

European Metrology Network for Radiation Protection

Strategic Research Agenda
Version 1.0 (09/2024)



**RADIATION
PROTECTION**

Authorship and Imprint

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Further information

This is the first version of the Strategic Research Agenda for EMN for Radiation Protection, which provides guidance towards industrial metrology needs and the technical challenges that need to be solved as a priority through collaborative efforts between National Metrology Institutes (NMIs), Designated Institutes (DIs) and stakeholders. This document will be revised periodically in accordance with priority changes from the Radiation Protection community.

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Acronyms and Abbreviations

BIPM-CCRI	Bureau International des Poids et Mesures, Consultative Committee for Ionizing Radiation
CEN/CENELEC	European Committee for Standardization / European Committee for Electrotechnical Standardization
EMN Clean Energy	EMN for Clean Energy
EMN COO	EMN for Climate and Ocean Observation
EMN Mathmet	EMN for Mathematics and Statistics
EMN PoIMo	EMN Pollution Monitoring
EURAMET	European Association of National Metrology Institutes
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
SRA	Strategic Research Agenda

Executive summary

To better protect European citizens, the EU's radiation protection regulations have become increasingly more sophisticated. Innovative technological developments and new threats can lead to new radiation exposure scenarios. Measures to respond to these new needs come by regulation and include for example increasingly restrictive exposure limits, the introduction of new reference values, and enhanced quality assurance requirements for legal dose assessment. Can metrology support the increasing needs laid down by regulation and ensure that Europe has a world-leading metrology capability, based on high-quality scientific research and an effective and inclusive infrastructure that meets the rapidly advancing needs of end users?

The European Metrology Network for Radiation Protection (EMN RP) responds to technical developments and aims to act as a single point of contact to cover the metrological needs related to radiation protection. To enable quality assurance in all areas, the network fosters a harmonized, sustainable, coordinated and smartly specialized infrastructure to underpin the needs expressed by stakeholders and in the European regulations for radiation protection. This includes the close cooperation with organisations that are key to the international work for radiation protection such as IAEA and ICRP or key for metrology like BIPM with CCRI and EURAMET with TC-IR. A special focus of the EMN is a cooperation with regulators and standardisation bodies to actively contribute to the generation of new standards and to the revision of existing ones (ISO, IEC and CEN/CENELEC).

The aim of the network is to support quality management in all radiation protection issues, to support the development of more harmonized service procedures and capabilities, analyse the needs and give support to research, thus contributing to the improvement of radiation protection as a whole. By doing so, the EMN for Radiation Protection improves the understanding of general metrology aims: quality assurance, quality of data and low uncertainties in measurements.

The EMN for Radiation Protection presents within this contribution a research agenda designed to ensure that suitable reference fields and standards can be developed to support radiation protection regulations, to address knowledge transfer requirements and to provide input to international standards. Based on the possibilities offered by European funding programs (Euratom and Horizon Europe), the EMN members propose joint research projects with the intention to develop solutions suitable for practical applications, develop new calibration services and facilitate the launch of new technologies.

EMN RP comprehensively underpins this by the metrological quality infrastructure for radiation protection and legal dose assessment. It maintains a constructive dialogue and liaison between metrology institutes, calibration and test laboratories, proficiency testing and the stakeholders of radiation protection regulations. Existing reference laboratories are formally integrated into the EMN infrastructure to help develop a joint strategy to identify and prioritize measurands. New radiation protection principles and quantities require knowledge sharing, development of new services and building new expertise. EMN RP resolves this by ensuring a significant quality infrastructure, strengthening the economy and cohesion of Europe.

1. INTRODUCTION

The Strategic Research Agenda (SRA) was first presented at the European Radiation Protection Week in 2023. It underscores the essential role of metrology services in supporting radiation protection regulations across multiple sectors, with a focus on safety, technical applications, and environmental factors. It highlights the importance of precise radiation measurements, traceability, and established standards to mitigate risks posed by ionizing radiation—crucial for public health, workplace safety, and environmental stewardship.

Developed as part of the EMPIR 19NET03 supportBSS project, the SRA outlines the necessary metrology services to comply with radiation protection regulations. As a first step, a workshop in September 2020 gathered over 100 experts from 40 institutes worldwide, (mainly from Europe), to identify gaps in radiation protection metrology. Key issues were highlighted included reference fields, activity standards, operational quantities, testing of radiation measurement devices, also infrastructure needs, including education, training, and harmonisation efforts were found to have great importance.

The findings were presented at the 9th International Conference on Radiation in Various Fields of Research (RAD 9) in 2021 and later incorporated into the SRA. Perspectives from prominent radiation protection platforms (such as MELODI, EURADOS, EURAMED) and organisations (including ICRP, IAEA, and BIPM) were integrated to address specific fields like dosimetry, medical applications, and emergency preparedness. Feedback from these platforms helped refine the SRA, to ensure alignment with European regulations, notably the European Council Directive 2013/59 EURATOM and the EURATOM Treaty.

A stakeholder questionnaire further shaped the final draft which considered other regulations like European Council Directive 2013/51 EURATOM and Regulation 2017/745 on medical devices. The finalized SRA, supported by two roadmaps, was designed to help stakeholders identify and meet the metrology needs for radiation protection in each sector.

In addition to outlining research areas such as safety, technical applications, and environmental considerations, the SRA emphasizes the need for continuous education and training to support advancements in radiation protection. The SRA is expected to be periodically revised to reflect technological advances in radiation protection metrology.

2. OBJECTIVES

The overarching goal of this SRA is to develop and maintain a robust, fit-for-purpose metrological framework that supports:

- Compliance with radiation protection regulations
- Ensuring the safety of individuals and the environment
- Facilitating advancements in technology
- Addressing emerging challenges related to environmental radiation monitoring

3. NEEDS OF RESEARCH TOPICS IN RADIATION PROTECTION METROLOGY

The advancement of radiation protection metrology is essential to address the evolving challenges and risks associated with radiation exposure. The following research topics highlight the critical needs across the three main areas—i) safety, ii) technical applications, and iii) environmental factors—along with a combination of these areas and iv) education and training:

3.1 Safety

3.1.1 New approaches in emergency preparedness, quick response and enhanced resilience:

1. **Metrological support for early warning networks and EURDEP:** Focus on sensor reliability, type testing, quality assurance, and handling large volumes of data.
2. **Citizen science:** Develop reliable, affordable public dosimeters, quality assurance methodologies and use big data for optimizing radiation protection of large populations during emergencies.
3. **Development of unmanned ground and aerial vehicles:** Focus on real-time radiation monitoring using advanced sensors and validated algorithms.
4. **Real-time external radiation and environmental radioactivity measurements:** Create new sensors for monitoring air, soil, and water in real time, with a focus on standardisation and harmonisation.
5. **In-Vivo and In-Vitro monitoring equipment:** Develop new equipment and methods for monitoring radionuclides in the body, with a focus on large-scale screening and standardisation.

3.1.2 New security situation: nuclear threats and counterterrorism

1. **Enhanced security protocols for nuclear installations:** Integrate spectral and dose measurements to form a comprehensive radiation protection system. Utilize unmanned vehicles equipped with gamma spectrometry and alpha detection methods, supported by validated algorithms to provide accurate dose and activity assessments.
2. **Detection and monitoring networks for nuclear detonations:** Adapt radiation detection systems for urban environments and include food contamination monitoring. AI and big data applications improve radiological impact assessments, aiding decision-making during emergencies and recovery efforts. Development of nuclear forensics methods ensures traceability and quality assurance in analysing radiological threats.
3. **Advanced screening methods for counterterrorism:** Implement new X-ray and millimetre-wave screening technologies at transportation hubs. Develop optimized test objects for validating AI-based automated detection systems, particularly for low-dose, pulsed fields. Focus on harmonizing safety protocols for radiation measurement in transit, including luggage passing through CT scanners.

These strategic initiatives aim to improve preparedness and response capabilities, fostering public engagement in radiation safety while addressing nuclear threats and terrorism. Through advancements in radiation protection metrology, these efforts ensure effective security measures, enhancing public safety and resilience during emergencies.

3.2 Technical application

3.2.1 New approaches in computational dosimetry (partially in collaboration with EMN Mathmet):

1. **Development of AI-supported dosimetry:** Focus on creating computational and AI-based dosimetry as alternatives to traditional dosimetry methods for some workplace environments. These approaches could offer improved efficiency and precision.
2. **Realistic calibration phantoms:** Work on the development and validation of more realistic reference calibration phantoms, both physical and computational, to ensure accurate dosimetry calibration.
3. **Testing and approval standards:** Establish testing criteria and approval processes for computational and AI-supported dosimetry, with a focus on uncertainty assessment to ensure reliability and compliance with safety standards.
4. **Improved real-time visualisation:** Enhance the speed and accuracy of computational and AI-driven dosimetry to improve radiation protection for workers. This includes real-time visualisation of radiation fields, potentially by implementing augmented reality (AR) for better situational awareness.
5. **Enhanced shielding calculations:** Utilize computational and AI-supported dosimetry to improve shielding calculations, ensuring optimized protection for workers in radiation-prone environments.

These approaches aim to improve radiation safety through advanced, efficient, and real-time dosimetry solutions.

3.2.2 New reference fields following technological developments:

1. **Dosimetry in pulsed fields:** Development of dosimetry methods for pulsed radiation fields using active devices to ensure accurate measurements in these dynamic environments.
2. **Specific reference fields for pulsed fields:** Creation of dedicated reference fields for pulsed radiation sources, such as those used in accelerators, to ensure reliable calibration and dosimetry.
3. **Replacement of radioactive source fields:** Establishment of alternative reference fields to replace traditional radioactive sources like Cs-137, Co-60, Am-241, and Cf-252, offering safer and more modern calibration standards.
4. **Spectrometry and conversion coefficients:** Development of methods for spectrometry of reference fields, including simulation, determination of conversion coefficients and uncertainty estimation to improve accuracy.
5. **Neutron reference fields:** Creation of neutron reference fields for various scenarios, including thermal fields and workplace environments, to enhance neutron dosimetry.
6. **Realistic reference fields:** Development of reference fields that simulate realistic radiation exposure conditions for more accurate assessment and protection.
7. **Accelerator and high-energy fields:** Establishment of reference fields for high-energy and pulsed radiation environments, such as those encountered in particle accelerators.
8. **Cosmic muon reference fields:** Creation of cosmic muon reference fields for quality assurance in applications like muon imaging systems, ensuring accuracy in advanced imaging technologies.

These developments aim to provide precise calibration and improved dosimetry across a wide range of radiation fields, enhancing safety and accuracy in radiation protection.

3.2.3 New approaches for operational quantities (like ICRU 95):

1. **New secondary standards:** Development of updated secondary standards for operational quantities aligned with ICRU 95, to improve measurement accuracy and consistency in radiation protection.
2. **New/modified dosimeters:** Design and creation of new or modified dosimeters that are compatible with the revised operational quantities, ensuring more accurate measurements in varying radiation environments.
3. **Photon and electron component measurement:** Development of advanced instruments capable of measuring photon and electron components separately, enhancing the precision of radiation monitoring and assessment.
4. **Reference fields for ICRU 95 quantities:** Establishment of reference fields specifically for the new ICRU 95 quantities, particularly in non-charged particle equilibrium conditions, to ensure accurate calibration and measurements.
5. **Scattered radiation in workplaces:** Focus on measuring and addressing scattered radiation in typical workplace environments, especially in low-energy ranges (< 60 keV), to enhance radiation protection strategies.

These innovations aim to refine radiation measurement practices and ensure compliance with updated operational quantity standards, thereby improving safety and accuracy in various radiation-exposed workplaces.

3.2.4 Radiation protection for a stronger European cohesion:

1. **Addressing regulatory differences:** Developing a strategy to manage differences in metrology-related regulations across EU member states focusing on exposure assessment, type testing, calibration, verification, characteristic limits and uncertainty assessment to ensure cohesive radiation protection standards across Europe.
2. **Harmonisation of type testing:** Standardizing type test requirements in international standards for similar measuring tasks, such as area and environmental dosimetry, to create consistent practices and improve cross-border collaboration.
3. **New technologies in environmental monitoring:** Promoting the harmonisation of new technologies and methodologies for environmental radiation monitoring to ensure standardized approaches to radiation protection across the EU.
4. **Development of photon dosimeters:** Creating photon dosimeters for lower energy measurements such as from 12 keV for $H^*(10)$, from 5 keV for $H'(0.07)$ and active $H'(3)$ area dosimeters for specific applications like mammography and ultra-short-pulsed lasers.
5. **Guidelines for handling large datasets:** Establishing guidelines for managing and processing large numbers of radiation measurements, including type testing of devices, integrating citizen science, and managing sensor networks. This will ensure accurate, reliable, and efficient data handling.

This approach promotes harmonisation and cohesion in radiation protection practices across Europe, fostering collaboration, improved safety standards, and the integration of new technologies.

3.2.5 Adaptation of radiation protection for staff due to developments in medicine:

1. **Staff dosimetry in radiology:** Implementation of comprehensive dosimetry protocols for staff involved in radiology and interventional radiology, focusing on whole-body, extremity, and eye lens exposure to ensure effective monitoring and protection against radiation.
2. **Staff dosimetry in nuclear medicine:** Development of specific dosimetry practices tailored for staff working in nuclear medicine, addressing unique exposure risks associated with radioactive materials and procedures.
3. **Accident dosimetry in medical workplaces:** Establishing dosimetry protocols to assess staff exposure in the event of accidents within medical environments, ensuring rapid response and accurate monitoring of radiation exposure during emergency situations.
4. **Validation of accelerator facility shielding:** Conducting dosimetry to validate the shielding effectiveness of accelerator facilities, including those utilizing FLASH radiotherapy, to ensure staff safety and compliance with radiation protection standards.

These adaptations aim to enhance radiation protection measures for medical staff in response to evolving practices and technologies in the medical field, ensuring their safety and well-being while providing patient care.

3.2.6 Adaptation of activity standards to meet new needs:

1. **Lower limit values for calibration:** Establishing new activity standards that set lower limit values for calibration at small orders of magnitude to accommodate advancements in detection technology and improve sensitivity in measurement practices.
2. **Reference values and certified reference materials:** Development and standardisation of reference values through the creation of certified reference materials to ensure accuracy and consistency in radiation measurements and calibration processes.
3. **Inclusion of new radionuclides:** Addressing the introduction of new radionuclides in nuclear medicine, particularly those with poorly understood decay schemes, short half-lives, complex chemistry and potential impurities, to establish appropriate activity standards that reflect these emerging needs.

These adaptations aim to ensure that activity standards remain relevant and effective in the face of evolving technologies and methodologies in radiation measurement and nuclear medicine.

3.2.7 Radiation protection in the area of new infrastructures and FAIR data:

1. **Muon-dosimetry at high power laser facilities:** Researching muon-dosimetry and general radiation protection measures at high power laser facilities, such as the Extreme Light Infrastructure (ELI), to ensure the safety of personnel and compliance with radiation protection standards.
2. **Dosimetry for space flight:** Developing dosimetry protocols specifically tailored for space flight, addressing the unique radiation exposure risks astronauts face in the space environment and ensuring effective monitoring and protection.
3. **Digitalisation and big data:** Implementing strategies for digitalisation and the management of big data, including real-time online data for regulators. This encompasses ensuring the reliability, usability, uncertainties and interpretation of data sourced from multiple channels, alongside addressing the handling of large datasets with a focus on accuracy and quality assurance.

4. **Cross section data for high energies:** Establishing reliable cross section data for high-energy interactions, essential for accurate radiation protection calculations and assessments in various applications, including nuclear physics and medical radiology.

These topics aim to enhance radiation protection measures in emerging infrastructures and harness the potential of FAIR data while addressing the challenges posed by new technologies and environments.

3.2.8 Topics related to developments in the fields of medicine:

1. **Reliability of dose data in X-Ray units:** Evaluating the reliability of dose data generated by built-in measuring and computational devices in various X-ray modalities, including mammography, conventional X-ray, CT and angiography, to ensure accurate patient dosimetry.
2. **Traceability of calibration radiation qualities:** Assessing the utility and traceability of calibration radiation qualities predominantly used for instruments in the medical field, focusing on the comparison between reference fields and clinical fields.
3. **Dosimetry for proton and ion beam radiotherapy:** Developing and standardizing dosimetry protocols specifically for proton and ion beam radiotherapy to enhance treatment accuracy and patient safety.
4. **Accuracy of radionuclide activity measurements:** Improving the accuracy of radionuclide activity measurements conducted with radionuclide calibrators, thereby ensuring precise dosing in medical applications.
5. **Traceability in brachytherapy:** Establishing robust traceability methods for brachytherapy, addressing challenges related to the measurement and calibration of radioactive sources used in this treatment modality.
6. **Measurements in intense magnetic fields:** Investigating the measurement of ionizing radiation in intense magnetic fields, particularly in the context of MRI-guided radiotherapy, to ensure effective radiation protection.
7. **New radionuclides for diagnostics and therapy:** Exploring the introduction and application of new radionuclides for diagnostics, therapy, or theragnostic, focusing on their potential benefits and challenges in clinical settings.
8. **Neutron reference fields:** Developing neutron reference fields, including thermal fields, workplace fields and epithermal regions, to support applications such as Boron Neutron Capture Therapy (BNCT) and ensure effective radiation protection.

These topics aim to address the advancements in medical technology and practices, ensuring that radiation protection measures keep pace with developments in the field.

3.3 Environmental factors

3.3.1 Strengthening of environmental monitoring (partially in collaboration with EMN PoIMo):

1. **Radon measurements at environmental monitoring stations:** Implementing systematic radon measurements at environmental monitoring stations to assess and manage radon exposure levels in various regions.
2. **Radon/Thoron metrology in sensor networks:** Developing metrology for radon and thoron in sensor networks, particularly in large buildings and future urban environments, to enhance indoor air quality monitoring and public health protection.
3. **Pollution monitoring of radioactive isotopes:** Establishing monitoring protocols for radioactive isotopes resulting from waste disposal or accidents to ensure rapid detection and assessment of environmental contamination.
4. **Metrology for radioactive tracers:** Advancing metrology for radioactive tracers used in radiation protection and climate observation, particularly focusing on interactions between different environmental compartments (e.g., soil-air, water-air).
5. **Dosimetry for wildlife and reference species:** Developing dosimetry methods for assessing radiation exposure in wildlife and reference species to evaluate the ecological impact of radioactive materials.
6. **Muon-dosimetry and instrumentation development:** Focusing on the development of muon-dosimetry techniques and related instrumentation to improve radiation detection capabilities in various environmental contexts.
7. **Dosimetry for solar particle events:** Establishing dosimetry protocols specifically for solar particle events to assess the potential radiation exposure risks associated with these phenomena, particularly for astronauts and high-altitude flights.

These initiatives aim to enhance the effectiveness and reliability of environmental monitoring systems, ensuring better protection for both public health and the environment.

4. IMPLEMENTATION OF SRA FOR RADIATION PROTECTION METROLOGY

The effective implementation of the Strategic Research Agenda (SRA) for radiation protection metrology requires a structured approach to ensure that the identified research topics and educational needs are thoroughly addressed. To facilitate this process, two specific roadmaps have been developed:

4.1 Roadmap 1: Metrological needs under Council Directive 2013/59/EURATOM

This roadmap is tailored to the metrological needs defined in the Council Directive 2013/59/EURATOM, which establishes essential safety standards for protecting individuals from exposure to ionizing radiation (see Figure 1). By addressing these standards, the roadmap ensures that the metrological infrastructure meets the directive's guidelines for safety and accuracy.

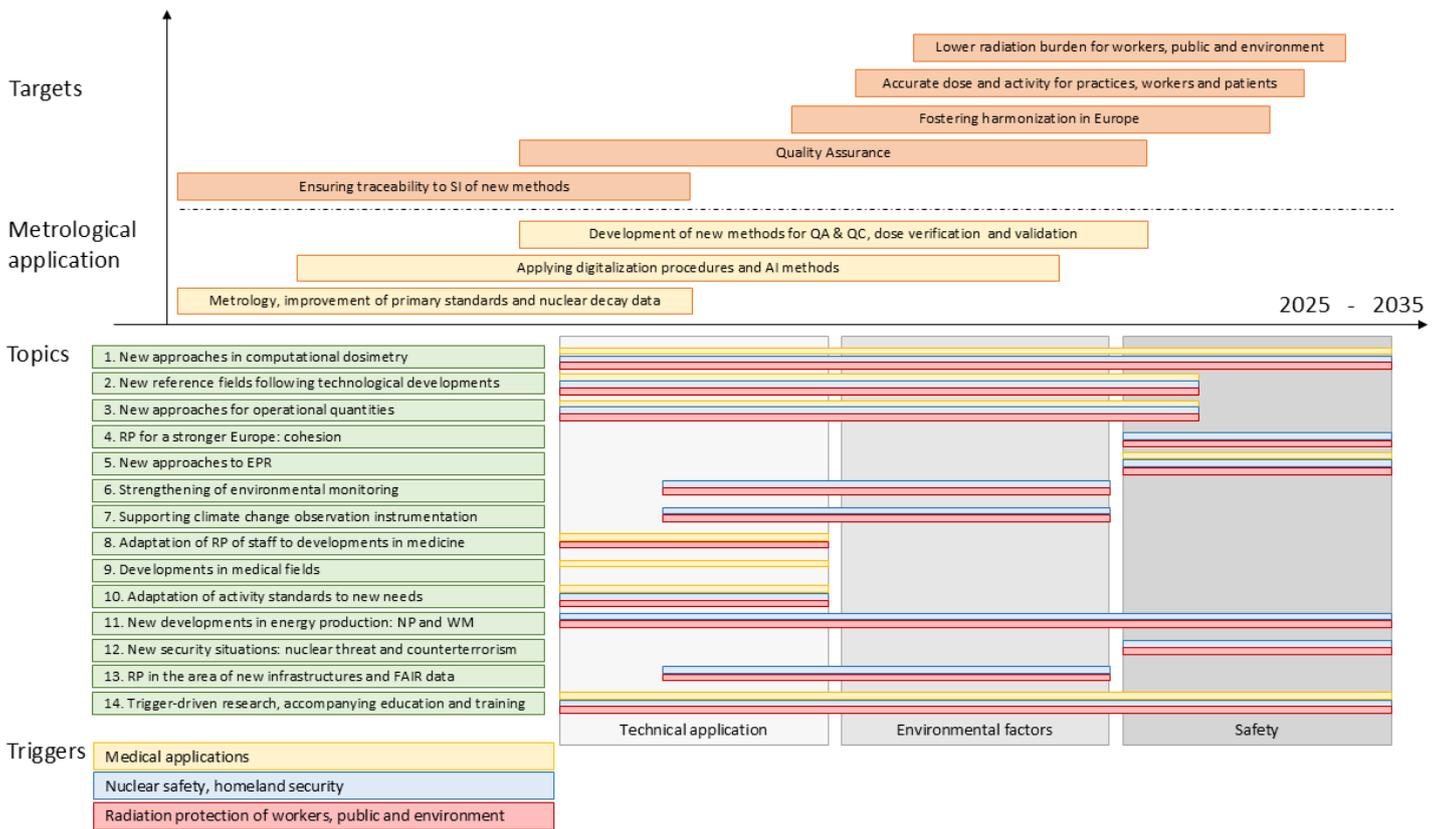


Figure 1. EMN RP Roadmap 1: Metrological needs under Council Directive 2013/59/EURATOM

4.2 Roadmap 2: Metrological needs of the EURATOM Treaty

This roadmap addresses the broader metrological needs associated with the EURATOM Treaty, which aims to create a framework for the safe and secure use of nuclear energy (see Figure 2). This involves building a robust metrological framework to meet both current and emerging needs in radiation protection.

By following these two roadmaps—focused on the BSS Council Directive and the EURATOM Treaty—stakeholders can effectively implement the Strategic Research Agenda for radiation protection metrology. This structured approach is designed not only to address current challenges but also to enhance safety standards and promote technological advancements in managing radiation risks. Ultimately, this will contribute to public health and safety through 2035 and beyond.

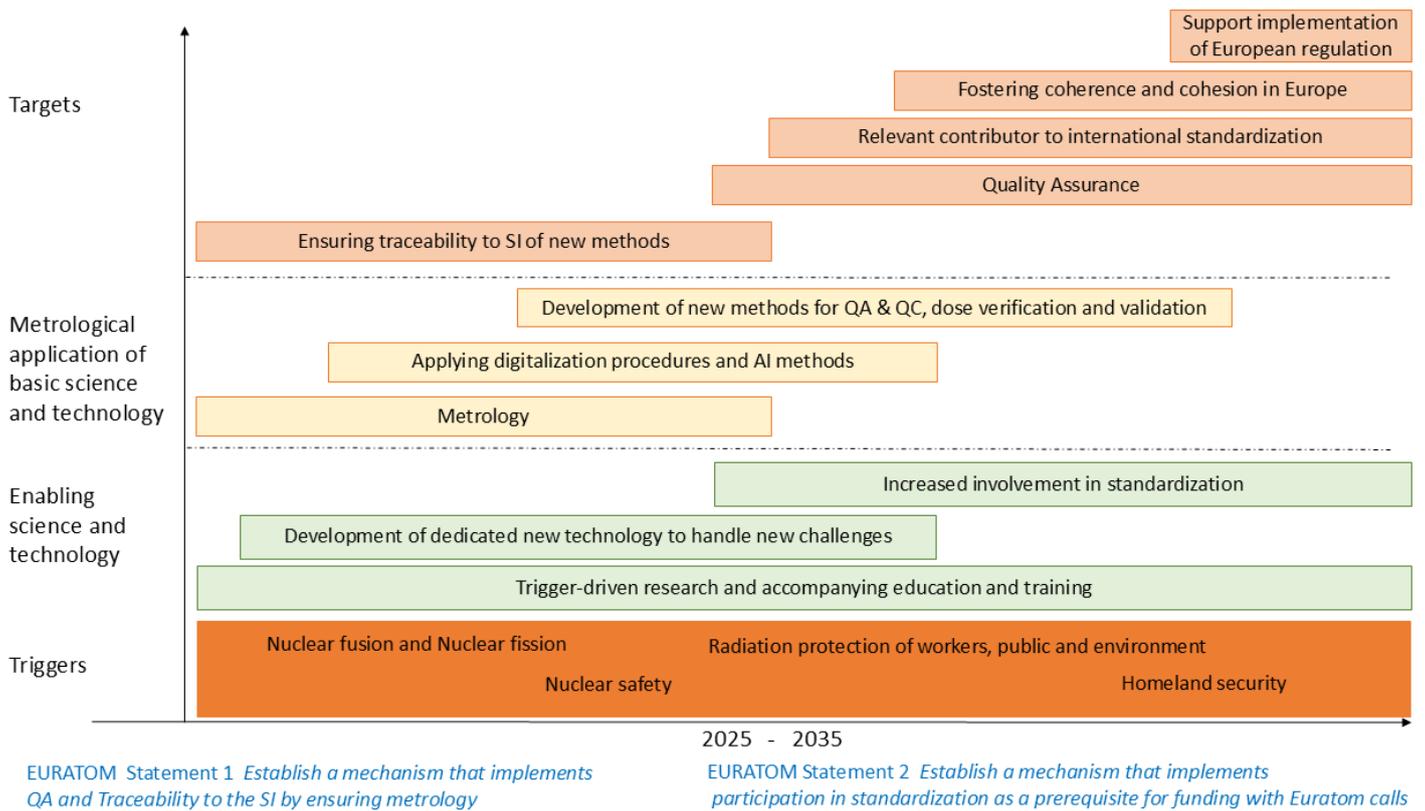


Figure 2. EMN RP Roadmap 2: Metrological needs of the EURATOM Treaty

4.2.1 Supporting climate change observation instrumentation (partially in collaboration with EMN COO):

1. **Crossover projects using natural radioactivity:** Initiating interdisciplinary projects that leverage natural radioactivity or ionizing radiation to enhance climate change research and monitoring.
2. **Data for digital twin of planet earth:** Contributing new datasets to create a digital twin of Earth which can simulate and predict climate patterns and environmental changes through advanced modeling techniques.
3. **Reliable databases for radiation interaction:** Establishing reliable databases that detail how radiation interacts with atmospheric constituents including greenhouse gases, aerosols and pollutants, while investigating their cross-effects on ultraviolet (UV) and infrared (IR) radiation.
4. **Radionuclides as climate process tracers:** Developing and validating innovative methods to utilize radionuclides as tracers to study climate-relevant processes improving our understanding of various environmental dynamics.
5. **Quality and traceability of soil humidity measurements:** Enhancing the quality and traceability of soil humidity measurements through radiation techniques, such as neutron measurements, to better understand soil moisture dynamics and their implications for climate change.

These efforts aim to bolster the instrumentation and methodologies used in climate change observations, ultimately aiding in the formulation of effective responses to environmental challenges.

4.3 Safety, technical application and environmental factors

4.3.1 New developments in energy production - nuclear power and waste management:

1. **Recycling and reuse of radioactive material and NORM:** Explore methods for the recycling and reuse of radioactive materials including Naturally Occurring Radioactive Materials (NORM), to minimize waste and promote sustainability in nuclear energy practices.
2. **Characterisation of radioactive and nuclear waste:** Develop techniques for the nuclide-specific characterisation of radioactive and nuclear waste to ensure proper handling, disposal and compliance with safety regulations.
3. **Need for traceable measurements for NORM:** Emphasize the importance of traceable measurements for NORM to ensure accurate assessment and management of these materials in various industries.
4. **Clearance measurements for decommissioning:** Create methods for conducting nuclide-specific measurements to assess the clearance of materials during decommissioning processes to facilitate safe disposal or reuse.
5. **Neutron dosimetry:** Focus on advancing neutron dosimetry techniques to better measure and manage neutron exposure in nuclear facilities and related environments.
6. **Small modular reactors (SMRs):** Investigate the releases and potential accidents associated with Small Modular Reactors, along with the implementation of online monitoring systems to ensure safety and compliance.
7. **Occupational and public exposure:** Assess and mitigate occupational and public exposure to radiation from nuclear power operations to ensure robust safety measures are in place.
8. **Radioactive pollutants in the environment:** Monitor and evaluate the presence of radioactive pollutants in the environment to understand their impact on ecosystems and public health.
9. **Incorporated radionuclides:** Research the behavior and health implications of incorporated radionuclides in humans and wildlife thus enhancing understanding of exposure risks.
10. **Radiation protection issues for future fusion reactors:** Address radiation protection challenges specific to future fusion reactors, ensuring that safety standards are established and maintained as this technology develops.

These initiatives aim to advance the safe and sustainable use of nuclear energy, improve waste management practices, and enhance public and occupational safety in the nuclear sector.

4.4 Education and training in radiation protection metrology

The following points outline the critical need for education and training in radiation protection metrology:

1. **Clarification of metrology terms** – Provide clear definitions and understanding of fundamental terms like traceability, calibration, verification, type testing and uncertainty for the radiation protection community.
2. **Relative importance of terms** – Emphasize the significance of these terms depending on the context, such as in medical fields, industry, radiation protection, or public initiatives like citizen science.
3. **Dosimetry and emergency preparedness** – Training of dosimetry principles and methods in the context of emergency response.
4. **European regulation for measurement devices** – Offer guidance on how to apply European regulations concerning metrology and measurement devices.
5. **Drafting national regulations** – Assist in the development of national policies related to metrology.
6. **Information sharing** – Promote improved sharing of information related to radiation protection and metrology, possibly through collaborations or platforms.
7. **Services required by legislation** – Address gaps where legislation demands services that laboratories may currently be unable to provide.
8. **Handling large volumes of measurements** – Implement standards for managing large datasets, ensuring quality in citizen science and sensor networks through proper type testing and verification processes.

These efforts aim to ensure more uniform practices and an enhanced understanding of metrology in various fields, ensuring safety and compliance in radiation protection.

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