy-producing country, as well as the recent escalation of tensions in the Middle East, including the bombing of Iranian nuclear programme facilities, further highlight the importance of radiation protection as part of comprehensive and harmonised national security strategies in times of raising geopolitical tensions that the EU is currently facing. As the Chornobyl and Fukushima Daiichi nuclear power plant accidents have proven, the consequences of nuclear incidents are not limited to the country in which they occur. The ability of EU countries to prevent, detect and respond effectively to radiological and nuclear threats - whether accidental, deliberate or linked to other hazards (Chemical, Biological, Radiological, Nuclear, and Explosives (CBNR-e)) - is essential to mitigating potential impacts on people and the environment.

In this context, strengthening infrastructures, emergency response capabilities and cross-border cooperation is critical. In particular, advances in radiation monitoring, data integration and artificial intelligence (AI) can further enhance early warning systems, risk assessment and crisis management. Continuously reinforcing already robust radiation protection frameworks based on the latest scientific findings and maintaining high levels of expertise among emergency responders and regulatory bodies, will enable Europe to adapt to the evolving security landscape.

The COVID-19 pandemic, and more recently the spillover of the raising geopolitical tensions onto international trade, have highlighted the importance of reliable supply chains, a robust and innovative

[1] Extract from the speech by European Commission by President von der Leyen at the 'Choose Europe for Science' event at La Sorbonne on 5 May 2025. https://ec.europa.eu/commission/presscorner/detail/en/speech_25_1130

[2] https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/european-cancer-information-system-21-increase-new-cancer-cases-2040-2022-03-16_en

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European industry and technological progress. There are a multitude of industrial applications of ionising radiation within the European competitiveness framework, ranging from non-destructive testing and medical applications to advanced material processing. These applications uphold product safety and quality, and enhance Europe's position in global high-tech and high-value markets. In the energy sector, while Member States individually decide on their energy mix, radiation protection framework adjustments rooted in the latest scientific knowledge are needed to accompany progress in nuclear energy applications and innovative approaches such as Small Modular Reactors (SMRs) or novel reactor technologies, to ensure they can potentially contribute to a climate-neutral energy system safely, efficiently and securely. Additionally, the revival of international interest in space technologies - sometimes accompanied by ambitious technological programmes - are further industrial applications that require advanced radiation protection knowledge in order to be carried out safely. Providing top-notch radiological protection knowledge to European industry and technologies will enable them to compete and innovate at the highest international level.

In light of the wide range of radiological protection aspects and applications that are directly relevant to EU priorities, the European partnership for radiation protection research (PIANOFORTE) was launched in 2022 as a collaborative initiative to pool resources, share expertise, and foster excellence. Its aim is to carry out the necessary research to ensure the highest level of protection for the public, workers, patients, and the environment against environmental, occupational, and medical exposure to ionising radiation. PIANOFORTE's research activities, implemented through open calls for research projects, directly support European policies such as the Europe's Beating Cancer Plan[3], the SAMIRA initiative[4], including the European Radioisotopes Valley Initiative (ERVI) activities, the European Green Deal[5] and the Action Plan on the Sendai Framework for risk reduction[6] (see Figure 1). And with the unsettled geopolitical context, connections with the AIEA and the European Defence Fund (EDF, https://defence-industry-space.ec.europa.eu/eu-defence-industry/european-defence-fund-edf-official-webpage-european-commission_en) request to be strengthened. So ionising radiation exposure thus radiation protection seals interdisciplinarity in the atomic energy area.

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[3] European Commission (2020), "Europe's beating cancer plan", Communication from the Commission to the European Parliament and the Council, https://health.ec.europa.eu/system/files/2022-02/eu_cancer-plan_en_0.pdf

[4] European Commission (2021), "SAMIRA: Strategic Agenda for Medical Ionising Radiation Applications: An Action Plan for security of radioisotope supply, quality and safety, and technological development and innovation", https://energy.ec.europa.eu/system/files/2021-02/swd_strategic_agenda_for_medical_ionising_radiation_applications_samira_0.pdf

[5] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[6] European Commission (2016), Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 - A disaster risk-informed approach for all EU policies", Commission Staff Working Document.

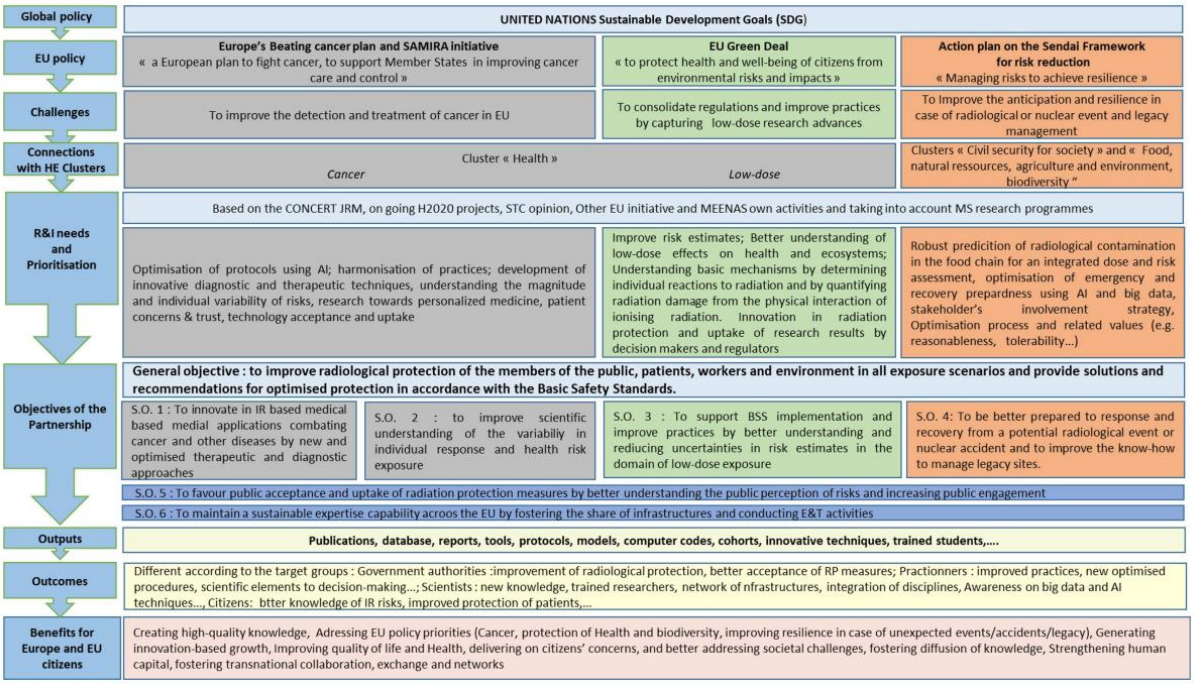

Figure 1: *Articulation of PIANOFORTE objectives with elements of the European policy context, identified challenges, relevant connections with Horizon Europe clusters and research and innovation priorities. Source: Garnier-Laplace et al. (2025), 'The PIANOFORTE partnership: Elevating European research for enhanced radiation protection', EPJ Nuclear Sci. Technol. 11 13.*

This document outlines PIANOFORTE's Strategic Research and Innovation Agenda (SRIA), which will guide its future activities and serve as a recommendation for potential future partnerships in radiation protection. For each of the three topics - 'Quality of Life', 'Security' and 'Competitiveness' - which are closely related to the European policy agenda, the SRIA provides an overview of the issues at stake and recent research achievements before addressing the priority issues to be tackled in the respective field in future. It also suggests a concrete list of research topical needs. Finally, it addresses some key elements of several cross-cutting topics, such as complexity reduction, use of AI, and stakeholder involvement, in short, dedicated chapters. Taken all together this reveals importance of PIANOFORTE pivotal role managing a topic overlapping with many others with the ability to stay flexible to fit to current and future geopolitical concerns.

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Chapter 2: Quality of life in Europe

Introduction

Quality of life can be defined as living healthy and wealthy in a high-quality environment, encompassing human well-being but also environmental sustainability. Public and occupational health, alongside the protection of natural resources and ecosystems, are thus key drivers for the quality of life for European citizens. Ionising radiation is used in several domains, not the least in medicine for diagnostic and therapeutic purposes. Increasing and ensuring individual and societal benefits of ionising radiation, while minimising deleterious effects of exposure to ionising radiation, are among the key priorities for the quality of life of the European population. In a constantly evolving world, an optimal use of ionising radiation is not possible without continuous research.

Consequently, radiation protection research is a major contributor to understanding and mitigating risks to human and ecosystem health associated with medical, occupational, and environmental radiation exposures, as well as to improve the beneficial use of ionising radiation, whether it relates to planned or emergency exposures. Radiation protection research enables, for example, the optimisation of the benefit-to-risk ratios for medical applications, as well as for industrial and energy-related uses of ionising radiation. It enables the development and safe use of new and emerging technologies allowing to improve patient care as well as economic and social welfare. Additionally, it helps maintaining a healthy, natural environment. Ensuring sound radiation protection science, underpinned by robust evidence, therefore allows society and individuals to benefit from the uses of ionising radiation while keeping the associated risks to health and the environment at an acceptable level – supporting healthy populations and environments.

Where we stand

EU-funded projects have, in recent years, generated significant new knowledge regarding risks of ionising radiation at low levels of exposure in humans. These efforts have addressed also environmental radiation-related issues like exposure to radon and other naturally occurring radionuclides and remediation of legacy sites (e.g., NORM affected sites), as well as recovery of areas affected by radiation accidents. These projects have contributed to advancements in radiation monitoring technologies, improved environmental impact assessments and risk assessment frameworks and models for environmental and occupational exposures, notably by improving the understanding of low dose risks among affected populations. They have also played a crucial role in updating regulatory frameworks and strengthening their implementation, fostering stakeholder engagement in decision-making processes, and strengthening radiation protection culture across industries.

In the medical field, recent EU funded projects, have made significant progress in assessing patient exposures, risk indicators and quality parameters, alongside active stakeholder engagement to ensure public awareness and patient safety. Important results on methods for optimisation of radiation therapy and medical imaging procedures were produced and steps were made to achieve standards on justification of imaging procedures throughout Europe.

The PIANOFORTE partnership has fostered and funded research through different open calls. To date these have focussed on developing a knowledge base for a better understanding of pathogenesis of ionising radiation-induced cancer to improve risk assessment, and for investigating the effects of temporal and spatial variations on the risk of health effects. The goal is to progress with personalisation and optimisation radiation therapy and imaging procedures and to interlink radiation biology and radiation medicine approaches to reduce detrimental effects of ionising radiation in medical applications. This includes implementation of new and optimised radiation therapy approaches for better targeting to protect healthy tissues better against detrimental effects of ionising radiation. Next to this an integrated approach for risk assessment and evaluation from environmental exposure to ionising radiation is being developed, including following the Russian geopolitical context.

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Collectively, all these actions are serving to enhance the quality of life for European citizens and allowing the benefits of the applications of radiation in industry, medicine and elsewhere to individuals and society to be realised.

What we have to do

New Technologies to Accelerate Research on Low-Dose Risks

Improving our understanding of the health effects of low dose ionising radiation, including both cancer and non-cancer pathogenesis, remains a high research priority. To enhance insights in this field, new technologies are opportunities to accelerate new findings. These are e.g., AI, advanced computational techniques, 'omics' approaches, and the 'Adverse Outcome Pathway' framework. Research on low-dose radiation is crucial for understanding disease mechanisms, identifying therapeutic targets, and developing early detection strategies. It also plays a key role in refining radiation protection guidelines. Given the widespread public health concerns linked to radiation-related diseases, advancing this research holds significant societal benefits. Furthermore, a clearer understanding of dose-response relationships is vital for establishing well-founded radiation protection strategies. This would lead to an effective and efficient risk management avoiding overprotection and potentially leading to a simplification of the whole radiation protection system. More knowledge on radiation exposure risks will also lead to improved diagnostic and therapeutic approaches with an optimised use of ionising radiation, benefiting public health and enhancing safety of medical settings. Similarly, moving towards individualised therapy will also lease better quality of life.

Radiation Technology Development and AI in the medical field:

The use of new technologies such as AI based systems could benefit patients, if implemented in a safe and secure way. This requires supporting research covering aspects of technology, data security, and addressing the heterogeneity of data sets and their description, as well as quality assurance of data and tools. The same holds for new X-ray sources as there is a lot of knowledge on developing and suitable use of sources for ionising radiation (ERSF, DESY, ELI etc.) and corresponding developments for new therapeutic approaches (FLASH, microbeam therapy, radionuclide therapy, etc.) as well as diagnostic approaches (phase contrast imaging, X-ray fluorescence imaging etc.). The possibilities of the newly emerging technologies and their radiation protection aspects are not addressed yet. Further developments enable the implementation of e.g., personalised radiation therapy or combining X-ray techniques with other imaging modalities, would be needed. These new evolutions in the medical field require thorough research to optimize the protection of the patients and staff by reducing and avoiding unnecessary radiation and further maximizing the benefits.

Radiation biology has in the past years developed more insight into specific, individualised radiation effects related to medical exposures. There is also need for combined efforts between researchers of different disciplines and clinicians for optimised individualised treatment of patients including new radiopharmaceuticals for diagnostic, therapeutic and theragnostic approaches as well as in combination with other therapeutic techniques.

Due to this broad knowledge European research is in an excellent position to develop clinical decision support systems related to the use of ionising radiation in medicine. In terms of expected outcomes, all these opportunities would allow better and more efficient patient health care while reducing the potential detriment due to the ionising radiation. By this, it will also reduce the occupational radiation burden for clinical staff.

Manage Complex Environmental Radiation Risks for Protecting Human Wellbeing and Ecosystems

Environmental radiation-related issues, such as exposure to radon and naturally occurring radionuclides, remediation of legacy sites (e.g., NORM sites, areas affected by accidents), and addressing radioactive residues in a circular economy, are complex and are thus not completely understood or predictable. Industries dealing with NORM require ongoing expertise in risk assessment, management and

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communication to prevent misinformation that could lead to economic and transboundary challenges, which may hinder the development of industries vital for new technologies. The risks are further compounded by climate change and the growing combination of exposures to radiation, hazardous physical stressors, and chemical substances. Furthermore, several countries intend to expand their nuclear energy power capacity, notably using emerging nuclear technologies and new siting configurations, which requires improved assessments for ensuring adequate emergency preparedness, response and recovery. We also need a solution to the repository issue, which is linked to many questions of classic radioecology. In addition, the consequences of potential domestic uranium production (from mining to enrichment) should not be ignored. Evidence-based risk assessments will support the sustainable development of industries that utilise ionising radiation science and technologies. Greater public understanding of radiation risks will facilitate effective risk management in the context of broader environmental challenges. These efforts are essential for managing radiation risks in an evolving environmental landscape and will lead to safer living conditions and better protection for communities and ecosystems exposed to radiation.

Improving monitoring of occupational exposure and reducing the occupational exposure

A portion of the European workforce is exposed to ionising radiation in various occupational settings, including healthcare, nuclear energy, war conflicts, and industrial applications. To ensure their safety while maintaining operational efficiency, new technologies, advanced detector developments, simulation and AI tools can improve radiation monitoring and dose assessment. These advancements not only help in reducing workers' radiation exposure but also simplify procedural complexities. Research in this field plays a crucial role in refining monitoring techniques, reducing uncertainties in exposure assessments, and ensuring compliance with evolving legal and regulatory requirements. The largest collective dose at workplaces is due to geogenic radon, so strategies are also needed to decrease these.

Bulleted list of research topics

- Biokinetic and Internal Dosimetry Studies for Theranostic Approaches
- Artificial Intelligence for CT and PET–CT Optimisation in Oncological Imaging
- Enhancing Oncologic and Interventional Imaging: Addressing Training Gaps, Quality Standards, and AI Integration in CT and PET/CT Practice
- New Technological Developments for Medical Use of Ionising Radiation
- Radioactive Waste Management in Nuclear Medical Applications
- Investigations on Biological Effects, Including Low-Dose and Therapeutic-Dose Effects and Especially Effects in Combination Therapies
- Mechanistic Pathways of Radiation-Induced Cancer and Non-Cancer Diseases
- Personalized Radiation Risk Assessment: Addressing Individual Variability and Susceptibility.
- Re-evaluating Cancer Risk from Low Dose Irradiation: Incorporating the Dose Modifying Effect of non-Targeted Effects in Risk Assessment.
- Long-Term Risks in Paediatric and Young Adult Patients.
- Understanding and Modelling Complex Radiation Dose Distributions: Temporal and Spatial Dynamics.
- Enhancing Safety and Risk Assessment in Advanced Radiation-Based Medical Applications
- Towards Improved Dosimetry for Safe and Effective Use of Emerging Radiotherapy and Diagnostic Techniques
- Towards improved dosimetry for patients and caregivers in radiopharmaceutical therapy and diagnostic
- Understanding of effects on ecosystems exposed to ionising radiation
- The relation between social sustainability considerations and radiation protection in the medical use of ionizing radiation

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- Integrated Risk Assessment of Combined Radiation Exposure Scenarios

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Chapter 3: Security in a changing world

Introduction

Nuclear and radiological emergencies have been and still pose complex and far-reaching challenges that demand continuous advancement in preparedness, response and recovery. Their inherent rare occurrence but far-ranging nature and potential impact necessitate robust planning, coordination, and scientific and technological advancement. Despite significant progress, critical gaps remain across all emergency phases, particularly in preparedness strategies, risk assessment methodologies based on models and monitoring, and crisis communication.

Given the transboundary nature of nuclear and radiological threats, European harmonisation of regulations, early warning systems, strategies and emergency protocols is essential. Nuclear and radiological emergencies require integrated approaches encompassing impact and risk assessment based on state-of-the-art modelling and monitoring, dosimetry, effective communication strategies, and agile decision-making frameworks.

Recent geopolitical shifts—including Russia's invasion of Ukraine, growing tensions among global powers, and instability in regions like the Middle East—have underscored the vulnerabilities in existing nuclear and radiological emergency frameworks. The renewed focus on nuclear energy expansion, including the deployment of small modular reactors (SMRs), coupled with heightened security threats in an era of hybrid warfare (e.g., novel cybersecurity issues, vulnerabilities for installations in remote areas), underscores the urgent need for a comprehensive and adaptive research agenda.

The complexity of dealing with the preparedness for, and aftermath of, potential nuclear or radiological accidents highlights the need for transdisciplinary research approaches involving different disciplines (e.g. natural sciences, social sciences and humanities) and a wide range of societal actors (e.g. radiation protection experts, authorities, industry, citizens).

To ensure Europe’s readiness for an evolving security landscape, the following questions must be addressed related to radiation protection research in the next years:

How can existing radiological emergency preparedness strategies be enhanced in an increasingly hostile geopolitical environment? This includes countering risks associated with e.g. nuclear attacks, sabotage of nuclear facilities, and threats/disruption to radiological material supply chains, including those related to medical isotopes.

How can the increased reliance on nuclear technologies—ranging from power plants to medical and industrial applications—be balanced with the heightened risk of conflict? What measures ensure the resilience and safety of radiation-related infrastructure in both peacetime and crises?

Where we stand

Over the past 15 years, EU funded research initiatives have yielded significant advancements in radiation emergency preparedness. Many lessons have been learned from the Fukushima accident in relation to public engagement and communication. These efforts have improved radiological risk assessment methodologies, decision-support systems for emergency management, public health response frameworks, stakeholder engagement and communication strategies. This progress through the projects includes e.g. improved computer models and tools for decision support, improved strategies for medical and health surveillance, improved consideration and coping with uncertainties in modelling and decision making, advanced approaches to reduce uncertainty where necessary, improved concepts for stakeholder participation in radiation protection and decision making.

The PIANOFORTE partnership identified two area that need prioritising. First, the development of risk assessment and risk management approaches and technological capabilities to cope with threats due to war or armed conflicts situations or natural disasters. Secondly, the use of AI and big data techniques

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to improve emergency response – covering radiological impact assessments, decision support, data collection response and recovery strategies as well as public engagement, communication, education and training.

What we have to do in the next years

CBRN-E and nuclear warfare

New emerging nuclear technology trends require further development of risk assessment and risk management approaches as well as technological capabilities to cope with novel threats and risk scenarios.

In the case of a chemical, biological, radiological, nuclear, explosive (CBRN-E) event, the challenge lies in the simultaneous occurrence of a nuclear security event alongside other disasters and/or security events. The development of an all-hazard approach - including standard operating procedures of common processes across involved authorities – is a key point in improving the ability of authorities to respond adequately. Also, more guidance, stockpiling and research on medical protective actions/countermeasures for CBRN-E events are needed. There is a need for a more holistic medical diagnostic approach, consisting of the interplay of biodosimetry, physical dosimetry and clinical outcome prediction for the medical management of radiological mass-casualty events. In addition, closer relationship with COUNTERACT (https://www.europarl.europa.eu/doceo/document/E-9-2023-003643_EN.html) actors needs to be set-up.

In the case of deployment of a tactical nuclear weapon of smaller yield, direct effects are severe but still localised. Effects due to fallout have a much larger range and are thus critical for radiation protection. This includes e.g. better and quicker identification of the initial dimensions of the mushroom cloud directly after explosion, improved abilities to assess the fallout of the nuclear explosion up to large distances, improved strategies and technical means to quickly alert the population in such scenarios. But also research on improved protection of monitoring and communication devices and other critical equipment against the various effects of a nuclear explosion is needed.

Another challenge is the ongoing change of radiological impact assessments, decision support and response and recovery strategy through the introduction of AI and big data techniques. This is a joint challenge for many practitioners in emergency preparedness—how to make the best, most efficient and rapid use of large amounts of uncertain data in crisis situations.

Transdisciplinarity to improve resilience

The war in Ukraine resulted in the identification of new challenges in conflict situations, e.g. the need to assess how fundamental radiation protection principles may be applied in armed conflict situations.

It is still – even after the experiences in Ukraine, unclear how to actually deal with the potential for deliberate attacks on nuclear facilities and the consequent risk of radioactive releases. Europe has to consider the challenges of radiological monitoring and alerting the population in conflict situations, how information will be communicated to the public in parallel to potential active electronic warfare and disinformation campaigns, and how the situation might alter behaviours, thereby affecting the effectiveness of any protective action strategy. The necessity to build resilience and prepare European citizens for the new security situation has to be aligned with parallel ongoing activities all over Europe in different silos of civil protection attempts and if possible also in accordance with EDF objectives.

Furthermore, there is a need for better integration of resilience and sustainable development principles including the consideration of Sustainable Development Goals in emergency preparedness, response and recovery strategies.

Address and reduce uncertainties

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The need for further improvements of radiological impact assessment for human dose and environmental impact also includes coping with uncertainties in crisis situations, where often only limited information is available. This includes research related to impact assessments for planning, real-time impact assessments during the response phase, dose reconstruction in a later phase, uncertainty quantification of the impact assessment and visualisation, as well as the reduction of uncertainty related to specific modelling approaches.

Large uncertainties still exist in the application and efficacy of management strategies for radiological emergencies. Further research is needed on the consideration of uncertainties in the decision making and in the communication of uncertainties to all relevant stakeholders and the public.

Altogether, these three topics lead to three research areas: first, in risk assessment, emergency response, and technological resilience; second, in transdisciplinary research and strategic adaptation and third, reducing uncertainties. All three topics will have to be accompanied by major development aspects in how to do emergency preparedness: AI-driven decision-support tools must be developed to integrate vast, uncertain data streams into rapid, actionable intelligence for first responders and policymakers. Additionally, research should focus on enhancing public preparedness and bridging gaps between radiation protection and broader civil protection frameworks, integrating efforts across law enforcement, intelligence agencies, healthcare systems, and disaster response units. To do so, multidisciplinary collaboration between natural sciences, social sciences, policy experts, defense capabilities and technology developers will be required. Important is also the "zeroth area of research" which is linked to avoiding CBRN-E events. Among other things, this includes strategies and techniques for detection and identification in states that may have little knowledge due to the prevention of proliferation.

Bulleted list of research topics

- Towards development of new technologies and calibration procedure for emergency dosimetry and preparedness
- Radiation protection of the environment in post-accidental and legacy contexts: from data to decision
- Critical perspectives of AI for radioecological risk management
- Optimisation of management strategies for emergency response, transition and recovery phases
- Improving Situational Awareness during Emergency Response
- Adapting EPRR to new geopolitical challenges
- Navigating Radiological Threats Amid Geopolitical Instability and Hybrid Warfare

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Chapter 4: Competitiveness

Introduction

Ensuring Europe's global competitiveness, fostering a risk-informed society and making informed choices about energy sources are essential for sustainable development and climate change mitigation. A competitive Europe must strike a balance between innovation and sustainable economic growth, without compromising or even while improving the quality of life. Whatever energy choices countries make, radiation protection research plays an essential role in this context by ensuring the safe use of nuclear technologies and the appropriate knowledge and know-how for a robust comparison of both their safety and environmental impact with other technologies, taking into account the associated safe storage of nuclear waste. Only this approach can enable countries to make the best choices for their energy portfolio, mitigating risks and boosting public confidence in energy choices. Understanding and managing radiation risks through robust research can enhance public trust in scientific assessments, leading to evidence-based energy policies. This includes Europe's ability to anticipate and manage risks from ionising radiation, through sustained investment in interdisciplinary research, without unjustifiably hindering the development of new technologies and solutions.

Furthermore, radiation protection research complements Horizon Europe's objectives, particularly in the context of energy transition and the shift towards a circular economy. As new energy designs or technologies and sustainable practices emerge including the reuse of materials containing low levels of radioactive substances, it is essential to develop knowledge and methodologies to assess potential risks and ensure harmonised regulatory compliance at a European scale.

Finally, non-energy applications of ionising radiation play a crucial role in the medical sector, as well as in related and many other industrial domains. These technologies bring in high revenues, create skilled jobs focused on innovation, and help improve the quality of life for people in Europe.

Where we stand

In recent years, EU funded research projects have significantly contributed to understanding radiation risks associated with energy production, industrial applications, and environmental exposures. These initiatives served as a foundation for PIANOFORTE research priorities and projects to pave the way to (i) improve and adapt radiation dose and risk assessment models, assumptions and data, for new nuclear technologies emerging in energy and non-energy related industries, (ii) foster stakeholder engagement and risk communication deploying modern tools to ease societal understanding of radiation risks and supporting informed decision-making, (iii) contribute to the development and deployment of sustainable practices (e.g., decommissioning of nuclear facilities, radioactive waste management, remediation of contaminated sites). Additionally, European projects have advanced radiation monitoring technologies, ensuring the safe operation of nuclear facilities and other industrial applications. The development of improved dosimetry methods has contributed to e.g., occupational safety in nuclear power plants and medical settings. For the medical area, such research has been fostering the potential for the health of European citizen in combination with the strong MedTech industry on all scales within Europe, like it is also reflected in the SAMIRA action plan. Actually, with ERVI activities which explore the possibilities for building European production capacity for metallic HALEU, enhancing Europe's production of enriched stable isotopes, strengthening the medical radionuclide production, expanding the European medical radionuclide programme (PRISMAP https://www.prismap.eu/), and developing more reliable monitoring of supply and demand. The results of the projects also allowed further potentials for market use of European MedTech products. In a nutshell, these achievements underline that Europe's progress in radiation protection has only been possible through strong research collaboration. By working together, PIANOFORTE and its predecessors have created a world-leading approach that should be more actively promoted as a joint European success.

What we have to do

Advancing radiation protection for sustainable energy choices

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The different energy choices and implementation of solutions to mitigate the impact of climate change require informed decision-making based on the best available scientific expertise within the Member States. Radiation protection research supports this effort by facilitating the energy transition and advancing sustainable practices and circular economy. As emerging energy technologies gain prominence, including novel nuclear technologies such as small modular reactors and fusion experimental facilities, it is crucial to develop robust methodologies and related knowledge for assessing their potential risks, including the radiation protection aspects of the safe storage of the nuclear waste. There is also the potential novel application of nuclear technologies as industrial heat sources, even in Europe. Improving research and simplifying radiation protection frameworks without compromising the underlying risk-proportionate approach for risk assessment and management, will enable to make these new technologies more efficient. Additionally, sustainable resource management, including the reuse of materials with low levels of radioactive substances and site remediation, requires clear regulatory frameworks and comprehensive human and environmental health impact and risk assessments to ensure both safety, environmental protection and stakeholder acceptance. The more we understand the science involved in such technologies, the more it will help to facilitate deployment for societal benefit and to improve energy security and independence.

By fostering a knowledge-based approach, radiation protection research enables the responsible deployment of new technologies fostering a risk-proportionate regulatory framework that encourages innovation while maintaining high safety standards, ultimately supporting Europe's leadership in sustainable energy development.

Fostering innovation in radiation protection tools and technologies

The rapid progress in nuclear science and technology, coupled with the growing influence of artificial intelligence and advanced computational tools, has created new opportunities for radiation protection research. AI-driven methods, including big data analysis and predictive modelling, offer unprecedented capabilities in radiation risk assessment and communication, understanding uncertainties in both exposure, effects and risk estimates, as well as challenges related to disinformation and misinformation. New radiation measurement techniques and the use of drones for radiation protection are examples of such technology innovation taking into account AI and increased computational power which will actually change the radiation protection practices. Advances in cellular and molecular biology, provide deeper insights into radiation-induced biological effects, enabling more precise health risk evaluations, and even personalised assessment, with tailored estimates of exposure, effects and risk. These developments underscore the urgent need for modern approaches to radiation protection that integrate cutting-edge scientific advancements. By establishing interdisciplinary collaborations that bridge nuclear science and technology, AI, and all radiation protection related research disciples, research outcomes will enable the refinement of risk assessment models and the adaptation of both standards and practices through scalable, risk-based approaches in medical, industrial, and environmental applications.

Radiation protection for space exploration

The expansion of space exploration and the increased presence of humans in space environments necessitate enhanced protection against cosmic radiation. Astronauts and space mission personnel are exposed to high levels of cosmic radiation, which poses significant health risks. A deeper understanding of the biological effects of different radiation particles, including protons and heavy ions, is essential for improving the safety and success of space missions. In this context, the development of both operational and biological mitigation strategies will be a priority, as current radiation protection dose limits alone will not ensure the safety of future space travel. Research in this field not only benefits space exploration but also has applications for medical treatments on Earth, particularly in cancer therapy, where particle radiation is increasingly used for targeted treatment.

Sustainability of innovation in all sectors of radiation protection

The rapid advancement of technologies involving ionising radiation demands continuous investment in research and expertise to maintain Europe's global competitiveness. Strengthening risk assessment (also for combined factors), risk communication, and risk management ensures that technological innovations are safely implemented while fostering public trust. Without these efforts, misinformation and uncertainty could hinder the adoption of sustainable energy solutions and disrupt industrial progress. In

medicine the awareness of radiation protection aspects had led to innovations which still allow the European industry an advantage compared to other competitors.

Bulleted list of research topics

- Towards improved occupational dosimetry in view of BSS regulation and practical application
- Development and Quality assurance of advanced computational methods and AI for all fields of dosimetry
- Strengthening radioecological infrastructures and capabilities for long-term societal challenges
- Emergency Planning, Response and Recovery Framework for Novel Nuclear Technologies
- Application of Artificial Intelligence to decision making in radiation emergencies
- Circular economy and sustainability in the context of waste management (including NORM)
- Advancing Energy Transition and Security: The Role of New Nuclear Technologies in Sustainable Radiation Protection
- AI in radiation protection

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Chapter 5: **SRIA Stakeholder Engagement**

In radiation protection research as for most research areas with applied focus, the strategic involvement of stakeholders plays a pivotal role in shaping research priorities, ensuring both societal and economical relevance, and enhancing the applicability of scientific advancements for increased impact.

Types of stakeholders in radiation protection encompass a diverse range of entities and groups including European and national policy makers, regulatory authorities, the scientific community including the field of education and training, occupational stakeholders, various industrial sectors, medical experts, patients and finally the public as a whole. In this heterogeneity they reflect the interdisciplinary nature and wide range of questions related to radiation protection. Their engagement is crucial to facilitate a well-grounded understanding and implementation of radiation protection measures that adequately meet both professional standards and public expectations, and ensure compliance with national and European legislation, i.e. the BSS directive. In radiation protection research itself, it is necessary to foster collaboration and exchange across sectors and to try to integrate different scientific domains in research activities as appropriate. In particular, transdisciplinary collaboration is essential to address complex, domain overlapping scientific challenges and shall ensure that research outcomes and recommendation meet the broader societal needs. In parallel, the stakeholder needs differ depending on the specific topic or concern being addressed and are not limited to the radiation protection science community. Diverse end-user groups and industry stakeholders for example from the medical field, the material and processing industry, the nuclear energy sector and many more need to develop, implement and use radiation and radiation-based technologies in various settings. Their perspectives, needs and expertise are crucial for ensuring that the research outcomes are relevant, actionable, and widely accepted. They cannot simply be “averaged” but have to be addressed individually according to the different dimensions of radiation protection research. Collectively, this comprehensive network of stakeholders from politics, research, and industry underscores the complexity and importance of radiation protection, as we have to work collaboratively to protect humans and the environment.

Involvement of stakeholders in radiation protection research should aim to involve all these stakeholder groups consistently throughout different stages of a research project's life cycle and follow a comprehensive approach in research and stakeholder engagement as far as possible. Therefore, research activities should identify and involve stakeholders from the earliest stages of the research design and continue this engagement specifically throughout potential dissemination and exploitation phases. This includes establishing communication channels and collaboration strategies to integrate the insights and needs of each stakeholder into the research efforts effectively. By doing so, scientists and researchers can ensure that their findings are not only scientifically valid but also directly applicable to the needs of the wider community, thereby enhancing the overall value and impact of radiation protection research.

For simplicity, in the following table/graphic we try to sort stakeholders according to the three pillars of net benefit for European citizens that radiation protection research can generate: (i) security, (ii) quality of life, (iii) increased competitiveness. This provides a non-exhaustive overview of stakeholders and groups relevant for the specific fields of the SRIA.

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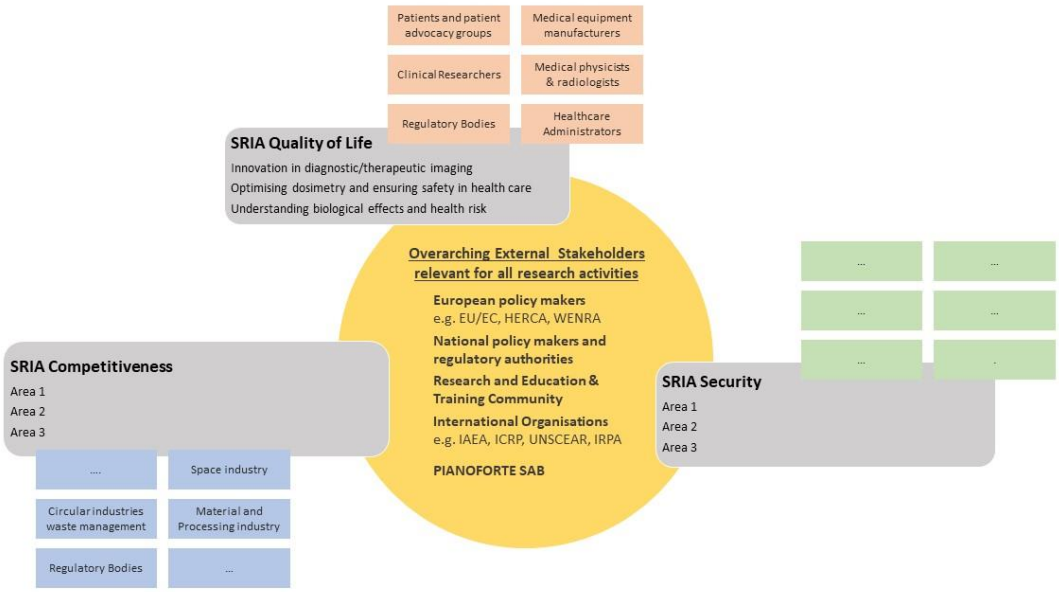
In the following, an exemplary table/graphic on stakeholders in the various domains of radiation protection is provided.



Draft - non exhaustive

		Relevant Stakeholders within the SRIA Chapters/Research Clusters (non-exhaustive)		
Stakeholder group	**Addressed by**	**Quality of Life**	**Security**	**Competitiveness**
European policy makers	PF	EC, Article 31 Group of Experts, HERCA, WENRA and others		
International organisations	PF/projects	IAEA, ICRP, UNSCEAR, IRPA, ENA, ERA and others		
National policy makers and POMs	PF/projects	ministries and other public bodies, including those at regional and local levels; POMs of the EU memberstates		
Regulatory authorities	PF/projects	Authority Medical	Authority civil security	Authority industry
PIANOFORTE SAB	PF	The PIANOFORTE Stakeholder and Advisory Board can be addressed in a coordinated manner via WP3		
Implementers users	Projects	Medical physicists, Public Health Officials, Patients and Patient Advocacy Groups,	Emergency Response Teams/First Responders, Nuclear Power Plant Operators,	Industrial Radiography, Waste Management Sector,
Industrial domains	Projects	medial equipment manufacturer,	Nuclear industries, measurements and equipment provider	RP in Space, NORM, Mining, Non-disruptive testing, Additive manufactureing and material processing,
EU R&I Initiatives	PF/projects	European Partnership for Personalised Medicine	Projects within the European Defence Fund	European Partnership for Metrology
Research platforms	Projects	EURAMED, MELODI, EURADOS, ALLIANCE, SHARE	EURADOS, ALLIANCE, NERIS	EURADOS, ALLIANCE, NERIS, SHARE
Research & education community	Projects	Health sector, biology, SSH	Meteorology, geology, SSH	Engineeering, SSH
Media & NGO	PF/projects			

Chapter 6: Infrastructure

Research infrastructures are defined by the European Commission to be facilities that provide resources and services for research communities to conduct research and foster innovation. They can be used beyond research e.g. for education or public services and they may be single-sited, distributed, or virtual.

Infrastructures of relevance for radiation protection research include:

• major scientific equipment or sets of instruments

• collections, archives or scientific data

• computing systems and communication networks

• any other research and innovation infrastructure of a unique nature which is open to external users

A key, jointly agreed, action within the radiation protection research community is the sharing and mutualisation of infrastructures at the European level, with maintenance and easy access to relevant research infrastructures being one of the jointly agreed pillars of excellent radiation protection research. Critical infrastructures need to be identified and appropriately supported, and access to these infrastructures should be possible for the whole radiation protection community.

Progress on infrastructures has been made under various collaborative projects at European Level, not least the inventory of European infrastructures and future needs performed during the H2020 CONCERT EJP. This work demonstrated that most infrastructures required for implementing the Joint Roadmap are already available within Member States, Associated Countries or beyond (Global Map). The next step, to be taken forward under PIANOFORTE, is to identify the infrastructures critical for radiation protection research and ensure best use is made of these. A specific WP (WP5) is dedicated to ensure the availability of state-of-the-art infrastructures and a specific budget is reserved to facilitate identification and support of critical infrastructures to meet the needs of the community.

Concentrated efforts are, and will continue to need to be, focused on supporting maintenance and development of, access to and training in respect of critical infrastructures. Through PIANOFORTE and otherwise, work will need to continue on harmonisation of quality standards, practices and protocols for the full range of different types of infrastructures, including through intercomparisons, to facilitate high quality data outputs and impact. In addition, work focused on understanding and planning to overcome the key challenges facing our critical infrastructures is required - not least ever decreasing funding, attraction, recruitment and retention of early career scientists to support maintenance and development of infrastructures, and the extremely fast pace of analysis and storage technologies (including those facilitated by AI). In respect of this latter point, the European radiation protection community will need to work closely together to further develop and put into practice the PIANOFORTE vision for FAIR (findable, accessible, interoperable and reusable) and open science, including in relation to data management and reuse of archived data.

In common with other aspects, stakeholder input into this work will be crucial, facilitated through the current international networks and with direct involvement in the work programmes as well as specific workshops with representatives of infrastructures, users and other relevant stakeholders (see Chapter 5) from across the full range of different types of activities currently ongoing within the community.

Overall, a mutually agreed, strategic, programme of work is needed to ensure long term sustainability of the critical radiation protection research infrastructures and their use in development of radiation protection science and operational practice.

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Chapter 7: Expertise / E&T

Education and Training (E&T) in radiation protection is a strategic enabler for ensuring the safe, effective, and innovative use of ionising radiation. It plays a pivotal role in translating scientific research into practical applications. As radiation technologies evolve rapidly—driven by advances in medicine, energy and industry, and fueled by potential game-changers such as artificial intelligence—the need for a well-trained, multidisciplinary workforce becomes increasingly urgent.

E&T actions are essential not only for empowering the next generation of researchers and professionals but also for supporting the current workforce in adapting to new scientific insights and technological developments. Moreover, E&T contributes to making research outcomes more accessible and understandable to broader audiences, complementing traditional dissemination efforts within the scientific community. In this context, building and sustaining expertise in radiation protection is not merely a support activity—it is a strategic imperative.

Europe has a strong foundation in radiation protection education, supported by academic institutions and research platforms, and also underlined in initiatives such as PIANOFORTE. The partnership has already implemented mechanisms to support education and training for students, early career researchers, and professionals. These include funding for targeted training courses, mobility grants for participation in conferences and exchange visits, support for networking activities and enabling PhD research in the various projects.

However, despite these efforts, challenges remain. There is currently no sustainable overarching framework for managing knowledge transfer activities specifically in the radiation protection domain. This makes the current initiatives vulnerable to fragmentation and loss of expertise. The ageing workforce, limited visibility of career opportunities in radiation protection, and declining enrolment in STEM disciplines further exacerbate the issue. General interest in RP is insufficient, as a consequence shortage of competent RP workers at all levels is a fact.

To ensure a robust and future-proof radiation protection workforce, coordinated action across three strategic dimensions is required within a European context: attracting new talent, building competences, and maintaining expertise. To achieve this, a sustainable E&T framework in radiation protection needs to be established, complemented by clear communication channels to increase the visibility and accessibility of existing initiatives. Without losing the essential link to radiation protection research, this framework will also need stakeholder involvement to bridge existing initiatives and to bring together organisations and platforms with common goals of building and maintaining competences in nuclear and radiological sciences.

Attracting New Talent

Outreach and science communication can be intensified to highlighting actions towards radiation sciences and inspire young individuals to pursue education and careers in STEM. Role model campaigns, teacher support programs, and engaging digital content such as webinars and podcasts are just a few examples of means that further enhance interest. Such actions can highlight the societal relevance of radiation protection and the diverse RP career opportunities in research, healthcare, industry, and regulation.

Building Competences

Education and training programs are to be developed and maintained to cover both foundational and advanced topics, enhancing knowledge and skills in RP. Whilst general education is more offered by academic institutions to students, training is seen as continued and advanced learning for both students and professionals. In both cases, involvement of RP experts from different stakeholders (industry, healthcare, governmental institutions, research centers, academia, …) brings immediate added value to the learning curve as these experts bring direct insights from their daily work and experience. Continued support from the PIANOFORTE community and associated platforms is therefore essential to optimize the education and training activities in RP, from theoretical courses to support for internships and thesis work, as well as to oversee and coordinate funding to support mobility and facilitate hands-on experience and international collaboration.

Maintaining Expertise

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Continuous professional development is essential to keep pace with scientific and technological advances. This includes for example transdisciplinary training courses, refresher sessions, webinars, and joint events showcasing ongoing research and converting theory to policy and practice. Competence-building activities could be embedded in funded research projects, with clear metrics for evaluation and impact. In line with research topics mentioned above in healthcare, industry and policy organisations, studies should also assess the needs, effectiveness, societal impact of E&T and its role in enhancing public understanding and policy uptake. Also in this phase, the support of PIANOFORTE as mentioned in the previous paragraph is essential.

By investing in a sustainable and strategic E&T infrastructure, Europe can secure its leadership in radiation protection, empower current and future workforce, and ensure that the benefits of ionising radiation are realized safely and responsibly across all sectors.

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Chapter 8: Basic Research

The system of radiological protection as developed by the International Commission on Radiological Protection (ICRP) underpins the IAEA and EURATOM Basic Safety Standards which in turn underpin national legislation in Europe and most parts of the world. The system is based on science, ethical values and practical experience. While it is true that ionizing radiation is relatively well characterized in terms of risks that exposures posed to human health and to the environment, the evidence base is incomplete and continues to evolve. Therefore, basic research into the effects of radiation exposures on human health and the environment will make an essential contribution to better protection, through informing judgements on risk and appropriate protection strategies.

In terms of health risks, the system is constructed to avoid acute tissue injury (such as burns to the skin, damage to the eyes and heart) and minimize the occurrence of stochastic effects (cancers and effects on future generations). There is good evidence of cancer risk in human populations down to around 100 mSv but protection is predicated on a linear non-threshold model of cancer risk, whereby there is no exposure with no risk and a direct proportionality between exposure dose and risk. This, in turn, has informed one of the fundamental principles of protection – that exposures should be kept As Low As Reasonably Achievable (ALARA). While the ALARA approach has driven a reduction in exposures in the nuclear industry over the years, it does have costs associated with its application. Therefore, a better characterization of radiation cancer risks below the 100mSv level, more in the region of exposure levels encountered in practice in industry today is necessary. Additionally, there are concerns that cancers are not the only risk of low dose exposures, with some evidence suggesting that circulatory diseases, cataract and effects on cognition may be present. Work in this area is essential to ensure adequate protection. Another key issue is that of the distribution of risk within the population. Currently the system assumes everyone on a population is at equal risk, with dose limits set on a population average basis rather than individual basis. Further evidence is required to investigate this area more thoroughly, to ensure everyone is adequately protected (and not over-protected) and consider if it is feasible to develop tests to assess individual risk.

Risks to the environment are controlled by the application of derived consideration reference levels (DCRLs), dose-rates that are considered to have modest and acceptable impacts on population and reproductive health. There are around 2 million described species on Earth, and this is likely an underestimate; it is therefore impossible to assess the risks to all species of non-human biota on the planet. Protection is directed by consideration of impacts on some twelve ‘reference animals and plants. From a biological and evolutionary perspective this is naïve. A deeper knowledge of the impacts of radiation exposures on a wider range of species is required to ensure protection of the environment is adequate and not over-protective.

Both human and environmental protection are underpinned by dosimetry – the measurement of radiation exposures. Clearly it is essential that doses are accurately and reliably measured or assessed to serve as a basis for research to evaluate radiation effects on the environment and humans. Furthermore, efficient and accurate dosimetry underpins the application of radiation protection in practice.

Thus, while radiological protection is fundamentally a practical discipline, it has to be based on sound evidence of risk. It is known that there are knowledge gaps in the evidence base, and some of the key ones are mentioned above. It remains essential that basic research into these areas is maintained and further developed to ensure protective measures are proportionate to risk and applicable in practice.

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Chapter 9: Radiation Protection Research as a Driver for Simplification

A robust system of radiological protection must be based on sound scientific evidence. Even though the regulatory framework for radiation protection is meant to be simple, the complexity has increased with time. New applications and new insights have led the ICRP (International Commission on Radiological Protection) to periodically update and extend the framework. Still, excessive layers of terminology, procedures, and administrative requirements can reduce the clarity, agility, and effectiveness of radiation protection efforts.

There is a growing need to simplify the system while upholding the foundational goal of keeping exposures *as low as reasonably achievable*. Strategic, targeted research can play an important role in enabling this simplification, by reducing uncertainties and providing a more solid basis for risk-informed decision-making.

Advances in key research areas—such as atmospheric transport and radioecological modelling, emergency response analysis, biological effect characterization, and dosimetric methodologies—can refine the scientific basis for protective actions. When risks are better quantified, unnecessary conservatism can be reduced, and regulatory measures can be tailored more precisely to actual needs. This, in turn, allows for reduced administrative burden without compromising safety.

Furthermore, emerging technologies such as artificial intelligence and real-time monitoring systems can transform how radiation protection is implemented. These innovations offer the potential to streamline procedures, automate decision-making support, and adapt protective measures dynamically to changing conditions.

To achieve meaningful simplification, scientists are encouraged to align their research with practical regulatory challenges and to focus on reducing key uncertainties. These key uncertainties need to be identified and addressed in the research calls. Policymakers, in turn, should be prepared to translate scientific progress into leaner, clearer, and more proportionate regulations.

A strategic agenda for radiation protection must therefore foster research that not only improves safety but also enables a more effective, efficient, and adaptable system—one that is scientifically sound, operationally practical, and resilient for the future.

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Chapter 10: Innovation / connection to SME/ startups

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Chapter 11: Artificial Intelligence

As in many fields AI based methods are already providing, will provide and may provide major improvements in radiation protection related topics and applications. There are already many approaches especially in the field of medical applications of ionising radiation as optimising imaging procedures to lower patient or staff exposures, enabling prediction of therapy responses to optimise therapy approaches including reduction of exposure to healthy tissues, planning of radiation therapy application and fast dose monitoring or therapy adjustments e.g. in MRI-Linac configurations etc. Also in other fields like dose monitoring of staff using camera based and calculation approaches or in dispersion calculations for radioactive releases or emergency situations AI based approaches can help dramatically to improve radiation protection of staff and the population. Especially in emergency preparedness people would benefit from faster modelling of dispersion by improved and faster prediction of exposure scenarios relevant for protection measures.

Reliable and efficient AI based approaches are needed to implement AI in radiation protection research and radiation-related applications, since it could have a high impact on patient and worker safety, accurate diagnosis, effectivity of medical treatments and radiation exposure of the European population. To achieve that there is a number of prerequisites which will have to be elaborated for the different application fields in radiation protection. These prerequisites include:

- Sufficient amount of independent data
- Separated data for training, validation and testing
- Quality assurance of such data in the sense that the way data are generated are well described
- Development of suitable models
- Definition of application purposes for each trained AI model
- Characterisation of out of distribution effects
- Developments of suitable methods for quality assessment and assurance.

Based on these requirements and related issues, well-founded research approaches should be developed for which adequate resources are needed. However, if these requirements are met, the potential benefit for the European population as a whole, patients and staff can be tremendous and radiation protection can be made more comprehensive, less expensive and more efficient. This might impact healthy living in Europe enhance security in the context of threads of nuclear emergencies and armed conflicts and encourage European industry to provide safer equipment e.g. in health settings, with the aim of maintaining or even strengthening economic performance.

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Conclusions [outstanding]

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Annex: Detailed description of research topics

Quality of Life

Topic Title	**Biokinetic and Internal Dosimetry Studies for Theranostic Approaches**
Challenge description	New theranostic approaches are going to play an important role for patient-specific treatment especially in cancer patients but potentially also for other diseases. As for radionuclides and radiopharmaceuticals intended for theranostic use both applications diagnostic as well as therapeutic ones the biokinetics are most probably completely different than those of known and often used radionuclides of today and not known yet. In addition, due to differences of the half-lives of such radionuclides as well as with respect to the emitted particles the dosimetric consequences will be completely different than of previously used radionuclides. Thus, investigations on the biokinetics and the corresponding dosimetric aspects are required to ensure a safe and optimized use of such radionuclides for the benefit of the patients
Objectives	- Improving knowledge about biokinetics and dosimetry for (new) radionuclides in theranostic medicine - Enabling the corresponding radiation protection for the clinical use of such radionuclides - Enable safe and meaningful application of new technologies, especially for the safe and optimised therapy of patients
Expected outcome	- Better individualised and personalised medical care, including radiotherapies for oncological patients - Better radiation protection for patients, staff and the population - Reduced costs for health care systems
Addressed stakeholders	Patients, medical staff, general public, policy makers especially those involved in radiation protection

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Topic Title	**Artificial Intelligence for CT and PET–CT Optimisation in Oncological Imaging**
Challenge description	CT and PET–CT are medical imaging modalities widely used for cancer detection, staging, treatment planning, and follow-up. However, both modalities face persistent challenges related to radiation exposure to patients, image quality variability, and inconsistencies in procedure protocols across institutions. These issues can compromise diagnostic and therapeutic accuracy, patient safety, and the reproducibility of clinical studies. Despite advances in CT and PET–CT technology, there is a critical need to optimise imaging protocols to balance diagnostic performance with radiation safety. Furthermore, image interpretation is time-consuming, and prone to human error. The integration of Artificial Intelligence (AI) offers a transformative opportunity to address these challenges by enabling personalised imaging based on clinical indications, real-time image interpretation, standardisation across clinical settings and adequate image quality to respond to clinical questions.
Objectives	• Develop AI-based tools to optimise CT and PET–CT imaging protocols for oncology patients • Implement automated image interpretation systems for CT and PET–CT • Enhance diagnostic accuracy and reduce radiation exposure through personalised protocols • Ensure reproducibility and standardisation of CT and PET–CT imaging across clinical sites
Expected outcome	• Development of AI tools that personalise CT and PET–CT acquisition parameters based on patient characteristics and clinical indications • Demonstrated reduction in radiation dose without compromising diagnostic quality • Integration of AI tools into existing CT and PET–CT scanners software and PACS systems, contributing to improve patient workflow
Addressed stakeholders	Patients, health professionals and industry

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Topic Title	**Enhancing Oncologic and Interventional Imaging: Addressing Training Gaps, Quality Standards, and AI Integration in CT and PET/CT Practice**
Challenge description	CT and PET–CT imaging plays a pivotal role in the diagnosis, staging, treatment planning and follow-up of cancer patients. It is also a critical tool in guiding interventional procedures such as biopsies, ablations, and drainages. As CT technology evolves, incorporating advanced reconstruction algorithms, dose-reduction techniques, and AI-based tools, the demands on healthcare professionals to maintain high standards of image quality, safety, and consistency have increased significantly. Despite the centrality of CT and PET–CT in oncological and interventional workflows, there is a lack of structured, evidence-based training programs that ensure consistent, high-quality imaging practice across institutions. Variability in the acquisition protocols, operator-dependent image quality, and inconsistent adherence to quality assurance standards can compromise diagnostic accuracy and patient safety. Furthermore, the integration of AI into imaging modalities introduces new complexities that require health professionals to develop digital competencies and ethical awareness. Research is required to analyse the current practices and to built up and optimise training and education programs throughout Europe.
Objectives	• To design, implement, and evaluate a comprehensive, evidence-based training framework that enhances the quality, safety, and consistency of CT and PET–CT in oncological and interventional procedures across Europe • To develop and integrate AI and digital literacy into clinical training
Expected outcome	• Improve and harmonise CT and PET–CT imaging practice • Structured and harmonised training programs across Europe • A competence-based training framework
Addressed stakeholders	Patients, health professionals and industry

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Topic Title	**New Technological Developments for Medical Use of Ionising Radiation**
Challenge description	Especially in molecular imaging procedures like, e.g., X-ray fluorescence, full-body PET scanners, theranostic applications, and new radiotherapy approaches like proton therapy, flash therapy, microbeam therapy and CDSS, there are many new developments which might improve patient care and also foster the health care system in Europe by more efficient personalized medical care. The role of radiation protection research in this aspect is twofold: First, the new technologies must be implemented in a safe way, new radiation protection measures might be needed. On the other hand, the new technologies can allow more efficient and more targeted use of therapies including such based on ionising radiation or combination therapies, sparing patients from high doses. Europe had been a driver for medical technologies, and corresponding research is needed to use the potential of new technologies also for societal and economic wealth by enabling European industry to stay in a world-leading position.
Objectives	- Develop and improve new technologies for molecular imaging, clinical decision support systems using ionising radiation-based diagnostics or for therapeutic approaches and new therapeutic approaches - Enabling the corresponding radiation protection - Foster European industry in the field of medical technology - Enable safe and meaningful application of new technologies - Understanding the ethical implications of new technological developments for patients
Expected outcome	- Better individualised and personalised medical care including therapies using ionising radiation for patients especially but not limited to oncological patients. - Less costs for healthcare systems - Successful industrial developments and commercial welfare for certain topics
Addressed stakeholders	Patients, general public, industry, policy makers especially those involved in healthcare systems

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Topic Title	**Radioactive Waste Management in Nuclear Medical Applications**
Challenge description	New theranostic approaches as well as new nuclear medical imaging approaches and therapeutic applications based on other radionuclides than those used in today's clinical routine will generate waste of such radionuclides after application to patients. It is in many cases unclear how this waste needs to be handled, including how long patients must stay in hospital excreting faeces and urine, or when they can go home still excreting some radioactive waste. In addition, the waste storage including secure systems, deactivation containers, safe storage and safe release have to be evaluated to allow broad applicability of such new diagnostic, therapeutic and theranostic applications. This is also necessary to allow commercial production and distribution of tracer linked radionuclides for economic welfare and optimized patient care. This became obvious just recently for one example (^{177}Lutetium-PSMA-617) for prostate cancer therapy as due to lack of scientific data various non-homogenous regulations are established for patient treatment in different European countries.
Objectives	- Improving knowledge for clinical radioactive waste management for currently not regularly used radionuclides in medicine - Enabling the corresponding radiation protection for the clinical use of such radionuclides - Foster European industry in the field of nuclear medicine especially radionuclide and radiotracers development and commercialisation - Enable safe and meaningful application of new technologies
Expected outcome	- Better individualised and personalised medical care including radiotherapies for oncological patients. - Better radiation protection for the population - Reduced costs for healthcare systems - Successful industrial developments and commercial welfare for radionuclides for medical care
Addressed stakeholders	Patients, general public, industry, policy makers especially those involved in radiation protection

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Topic Title	**Investigations on Biological Effects, Including Low-Dose and Therapeutic-Dose Effects and Especially Effects in Combination Therapies**
Challenge description	Over the last 20 years, advances in physics and medical imaging have enabled us to achieve a revolution in clinical radiotherapy protocols by seeking to deliver higher doses to the tumour. These new radiotherapy procedures called IGRT, stereotactic-RT, IMRT, proton-RT or vectorised radioimmunotherapy using alpha or beta emitters, represent scientific and societal challenges in terms of radiobiology and patient radioprotection due to changes in dose distribution to healthy peritumoral tissues, often involving large volumes with low exposure but in some cases smaller areas with very high irradiation. Analysis of clonogenic survival curves after low and high doses shows that the dose response does not follow a well-established linear quadratic model at low and high doses, suggesting the emergence of specific radiobiological mechanisms such as lipid or mitochondrial metabolisms or epigenetics. The definition of these precise and unique molecular events will improve new range of tumor radiosensitizers or normal tissue radioprotectors and patient care in Europe by more efficient personalized medical care. Later, radiotherapy is combined with adjuvant systemic chemotherapy and targeted therapies, which also need to be better understood in order to better assess their involvement in the toxicity of irradiated healthy tissue. Europe has been a catalyst for the clinical development of these new radiotherapy protocols. Research into radiobiology for these clinical applications is needed to harness the potential of the new technologies for the benefit of society and the economy, enabling European industry to remain among the world leaders.
Objectives	- Improving knowledge in radiobiology for innovative radiotherapies combined or not with chemotherapies - Enabling the corresponding radiation protection - Foster European industry in the field of radiomedical technology - Enable safe and meaningful application of new technologies - Understanding the ethical implications of new technological developments for patients
Expected outcome	- Better individualised and personalised medical care including radiotherapies for oncological patients. - Reduce costs for healthcare systems - Successful industrial developments and commercial welfare for certain topics
Addressed stakeholders	Patients, general public, industry, policy makers especially those involved in health care systems

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Topic Title	**Mechanistic Pathways of Radiation-Induced Cancer and Non-Cancer Diseases**
Challenge description	Growing evidence highlights cardiovascular, cerebrovascular, neurocognitive, metabolic, and immune disorders as relevant outcomes of low and intermediate dose ionizing radiation exposure. However, as for radiation-induced cancer, biological mechanisms remain poorly characterized, particularly at intermediate and low doses.
Objectives	• Identify mechanisms underlying radiation-induced non-cancer diseases (cardiovascular, cerebrovascular, neurocognitive, metabolic, and immune disorders), including near-field, out-of-field, and non-targeted effects. • Apply methodologies like 'omics technologies, cellular models, cell tracking/imaging, molecular epidemiology and artificial intelligence-based modelling to investigate these effects. • Develop Adverse Outcome Pathways (AOPs) to formalize links between radiation exposure and disease. • Use molecular epidemiological approaches in search for biomarkers.
Expected outcome	• Establish biomarkers for early detection of radiation-induced cancer and non-cancer effects. • Inform more robust exposure limits and public health guidelines for long-term disease prevention
Addressed stakeholders	Radiobiologists, medical practitioners, environmental health researchers, radiation safety regulators

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Topic Title	**Personalized Radiation Risk Assessment: Addressing Individual Variability and Susceptibility**
Challenge description	Current radiation protection standards are primarily population-based and fail to adequately consider individual differences in radiosensitivity. Factors such as genetics, sex, age, comorbidities, immune status, environmental exposures, and lifestyle significantly influence individual responses to radiation. As a result, vulnerable subgroups—including children, the elderly, patients undergoing concurrent treatments, or individuals with genetic predispositions—may be either under- or over-protected by existing frameworks. This poses serious implications for both safety and therapeutic efficacy.
Objectives	• Identify and validate biomarkers of radiosensitivity and/or radiosusceptibility using cellular, molecular, systems biology approaches and epidemiological investigations. • Taking use of in vitro, in vivo and in silico studies as well as epidemiological data develop personalized dose-response models. • Assess risk profiles of vulnerable populations, including those with pre-existing conditions or undergoing co-exposures (e.g., radiation combined with chemotherapy). • Examine sex-based and genetic differences in radiation response to refine population subgroup-specific protection guidelines.
Expected outcome	• Implementation of precision-based radiation protection strategies that tailor exposure limits and treatment protocols to individual biological profiles. • Enhanced safety for sensitive subpopulations, reducing the risks in occupational, and environmental contexts and avoiding radiation overexposure or under-treatment in clinical exposures. • Evidence-based policy development for occupational and therapeutic settings that accounts for personal health status and demographic variability. • Acceleration of personalized medicine adoption, improving equity and effectiveness in radiation-based diagnostics and therapies.
Addressed stakeholders	Healthcare providers, personalized medicine specialists, radiation protection policymakers, occupational health agencies, patient advocacy organizations, ethicists, and insurance and regulatory bodies.

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Topic Title	**Re-evaluating Cancer Risk from Low Dose Irradiation: Incorporating the Dose Modifying Effect of non-Targeted Effects in Risk Assessment**
Challenge description	Traditional radiation risk models assume that health effects, including cancer risk, result primarily from direct DNA damage in irradiated cells and follow a linear dose-response relationship. However, low dose irradiation (<100 mGy) has been shown to induce non-targeted effects, such as bystander effects, genomic instability, and inflammatory signaling in cells that were not directly irradiated. These phenomena challenge current assumptions and introduce uncertainties in risk estimation, particularly at low exposure levels relevant to medical imaging, environmental exposure, occupational settings, and space travel.
Objectives	• Investigate the biological mechanisms underlying non-targeted effects (e.g., bystander signaling and intercellular communication, systemic inflammatory responses, tissue-level responses such as stem cell competition) following low dose irradiation. • Quantify the contribution of non-targeted effects to cancer initiation and progression at low doses. • Integrate direct dosimetric data with the dose modifying effect of non-targeted reactions in a tissue-specific manner to evaluate actual biological damage by using experimental models that allow distinguishing hit and non-hit cells. • Refine cancer risk estimation models by integrating data from in vitro studies, animal models, and human epidemiological cohorts that account for both targeted and non-targeted effects. • Explore dose-rate and tissue-specific variations in the manifestation of bystander and other non-targeted effects. • Assess implications for radiation protection policies across diagnostic medicine, nuclear industry, and long-duration spaceflight.
Expected outcome	• Improved understanding of cancer risk associated with low dose radiation, especially in medically and environmentally relevant scenarios. • Evidence-based updates to risk estimation models that account for non-targeted biological responses. • More accurate and protective regulatory thresholds for low-dose exposures across healthcare, industry, and space exploration. • Enhanced risk communication for the public and vulnerable populations regarding the true implications of low-dose exposure.
Addressed stakeholders	Radiation biologists, medical imaging professionals, radiation protection authorities, space agencies, epidemiologists, public health policymakers, and cancer researchers

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Topic Title	**Long-Term Risks in Paediatric and Young Adult Patients**
Challenge description	Pediatric and adolescent patients undergoing imaging or radiotherapy are at an increased risk for long-term secondary effects, such as cardiovascular disease, cognitive impairments, and secondary malignancies
Objectives	• Investigate risks associated with repeated diagnostic procedures or intensive therapies (e.g., brain CT, cardiac catheterization) using epidemiological approaches. • Develop tools for long-term follow-up and outcome tracking in vulnerable populations. • Identify biomarkers for early detection of secondary malignancies or adverse effects. • Integrate mechanistic models of radiation-induced tissue damage to better understand age-dependent sensitivity and latency of late effects. • Apply AI to identify markers of increased risk in existing data sets
Expected outcome	• Enhanced long-term safety for young patients exposed to ionizing radiation. • Reduced healthcare costs by enabling preventive measures and personalized follow-ups. • Improved understanding of biological processes underlying long-term radiation risks in paediatric tissues, informing more accurate predictive models and intervention strategies.
Addressed stakeholders	Pediatricians, radiotherapy specialists, cancer researchers, public health experts.

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Topic Title	**Enhancing Safety and Risk Assessment in Advanced Radiation-Based Medical Applications**
Challenge description	The expanding use of ionizing radiation in modern medicine—through advanced diagnostic technologies (e.g., combined CT, PET, and SPECT imaging) and cutting-edge therapeutic approaches such as proton and ion therapy, radionuclide theranostics, FLASH radiotherapy, and combined treatments (e.g., radiation plus chemo/immune/targeted therapy)—is transforming cancer care and other medical interventions. However, these innovations introduce significant uncertainty and complex health risks, including not only secondary cancers but also non-cancer outcomes such as cardiovascular disease, neurocognitive impairment, immune dysregulation, and endocrine dysfunction. These risks are especially pronounced in vulnerable populations, such as children, young adults, and individuals with pre-existing conditions. Existing radiation protection and risk estimation frameworks are not well equipped to handle the spatial, temporal, and biological complexity of these personalized and multimodal treatments, limiting our ability to fully understand, predict, and mitigate long-term adverse outcomes.
Objectives	• Quantify both cancer and non-cancer risks associated with advanced diagnostic and therapeutic radiation procedures (e.g. CT imaging, cardiac catheterization, proton/ion therapy, radionuclide and targeted radiotherapy, FLASH therapy), especially in vulnerable populations. • Assess short- and long-term biological effects using mechanistic investigations, epidemiological studies, and pre-existing datasets to establish reliable dose–response relationships for critical organs and systems, including endpoints such as cognitive decline and cardiovascular dysfunction. • Investigate tissue-specific radiosensitivity and risks of secondary malignancies, particularly in the context of emerging radiotherapies and combination treatments (e.g. radiation combined with chemotherapy/immunotherapy/targeted therapies). • Support the clinical integration of molecular imaging and theranostics by establishing acceptable cumulative exposure thresholds from combined diagnostic and therapeutic applications. • Develop and harmonize standardized dosimetry, treatment, and investigation protocols to ensure reproducibility and consistency across healthcare systems. • Identify and validate predictive biomarkers for adverse radiation effects to support personalized treatment strategies and clinical decision-making. • Leverage artificial intelligence (AI) and machine learning to integrate multi-modal data (e.g. imaging, genomics, dosimetry, clinical records) for individualized risk prediction, treatment optimization, and early detection of adverse effects.

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	• Improve patient-provider communication by developing tools for informed, shared decision-making based on individualized risk-benefit profiles.
Expected outcome	• Scientifically grounded, personalized treatment strategies that optimise therapeutic efficacy while minimizing short- and long-term radiation-induced side effects. • Evidence-based guidance and safety thresholds for integrating advanced radiation technologies and combination therapies in routine clinical care. • Harmonized European and global safety standards and standardised protocols to support quality assurance and clinical audits. • Improved justification of diagnostic and therapeutic radiation use at both the population (level 2) and individual (level 3) levels. • Empowered patients and clinicians through the use of predictive biomarkers, individual health data, and advanced communication tools for risk–benefit assessment.
Addressed stakeholders	Radiation oncologists, nuclear medicine specialists, medical physicists, clinical researchers, regulators, health economists, patient advocacy groups, and developers of radiopharmaceuticals and radiotherapy equipment

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1-Topic Title	**Towards Improved Dosimetry for Safe and Effective Use of Emerging Radiotherapy and Diagnostic Techniques**
Challenge description	Despite major technological advances in radiotherapy, key physical (e.g., dose rate, LET, spatial fractionation) and biological (e.g., RBE, tissue radiosensitivity) parameters not yet fully exploited in clinical practice. As cancer treatments become increasingly multimodal, the need for accurate, standardised dosimetry is greater than ever—not only to ensure safe and effective dose delivery but also to support a better understanding of dose–effect relationships and biological mechanisms. The treatment of metastatic and advanced-stage cancers remains a major challenge. Radiotherapy approaches are still primarily focused on local control, and the potential for systemic effects—either alone or in combination with other modalities—remains insufficiently explored. Existing radiological protection frameworks, still based on the concept of effective dose, do not adequately reflect individual patient risks.
Objectives	• To optimize the interplay of physical and radiobiological parameters—such as RBE/LET, dose rate, and spatial fractionation—to improve tumor control while minimizing toxicity. • To investigate novel treatment and imaging modalities and improve their integration into clinical workflow • To develop dosimetric protocols and quantities for emerging radiotherapy techniques to support their clinical translation. • To investigate the synergy between radiotherapy and other treatment modalities, such as immunotherapy, nuclear medicine, hyperthermia or targeted therapies • To explore the systemic potential of radiotherapy • To integrate advanced imaging techniques, such as optical dosimetry using Cherenkov radiation, for real-time treatment verification • Development, validation and quality insurance of AI/ML-driven tools for personalized dosimetry, quality assurance, and advanced modelling • To enhance patient dosimetry not only for accurate tumor targeting but also for assessing long-term risks and optimizing overall treatment outcomes To develop and test different approaches to patient radioprotection especially in growing procedures such as radiotherapy, interventional practices, and imaging procedures in radiotherapy.
Expected outcome	More precise, individualized and cost-effective treatment strategies that maximize tumor response while minimizing toxicity. Enhanced dosimetry and QA tools supported by AI and advanced modelling. More accurate risk assessment for patients leading to improved radiation protection policies.
Addressed stakeholders	Patients, Medical Physicists, Oncologists, Radiobiologists, Academic and Research Institutions, Regulatory and Standardization Bodies, Industry

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Topic Title	**Towards improved dosimetry for patients and caregivers in radiopharmaceutical therapy and diagnostic**
Challenge description	Radiopharmaceutical therapy has undergone impressive developments. New radiopharmaceuticals are under clinical trials and are expected to become available in a near future. Currently treatments are not optimised due to a lack of understanding the mechanisms, lack of dose-effect relationship and lack of appropriate dosimetry. As a result, many patients are thus over- or under-treated. To obtain robust dose-effect relationships, harmonized and clinically feasible imaging and dosimetry protocols are needed. Furthermore, due to the spatial and temporal heterogeneity of dose delivery radiobiological models from external beam radiotherapy cannot be directly applied for radiopharmaceuticals. Micro- or nano- dosimetry might thus help in better understanding the radiobiological effects. Radiation protection of caregivers and members of the public is also an issue since there is a lack of robust data to define harmonized patients' release criteria. With the increased number of radiopharmaceuticals coming into clinical practice, also the radiation protection of staff, handling these isotopes and the patients, needs permanent attention. Finally, for radiopharmaceuticals used for diagnostic purposes, doses should be optimized for children to avoid unnecessary exposure.
Objectives	• To improve individualized dosimetry with timely acquired imaging data. • To develop population based biokinetic models to supplement missing individual data and assess the influence on dose assessment. • Set-up and maintain patient database for training and harmonization of dosimetry practice. • To give guidance on implementation of individualized dosimetry • To advance small-scale dosimetry for short range emitters by combining advanced imaging, Monte Carlo simulations, and biokinetic modelling. • To carry out dose estimation and bioeffect modelling through micro-nano-dosimetry • To improve assessment of exposure from nuclear medicine patients. • To contribute to the harmonization on patient release criteria in Europe • To improve paediatric dosimetry regarding physiological and pharmacokinetic differences; balance low radiation dose with adequate image quality. • To improve paediatric-specific data and the adult-based/scaled paediatric dosimetry models
Expected outcome	Treatment optimization and reduction of side effects for current and future radiopharmaceuticals. Imaging optimization for children. Better understanding of radiation effects at small scale. Justification and harmonization of patient release criteria in Europe.
Addressed stakeholders	Patients, medical physicists, nuclear physician, academic society, legislator

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Topic Title	**Understanding of effects on ecosystems exposed to ionising radiation**
Challenge description	The ecological consequences of ionising radiation exposure remain insufficiently understood, particularly under chronic or spatially heterogeneous exposure conditions. This lack of mechanistic knowledge limits the integration of ecosystem-level processes in radiation protection frameworks and hinders the development of ecologically realistic risk assessments.
Objectives	To investigate the mechanistic effects of ionising radiation at different levels of biological organisation in ecosystems. To identify key ecological functions and species traits that are most at risk under chronic or spatially heterogeneous exposures. To improve the scientific basis for ecological risk assessment and support integration of environmental protection into One Health strategies.
Expected outcome	Improved ecological realism in radiation protection; identification of key ecosystem vulnerabilities; enhanced tools for environmental risk assessment; stronger alignment between environmental and human health protection.
Addressed stakeholders	Environmental regulators, ecosystem managers, radiation protection authorities, ecotoxicologists, biodiversity conservation agencies.

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Topic Title	**The relation between social sustainability considerations and radiation protection in the medical use of ionizing radiation**
Challenge description	The use of ionizing radiation in the medical field -both in diagnostic and therapeutic contexts- is increasing and expected to significantly expand still in the (near) future. Developments such as Artificial Intelligence or novel therapies, which could facilitate a further deployment of nuclear medicine -e.g. in the form of personalized treatments- are driving forces of such expansions, while also significantly altering the field. In this light research on the relationship between social sustainability and radiation protection becomes increasingly important, in order to ensure that healthcare practices are not only clinically effective but also socially responsible, equitable, and ethically adequate. By understanding how radiation safety practices and measures impact patients' rights, healthcare professionals' well-being, and community trust, policies and approaches can be developed that promote long-term public health benefits and fair access to safe and quality care for all those who need it.
Objectives	Understand the potential impacts of (novel) nuclear medicine practices and developments on social sustainability, with particular attention for responsibility, equity and ethics.
Expected outcome	Practices and approaches in the field of nuclear medicine that build on a stronger awareness about and incorporation of social sustainability concerns and impacts.
Addressed stakeholders	Healthcare professionals, patients, policymakers, regulators

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Topic Title	**Integrated Risk Assessment of Combined Radiation Exposure Scenarios**
Challenge description	Modern environmental and public health risk assessments face growing complexity due to the multifactorial nature of real-world exposure scenarios. Populations and ecosystems are frequently exposed to multiple, interacting stressors—including radioactive contaminants (both chronic and acute exposures; internal and external emitters), chemical pollutants (e.g., heavy metals), climate-induced environmental changes, and physical habitat disruptions. These co-exposures often result in non-uniform, heterogeneous dose distributions and biological effects that current models fail to accurately capture. The interplay between radiological and non-radiological stressors can be additive, synergistic, or antagonistic, further complicating risk characterization. Current frameworks remain largely compartmentalised between human and environmental health assessments, and the lack of harmonized methodologies and interoperable tools, hinder the development of coherent cross-sectoral responses and . Evidence of variability in biological responses—including resilience or adaptation in certain populations—underscores the need for integrated, dynamic, and systems-level approaches to risk assessment and management.
Objectives	• Design and implement integrative methodologies that combine radiological, chemical and environmental stressor assessments into unified risk frameworks. • Model complex, real-world contamination scenarios, accounting for temporal and spatial dose heterogeneity, internal versus external exposures, and co-occurring stressors. • Advance understanding of low-dose radiation effects on critical biological endpoints (e.g., carcinogenesis, circulatory and cognitive function), especially under multi-stressor conditions. • Apply AI and machine learning to create predictive tools that reflect the evolving nature of exposure patterns and adaptive biological responses. • Align protection goals and assessment endpoints across sectors to support comprehensive risk governance.
Expected outcome	• Harmonized, multi-stressor risk assessment frameworks that bridge human and environmental health considerations. • Predictive models and decision-support tools capable of accommodating the complexity and dynamics of real-world exposure scenarios.

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	• Improved coherence across sectors and stronger scientific support for cross-sectoral regulatory, clinical, and environmental decision-making. • Enhanced capacity to anticipate and mitigate long-term impacts of combined exposures on vulnerable populations and ecosystems.
Addressed stakeholders	Environmental and health regulators, public health agencies, radiation and chemical risk assessors, ecologists, dosimetry and medical physics experts, policymakers, industrial operators, clinical researchers, space and safety authorities, and social scientists.

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Security

Topic Title	**Towards development of new technologies and calibration procedure for emergency dosimetry and preparedness**
Challenge description	Dosimetry is essential in support of radiation accident or incident emergency response. New detection systems for environmental, individual and population monitoring in the event of a radiological accident have been developed in recent years and the availability of such low-cost, easy-to-use detectors is expected to increase. Data from citizen measurements can contribute to creating a more comprehensive map of the radiological situation during an emergency. In post-accidental phases, passive area dosimeters would be a suitable system for long-term measurements to improve resilience; however, there are no currently available technical recommendations on passive area dosimetry systems and legal requirements are diverse. In addition, very few designs for passive neutron area dosimetry are currently available. Existing and developmental methods of dosimetry vary in the quality of the associated uncertainty assessment methods; some are very well standardised and some are still very much *experimental in nature*. Incorrect assessment of uncertainties can have a dual impact: from a decision-making perspective, it can slow down or reduce the effectiveness of responses. From the perspective of potential victims, it can lead to mistrust in dose estimates. Inconsistent or unreliable dose assessments may create scepticism about the measures taken to protect the public. Increased uncertainties in doses estimated in support of epidemiological studies can also lead to underestimation of risk factors. Finally, estimation of internal doses resulting from public emergency monitoring, including children and pregnant women, should be carried out according to updated ICRP models.
Objectives	• To have a metrological system, providing measurements results with reduced uncertainties and traceable to the SI system, including the new detectors and citizens platforms, for individual and environmental monitoring. • To implement AI-based methods for the analyzation of data from different detection systems. • To extend network databases for implementation of harmonization algorithms for real time data. • To develop strategies to include and to educate citizens in case of an emergency scenario • To harmonize passive area dosimetry by elaborating recommendations on a common ground of requirements for passive area dosimetry. • To develop passive area neutron dosimeters. • To improve the decision-making process by better estimation of uncertainties in retrospective dosimetry

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	• To avoid inappropriate reliance on dose estimates; and increase the level of trust in dose estimates • To improve confidence in the measures taken to protect the public. • To establish reference retention and excretion curves, based on last ICRP series, for internal contamination monitoring
Expected outcome	Improved information for citizens and decision makers. Platforms for exposure visualization with increased resolution in space and time Validated methods of dose and uncertainty estimation to support routine dose assessment, radiation emergency response, and long-term studies of health risk. Implementation of new technologies including AI. Reference data for the assessment of internal contamination of the public.
Addressed stakeholders	Decision makers, legislators & regulators, first responders, general public, emergency workers.

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Topic Title	**Radiation protection of the environment in post-accidental and legacy contexts: from data to decision**
Challenge description	Environmental contamination from nuclear accidents or past industrial activities presents complex, long-lasting challenges. Although monitoring data exist, there is often a disconnect between these data and the decisions needed for effective site management. Issues such as spatial heterogeneity, uncertainty, and limited integration of ecological and social dimensions impede effective remediation, zoning, and long-term planning.
Objectives	To develop integrated approaches that translate environmental data into spatially explicit, ecologically meaningful, and socially relevant decision-making inputs. To incorporate stakeholder engagement and long-term vision into site remediation and land-use strategies. To support effective communication and governance in contexts marked by uncertainty and public concern.
Expected outcome	Operational decision-support systems for post-accidental and legacy contexts; strengthened links between data and action; improved stakeholder confidence and transparent management of contaminated environments.
Addressed stakeholders	Site managers, Remediation planners, local decision-makers, impacted communities

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Topic Title	**Developing AI-based decision support tools for radioecological risk management**
Challenge description	The rise of Artificial Intelligence (AI) is transforming risk assessment and management in radioecology. However, the integration of AI tools into decision-making raises critical issues: how to ensure trustworthiness, interpretability, and appropriate use in sensitive environmental and health-related contexts? Existing tools struggle to process and integrate the growing volume and complexity of environmental monitoring and modelling data, particularly under crisis conditions.
Objectives	To co-develop AI-based systems capable of synthesising diverse data streams—monitoring, modelling, expert input—into decision-ready outputs for routine and emergency use. To embed principles of transparency, explainability, and stakeholder engagement into these systems, ensuring they are trusted and usable. To delineate the respective roles of AI and human expertise in high-stakes radioecological decisions.
Expected outcome	User-focused AI tools that enhance situational awareness, accelerate risk analysis, and support robust decision-making. Improved governance of AI in radioecological contexts, including ethical and procedural safeguards for its deployment.
Addressed stakeholders	Decision-makers, Emergency responders, Software developers, Data scientists

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Topic Title	**Optimisation of management strategies for emergency response, transition and recovery phases**
Challenge description	Optimisation of management strategies is a key requirement in the decision-making process for all phases of an accident. This is most challenging in the transition and recovery phase as alongside radiological aspects, technical, environmental and socio-economic factors as well as reference levels, waste management and context-specific constraints and possibilities need to be considered as well as taking an 'all-hazards' approach to decision-making accounting for non-radiological risks.
Objectives	Existing Decision Support Systems (DSS) may require adaptation Research areas that require consideration are, among others: (1) the improvement and the extension of the European Handbooks, including the experience gained over the last decade, (2) consideration of new threats in decision support material, (3) monitoring strategies and data assimilation to optimise the practical implementation of protective action strategies, (4) big data technologies and AI based methods to analyse requirements and optimise general preparedness for a wide-range of scenarios, (5) adaptation of existing DSS to allow the application of AI based optimisation methodologies, (6) application of a more comprehensive view on the concepts of tolerability and reasonableness, and (7) processes for direct stakeholder involvement and co-expertise
Expected outcome	Improved tools for decision-makers
Addressed stakeholders	Decision-makers, public

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Topic Title	**Improving Situational Awareness during Emergency Response**
Challenge description	Improving the understanding of uncertainty quantification, propagation and communication in experts' products including in direct and inverse modelling tools will help ensure that the decisions made in radiation emergencies are based on the best possible awareness during a rapidly evolving situation. There are areas such as modelling (direct and inverse), monitoring strategies such as UAVs or citizen science and data assimilation or AI that can all be combined to improve awareness. To ensure mobilisation of this knowledge, consideration will need to be given on how the uncertainties will be applied in decision-making.
Objectives	To ensure the widest range of available situational information is applied to improve decision making during radiation emergency response. There are some common topics between different types of risks for example in uncertainty quantification which could benefit from cross-disciplinary working. Learning could benefit from considering relevant external projects such as the French iRiMa programme.
Expected outcome	Greater understanding of uncertainties and application of these in decision making processes and systems
Addressed stakeholders	Responders, experts, decision-makers, public

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Topic Title	**Adapting EPRR to new geopolitical challenges**
Challenge description	The war in Ukraine as well as other political tensions has identified several areas where there is a requirement to develop the emergency preparedness and response approaches typically used to protect the public during radiation emergencies. The EPRR systems as well as the technological capabilities typically used for such emergencies were not necessarily designed for war or armed combat situations. As well as the EPRR framework, consideration of the resilience of communities in such situations needs to be considered Potential rapid changes in behaviour of people in such conditions could occur so there is the potential for novel techniques to understand the location, density and behaviours of affected populations in real-time could be used to help optimise protective actions strategies and communications.
Objectives	Review of EPRR systems for geopolitical challenges with the aim of improved resilience. Lessons can be taken from recent experience from Ukraine for example where data has been gathered for demining processes to understand the behaviours and locations of the population. Once an approach has been identified, this could be used to test existing decision-support models but also to consider dynamic optimisation of strategies during response.
Expected outcome	Evolution of the EPRR framework to improve resilience for conflict situations
Addressed stakeholders	Experts, decision-makers, public

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Topic Title	**Navigating Radiological Threats Amid Geopolitical Instability and Hybrid Warfare**
Challenge description	Increasing attention is being directed towards the impact of geopolitical instability and hybrid warfare on the management of radiological threats, environmental, and occupational radiation exposure. These concerns are often linked to national security and resilience and have been increasingly studied from strategic and policy perspectives. The evolving nature of hybrid warfare, which blends conventional military tactics with cyber attacks and disinformation campaigns, requires adaptive radiation protection strategies. However, broader impacts—particularly concerning misinformation and public perception—still require significant consideration. When geopolitical tensions introduce new stakeholders or disrupt existing protocols, the ways in which potential radiological risks are perceived and managed become critically important. How do professionals and broader stakeholder groups perceive the threats posed by radiological materials in the context of geopolitical instability? How do these perceptions influence the acceptance and implementation of radiation safety measures? Moreover, how does the spread of misinformation and disinformation impact public trust and compliance with radiation protection guidelines? These are key questions that demand comprehensive research and engagement to ensure effective and resilient radiation protection strategies in an era of complex global challenges.
Objectives	Analyze the effects of geopolitical instability and hybrid warfare on radiological threat management, focusing on public perception, misinformation, and adaptive radiation protection strategies.
Expected outcome	Development of resilient radiation protection frameworks that address the challenges posed by misinformation and geopolitical tensions, enhancing safety measures and public trust.
Addressed stakeholders	Professionals in various research fields related to radiation protection. The general public. Policymakers and authorities.

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Competitiveness

Topic Title	**Towards improved occupational dosimetry in view of BSS regulation and practical application**
Challenge description	Radiation application in all fields requires a reliable assessment of the possible exposure under various conditions. For this, additional tools are needed, including sophisticated computational models and AI application. This is particularly relevant for the operator working in complex medical irradiation scenarios characterized by partial shielding, sources varying their position/intensity/energy during the practice, or in case of contamination during the preparation and handling of unsealed sources.
Objectives	• To develop measurement devices with spectrometric capability including unfolding techniques. • To generate the physical data needed to underpin exposure modelling (including benchmarking of nuclear cross-sections for high energy exotic particle radiations). • To explore and exploit potential developments in online dosimetry including development of new AI driven calculation methods. • To develop and test different and updated approaches based on measurements, simulations, with the aim of providing more reliable and fast dose estimation for a better dose management and planning • To develop quality assurance protocols to ensure trustworthy AI in radiation protection • To investigate the practical implementation of the new ICRU 95 quantities, e.g. modification of instrumentation, guidelines and procedures in medical fields with low photon energies • To develop QA and best-practice guidance for users, in particular with regards to the design and development of the detectors needed for the new dose quantities, • To improve neutron personal dosimetry, measurement uncertainty and dosemeters
Expected outcome	Validated physical data (e.g. cross sections) for improved dose calculations. Fast, robust and validated measurement devices, computational tools, trustworthy AI driven algorithms. Recommendation of best practice, particularly for implementation of ICRU recommendations.
Addressed stakeholders	General public, patients, exposed workers, legislator & regulators, radiation protection experts, dosimetry service

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Topic Title	**Development and Quality assurance of advanced computational methods and AI for all fields of dosimetry**
Challenge description	Computational phantoms have reached such a level of complexity that details such as skin or cell layers can be included in the phantoms. These phantoms can also be varied in shape and posture to better represent specific individuals. Coupled with Monte Carlo codes such phantoms can be used to assess exposure more precisely than reference phantoms, applications go from emergency situation to dose reconstruction in epidemiology. Such phantoms are mainly developed and used in Korea and in the US, so Europe should catch up. Images and video can be generated by AI, one might explore the possibility to generate digital twins of exposed individual from photos, videos, imaging data. AI might also increase exposure calculation speed in complex radiation fields, help in unfolding neutron spectra, help in identifying most exposed individuals in emergency situations. Whatever all these promises, AI driven method should be tested for their robustness, benchmarked and pass quality assurance tests to be defined.
Objectives	• To support and improve the usage and implementation of advanced anthropomorphic phantoms within the EU. • To foster further development of more personalized phantoms, also by AI-application in phantom generation from images. • To develop phantoms for fast calculations and easy implantation in an open access environment enabling first estimates of exposure in specific cases like emergency, medical imaging, exposure of pregnant women and children. • To explore scenarios with patients and workers, internally or externally exposed, for several exposure conditions (imaging, radiotherapy, internal contamination) and assess the merits of using advanced computational phantoms. • To explore AI techniques enabling fast or real time exposure assessment and assess their advantages and limits. • To explore AI techniques applied to biological dosimetry, e.g. to improve detection of chromosomal aberrations. • To develop methods to ensure trustworthy AI and Quality Assurance of AI in all fields of radiation protection
Expected outcome	Increased competency Realistic, personalized and trustworthy models of exposure situations Fast assessment of exposure accessible to professionals and the public Protocols ensuring the robustness of the developed applications
Addressed stakeholders	Public, patients, exposed workers, regulators, radiation experts

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Topic Title	**Strengthening radioecological infrastructures and capabilities for long-term societal challenges**
Challenge description	Europe's radioecological research and training infrastructures are fragmented, ageing, and face declining support. This weakens the continent's ability to maintain leadership in radiation protection science and to respond to emerging environmental and societal challenges. Without sustained investment and coordination, critical capabilities—including field observatories, data platforms, and expert human resources—are at risk.
Objectives	To identify and strengthen key infrastructures in radioecology, including long-term monitoring sites, analytical platforms, and harmonised data systems. To foster interdisciplinary education and collaborative research networks. To support career development, ensure knowledge transfer across generations, and build long-term strategic capacity in environmental radiation protection.
Expected outcome	A shared roadmap for sustainable infrastructure and capacity development; enhanced access to high-quality data and training; secured European expertise in radioecology to support science-based policy, innovation, and societal resilience.
Addressed stakeholders	Academic institutions, Research infrastructures, Funding bodies, Educational networks

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Topic Title	**Emergency Planning, Response and Recovery Framework for Novel Nuclear Technologies**
Challenge description	The deployment of novel nuclear technologies such as Small or Advanced Modular Reactors and fusion experimental facilities poses some new challenges for emergency preparedness. Whether this relates to different applications of such as use in urban areas, as floating facilities or use in industrial areas as a heat source, such new challenges will require consideration of the most appropriate emergency response and recovery framework.
Objectives	To ensure that emergency response planning and systems are ready to meet the needs of wider deployment of such facilities. This will include ensuring we have knowledge of the potential emergency situations that may arise, tools, data and technology to be ready to respond. This should also consider the potential links to sustainability and the alignment to SDGs especially considering some of the potential actions that may be required during any recovery from a radiation emergency.
Expected outcome	Improved understanding of novel nuclear technologies and practical implementation of such knowledge in the emergency response framework
Addressed stakeholders	Operators, regulators, decision-makers, public

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Topic Title	**Application of Artificial Intelligence to decision making in radiation emergencies**
Challenge description	The application of AI for decision-making purposes should be considered and a framework developed for its use. There are many examples of use of AI in specific RP situations ranging from modelling to monitoring, but if decision-makers are to rely on AI recommendations then there needs to be robust governance in place to ensure the public is protected in response. The robustness of AI and the reliability of AI processes as applied to decision-support should be evaluated. This is include answers to questions such as how can we validate use of AI for decision-making; how can AI input to framework for decisions; and how consistent is the response of AI systems given similar starting conditions. There is clearly potential for AI to be of great help in evaluating multiple sources of data and proposing the optimal response if such a governance framework can be put in place.
Objectives	To review the use of AI and propose a means of testing and validating the use of AI for EPRR decision making. There are examples of the use of AI in Ukraine, with different data sources, including the population density, different population groups such as students and details of surrounding infrastructure. These could help to make decisions for evacuation for example. Review of such approaches would help to develop a proposed approach.
Expected outcome	Development of AI quality criteria and governance arrangements for their use in decision-making support.
Addressed stakeholders	Experts, decision-makers, public

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Topic Title	**Circular economy and sustainability in the context of waste management (including NORM)**
Challenge description	Increasing attention is being directed at the potential implementation of circular economy principles and practices in the management of radioactive waste and NORM (cfr. the HARPERS project). Such attention is often linked to sustainability concerns, and has been increasingly studied from a perspective of technical feasibility. Practices such as recycling and re-use are drawing growing attention, and also waste minimization is considered as a key topic from a circular economy perspective. However, broader impacts -not in the least regarding radiation protection- still require significant consideration. Especially if circular economy strategies and practices (such as recycling or re-use) entail that novel stakeholders are coming into contact with NORM or other radioactive materials, the ways in which potential risks are perceived and handled are of critical importance. How do professionals but also broader stakeholder groups (e.g. end-users) perceive the potential (re-)uses of NORM or other (potentially) radioactive materials? How do these perceptions connect to the acceptance and adoption of circular economy practices among these stakeholder groups? And how do these perceptions impact upon radiation protection behaviors? These are some of the key questions which still warrant a significant research engagement.
Objectives	Identify and understand stakeholders‘ perceptions and behaviors regarding circular economy practices in the field of waste management (including NORM), with a particular focus on radiation protection
Expected outcome	Improved alignment of circular economy practices with radiation protection principles
Addressed stakeholders	Professionals in NORM and radioactive waste industries, and in related industries potentially affected by circular economy practices. The general public. Policymakers and authorities.

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Topic Title	**Advancing Energy Transition and Security: The Role of New Nuclear Technologies in Sustainable Radiation Protection**
Challenge description	The development and deployment of new nuclear technologies, such as Small Modular Reactors (SMRs), are gaining momentum as potential solutions for advancing energy transition efforts. These innovations promise to alter the landscape of nuclear energy by offering scalable, flexible power generation options that can be integrated into diverse energy systems, thereby enhancing energy security by providing reliable and consistent power supply. As SMRs and other technologies advance, it is crucial to examine what challenges they pose for radiological protection. What are their implications for normal operations, occupational exposures, and emergency preparedness? Research into the interplay between technological sustainability and radiation protection is increasingly vital to ensure that nuclear energy practices are not only technically sound but also socially responsible, equitable, and ethically appropriate. By understanding how radiation safety measures impact workers' health, community perceptions, and stakeholder trust, policies can be crafted to promote sustainable energy solutions, ensuring long-term safety and equitable access to clean energy for all.
Objectives	Explore the integration of new nuclear technologies, such as SMRs, into energy systems, focusing on their operational safety, occupational impacts, and emergency preparedness to promote a socially responsible energy transition.
Expected outcome	Establishment of comprehensive frameworks that ensure the safe, equitable, and ethical deployment of nuclear technologies, and facilitating sustainable energy solutions.
Addressed stakeholders	New stakeholders whose core business is not radiation protection

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Topic Title	**AI in radiation protection**
Challenge description	Growing interest is being directed towards the application of artificial intelligence (AI) in the realm of radiation protection. This attention is largely driven by AI's potential to enhance efficiency and accuracy in monitoring and managing radiation risks, potentially leading to better protection of humans and the environment. While the technical feasibility and advancements in AI applications have been thoroughly studied, the broader implications demand further exploration. What are the foreseeable uses of AI in various spheres of radiological protection, and what novel challenges related to the perception and management of potential risks does it introduce? How is AI used in risk assessment, how does it intervene in decision-making, and how is it employed in communication and engagement? How do different stakeholders view the role of AI in enhancing radiation protection measures? What are the perceived benefits and drawbacks of AI adoption in this field? How do these perceptions influence the acceptance and implementation of AI-driven strategies? Finally, links between AI use and academic freedom, open science, cybersecurity, science diplomacy/transnational co-petition, innovation, teaching and learning, disinformation, and manipulation need further elaboration. This exploration will ensure that AI is effectively and responsibly integrated into radiation protection frameworks, ultimately enhancing safety and public confidence in these new technologies.
Objectives	Explore the multifaceted roles of artificial intelligence in radiation protection, examining its applications, challenges, stakeholder perceptions, and broader societal impacts.
Expected outcome	Increased understanding and strategic guidance for integrating AI into radiation protection practices, ensuring enhanced safety measures and fostering public confidence in the technology.
Addressed stakeholders	Professionals in various research fields related to radiation protection. The general public. Policymakers and authorities.

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