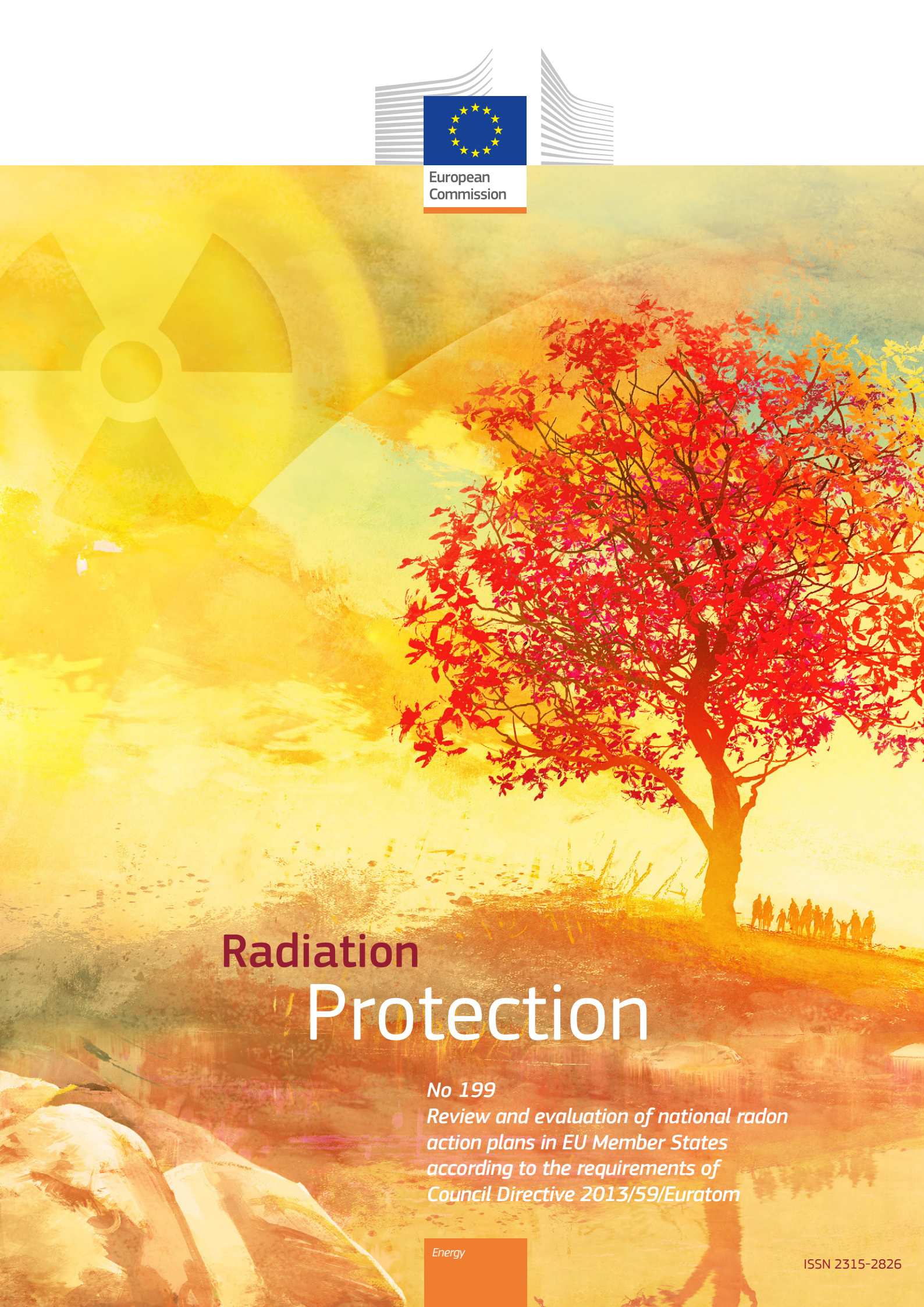

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EU-RAP Project

Review and evaluation of national radon action plans in EU Member States according to the requirements of Council Directive 2013/59/Euratom

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Abbreviations:

AGES	Austrian Agency for Health and Food Safety
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
ANVS	Authority for Nuclear Safety and Radiation Protection (the Netherlands)
APA	Portuguese Environment Agency
ASN	Nuclear Safety Authority (France)
BBRI	Belgian Building Research Institute
BfS	Federal Office for Radiation Protection (Germany)
BGS	British Geological Survey
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Germany)
BSS	Euratom Basic Safety Standards
BUILD	Department of the Built Environment at Aalborg University (the Netherlands) Building Confederation in Belgium
BZK	Ministry of the Interior and Kingdom Relations (the Netherlands)
CCW	Centre for Studies and Expertise on Risks, the Environment, Mobility and Urban
CEREMA	Planning (France)
CIBSE	Chartered Institution of Building Services Engineers (UK)
CNCAN	National Commission for Nuclear Activities Control (Romania)
CPD	Continuing Professional Development
CSN	Nuclear Safety Council (Spain)
CSTB	Scientific and Technical Centre for Building (Centre Scientifique et Technique du Bâtiment) (France)
DG	Directorate General
DIN	German Institute for Standardization
DIY	Do It Yourself
EC	European Commission
EEAE	Greek Atomic Energy Commission
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency (Ireland)
ERA	European Radon Association
E&T	Education and training
EU	European Union
FANC	Federal Agency for Nuclear Control (Belgium)
FILHA	Specialist Association for Tuberculosis and Lung Diseases (Finland)
GIS	Chief Sanitary Inspector (Poland)
GDPR	General Data Protection Regulation
HAEA	Hungarian Atomic Energy Authority (HAEA)
HEIs	Higher Education Institutions
HERCA	Heads of the European Radiological Protection Competent Authorities
H&S	Health and Safety
IAEA	International Atomic Energy Agency
IAQ	Indoor Air Quality
ICRP	International Commission on Radiological Protection
IenW	Ministry of Infrastructure and Water Management (the Netherlands)
INAIL	National Institute for Insurance against Accidents at work (Italy)
INSP	National Institute for Public Health (Romania)
IRSN	Institute de Radioprotection et de Sûreté Nucléaire (France)
IRVM	National Institute for Public Health and the Environment (the Netherlands)

ISIN	National Inspectorate for Nuclear Safety and Radiation Protection (Italy)
ISS	Italian National Institute of Health
JRC	Joint Research Center
KIIP	The Chamber of Engineers in the Investment Design (Bulgaria)
MARNA	MARNA map: natural gamma radiation in Spain
MiTE	Ministry for Ecological Transition (Italy)
MoU	Memorandum of Understanding
MoE SR	Ministry of Economy of the Slovak Republic
MZ SR	Ministry of Health of the Slovak Republic
NAP	National Radon Action Plan of the Slovak Republic
NCRRP	National Center of Radiobiology and Radiation Protection (Bulgaria)
NCC	National Coordination Council (Bulgaria)
NORM	Naturally Occurring Radioactive Material
NGO	Non-Governmental Organisations
NPHC	National Public Health Centre (Hungary)
QA	Questions answers
OETIS	Labor and Social Security Inspection (Spain)
QC	Quality control
RadoNorm	European research project funded under Euratom Horizon 2020 entitled "Towards effective radiation protection based on improved scientific evidence and social considerations – focus on radon and NORM"
RPA	Radon Priority Area
RAPs	Radon Action Plan/s
RICS	Research Institutes of Sweden AB
RIVM	National Institute for Public Health and the Environment (the Netherlands)
RL	Reference Level
RPC	Commission for the Protection from Ionising and Non-Ionising Radiation (Malta)
RWP	Radon Working Party (Malta)
SBi	Statistics Sweden
SCB	Geological Survey of Sweden
SEPR	Spanish Society of Radiological Protection
SGU	Geological Survey of Sweden
SIS	Danish Health Authority and Radiation Protection
SÚJB	State Office for Nuclear Safety (Czech Republic)
SMEs	Small and Medium sized Enterprises
SRPA	Slovenian Radiation Protection Administration
SSM	Swedish Radiation Safety Authority
STM	Ministry of Social Affairs and Health (Finland)
STUK	Radiation and Nuclear Safety Authority (Finland)
TC	Technical Committee
ToR	Terms of Reference
TSO	Technical Support Organisation
TCD	Trinity College Dublin
TESU	Municipal Health Protection Authority, Occupational Safety and Health (Finland)
UK	United Kingdom
UKHSA	UK Health Security Agency
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

UNVEIL	Understanding Ventilation and radon in energy-efficient buildings project (Ireland)
ÚVZ SR	Public Health Authority of Slovakia
VWS	Ministry of Health Welfare and Sport (the Netherlands)
Valvira	Social and Health Licensing and Inspection Agency (Finland)
WG	Working Group
WHO	World Health Organisation

Executive summary and main conclusions

The indoor air pollutant radon is a major contributor to lung cancer in European Union Member States (EU MS) and poses a significant public health threat to the European population, especially in areas with high radon levels. To address this issue, all EU MS are required to implement national radon action plans in accordance with the Council Directive 2013/59/Euratom.

The EU-RAP study was conducted to evaluate the development and implementation of radon action plans in all EU MS and the UK. The study adopted a holistic methodology to horizontally evaluate the practical implementation of national radon action plans (RAPs) across all EU MS and the UK. The research was conducted from August 2020 to January 2023 and encompassed a variety of techniques, including online surveys, legal document analysis, group interviews, four regional workshops and a final workshop. The EU-RAP Reference Group was established at the outset of the project to provide guidance and expertise to the research consortium and to validate the findings of the study. The study's approach ensured a thorough and comprehensive evaluation of the implementation of national action plans, regardless of a particular country's level of radon exposure risk.

Overall, the EU-RAP study provides a comprehensive evaluation of the implementation of radon action plans in EU MS and the UK, highlighting areas for improvement and good practices for reducing radon exposure and protecting public health.

The requirements on national radon action plans in Council Directive 2013/59/Euratom have been transposed into the national regulation of all EU MS, except Italy, Latvia, Lithuania and Spain as of 14 February 2023.[1] Later in 2023, following the conclusion of this study, both Latvia and Lithuania have successfully incorporated the regulation into their respective national legal frameworks. The study's findings show that there is a varying level of progress in the implementation of national radon action plans, with some countries making commendable progress in addressing indoor air pollution caused by radon, while others still have room for improvement in the issue. The study highlights the importance of coordination at the national level and collaboration among EU MS, and relation with other related relevant programs, as well as the need for clear guidelines, financial support, and communication strategies to effectively address long-term risks from radon exposures.

The study also underscores the significance of preventative measures, including building code regulations, communication, and stakeholder engagement, to reduce radon exposure and minimise the risk of lung cancer. Additionally, the study highlights the need for effective and reliable measurement and testing strategies, as well as support for remediation actions and re-testing to ensure the continued safety of the public.

Finally, the study highlights the importance of education and training activities, as well as the establishment of links with EU research and innovation initiatives, to improve awareness

[1] According to the Article 106 of the Council Directive 2013/59/Euratom, Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 6 February 2018.

raising, knowledge and competences in this field and support the effective implementation of national radon action plans.

In conclusion, the EU-RAP study provides valuable insights into the practical implementation of national RAPs across EU MS. The results of the study support the European Commission in evaluating the compliance of the RAPs with the requirements laid down in the Council Directive 2013/59/Euratom, which outlines basic safety standards against the dangers arising from exposure to ionising radiation.

The study offers practical recommendations and solutions to the challenges faced by EU MS and the UK in implementing their RAPs effectively. It provides a comprehensive overview of the establishment and contents of the national RAPs and helps radiation protection authorities to learn from each other's experiences and share effective strategies for reducing the health impact of radon. Furthermore, the results of the EU-RAP study can assist EU MS and the UK in ensuring that their RAPs align with the requirements of the Directive and take the necessary steps to protect their populations from the harmful effects of radon exposure. Overall, the study provides a valuable resource for EU MS and the UK to better understand and address the issue of indoor air pollution from radon.

A synthesis of the main findings of the EU-RAP study is presented below. Previous EU-RAP documents (Deliverable D2 – September 2022; Deliverable D3) presented the analysis of RAPs based either on the analysis of each of the elements of Annex XVIII of the EC Council Directive 2013/59/Euratom per country or on the analysis of all elements per each individual country. The EU-RAP study has pointed out the substantial overlap among elements, leading to redundant information being presented. As a result, the present document reports main conclusions in a horizontal and holistic manner, starting with status of RAPs, coordination and improvement mechanisms, strategies for prevention, measurement and testing, remediation and re-testing, communication and engagement and education, training and research related to radon.

Main conclusions related to status of radon action plans in EU MS and the UK

The findings of the EU-RAP study reveal disparities in the implementation of national radon action plans among the European Union Member States and the United Kingdom as of January 2023. While one EU MS has no plans to establish a dedicated radon action plan, three EU MS have only draft plans. Later in 2023, after the conclusion of this study, Latvia and Lithuania successfully incorporated the regulatory framework into their respective national legislations as well. The remaining countries have established their radon action plans and are currently in varying stages of implementing the practical actions outlined in their strategies. This inconsistency in implementation is not aligned with the EC Council Directive 2013/59/Euratom, which requires all EU MS to establish and implement such plans for the protection of the public and workers against indoor radon exposure.

Main conclusions related to coordination of implementation of RAPs and continuous improvement at national level

The findings of the study suggest that the responsibility for establishing RAPs varies across countries, with some assigned to nuclear/radiation safety authorities, and others to specific ministries or governmental departments. The mechanisms for collaboration among different actors involved in radon tasks vary, but mostly consist of regular meetings of groups or

committees. The lack of resources allocated to organisations responsible for radon and the prioritisation of other topics pose challenges to efficient coordination of radon related tasks. The schedule for review and assessment of RAPs varies among MS, ranging from 2 to 10 years, and is mostly based on the degree of completion of actions planned in the RAPs. Few countries have defined indicators for evaluating the effectiveness of RAPs, but many are working to define such indicators in the short and long term.

Main conclusions related to elements for preventing indoor radon exposures

The majority of countries have established their radon reference level (RL) at 300 Bq/m^3, while a few set it at a lower value. The setting of RLs considers manageability and some countries have also established supporting levels. The process of defining radon priority areas (RPAs) is ongoing in some countries and involves technical, scientific, and socio-economic considerations. Cooperation with the building sector is essential in protecting against radon exposure, and protective measures are required in most countries, though the requirements differ. The execution of protective measures relies on the building code in each country and may involve requirements in building permits or simply the dissemination of information. The prevention of radon exposure during building reconstruction is important for indoor air quality. Some countries regulate radon during the building reconstruction process, but the regulations vary. In a few countries, building measurements are taken before or after reconstruction, particularly in school facilities, to ensure radon protection. The EU-RAP study revealed that there is a need for improvement in the communication of preventive measures and alternative technologies for radon exposure prevention in new builds. While some countries have successful practices, such as communication campaigns for prevention at workplaces in RPAs, the communication of prevention actions in new builds is limited and mainly conveyed through technical documents. The information on natural radionuclides in construction materials is not widely communicated, with only a few countries publishing lists of products publicly. Communication with the building industry and producers is not consistent, although there have been attempts of collaboration in some countries. Nevertheless, the study highlights the importance of stakeholder engagement and decision-making practices in radon exposure prevention in all countries.

There is currently a lack of systematic links between RAPs and other related programmes, such as energy saving, indoor air quality, cancer programmes, anti-smoking programmes, lung cancer screening or the Europe's Beating Cancer Plan. The cooperation between programmes is either ad hoc and the result of the initiative of other programmes and actors or remains only on strategic level. Most EU MS are considering or preparing such programmes; however, their implementation may only occur in future RAPs. There are some good practices such as including radon in an indoor air quality measurement campaign or in an indoor air quality and energy saving action plans. Overall, there is a need to further explore the counter effects of implementing energy efficiency measures which may lead to increasing indoor radon levels, and to connect cancer programmes with RAPs.

Main conclusions related to measurements and testing of radon in dwellings, workplaces and public indoor spaces

Measurement of indoor radon concentration can be divided into two groups, measurement in dwellings and measurement at workplaces. National guidance, i.e. measurement protocol, is implemented in 20 countries while 5 countries are still developing their protocols. Measurement

guidance is rarely part of RAPs. The main method for indoor radon measurement is passive track etched detectors in diffusion chambers. The duration of measurement can vary from 30 days to 1 year, with the heating season being the preferred time for measurement. A graded approach to indoor radon measurement is recommended, where detailed measurement is carried out if the initial results exceed the RL. Many countries have already adopted this approach in their measurement protocols.

In summary, guidance on the method of measurement of radon exhalation from building materials is not yet developed or implemented in EU MS and the UK. Some countries have conducted surveys with no significant radon exhalation from building material found. Radon in water is regulated under the Council Directive 2013/51/Euratom of 22 October 2013, but measurement methods and guidance are available in 17 countries with a protocol being developed in 3 countries. Radon in water is part of the RAP in a few countries.

The criteria for accreditation/licensing of measurement services vary among different countries. Some countries require accreditation in compliance with ISO/IEC 17025, while others focus on national proficiency testing. In some countries, the recognition process involves both accreditation and compliance with a specific measurement protocol. Accredited laboratories are often listed in a public database. In at least one EU MS, there is a legal requirement for a radiation protection specialist to be a member of the staff, leading to a lack of available measurement services. The participants at the EU-RAP workshops agreed that defining a minimum set of rules and requirements for providers of measurement services would increase reliability and public confidence in the results.

Radon measurements in all workplaces at a country territory are legally required in 5 countries. Identification of workplaces where the radon measurement will be obligatory is ongoing in 3 countries. In few countries the employer is responsible for assessment of health risks, including radon, for employees. Some countries prioritise radon measurement in high-risk workplaces such as water treatment facilities, underground workplaces, and public buildings with long-term stay. Since the priority of radon measurement at work is connected to the delineation of radon priority areas, the measurements are on a voluntary basis in countries without delineated areas. However, priority for measurements is given to school and preschool facilities, public buildings and underground workplaces. Some countries also use exemptions based on time spent at the workplace, with the allowed duration ranging from 10 hours to 100 hours per year.

Most countries have established procedures for employers to follow if elevated radon levels are detected in the workplace. If the radon level exceeds the RL, the employer must optimise or reduce the levels. Some countries provide more support to employers than others. In some countries verification measurements after remediation is implemented. If despite the remediation, the RL remains exceeded, the workplace is notified, and workers' effective doses is assessed. The employer is responsible for employee radon exposure optimization. The property owner must optimise radiation protection in public access premises and dwellings.

Calculating the effective dose from radon exposure is complex and considers variables such as seasonal and diurnal variation, occupancy time, and radioactive progenies contribution. In most domestic homes and some workplaces, average radon levels are used to assess the hazard, but in complex cases, an effective dose analysis may be conducted. 15 EU countries have adopted the ICRP Publication 137 dose conversion coefficient, while implementation is under discussion in 6 countries. The UK uses the ICRP Publication 65 conversion convention, and

Sweden has not formally adopted the ICRP 137 coefficient. Malta chose not to adopt any coefficient due to low radon levels, and information was not provided by 4 countries.

There are significant differences in the strategies for conducting indoor radon measurements in EU MS and the UK, including the frequency of measurements and target areas. Some countries have reduced the number of measurements campaigns carried out each year, while others recognise the need for further measurements. Countries with long-standing radon programmes have representative radon survey results which are around 20-30 years old, and some are updating their surveys. Most countries prefer to conduct long-term (over 6 months) measurements using passive track detectors. There is limited information on the number of detectors per building. An identified common challenge in some countries is the low interest from citizens to measure radon in their homes and the low return rate of detectors for evaluation.

The EU MS and the UK vary in how they manage radon related data. 17 countries have a national radon database, while 3 are in the process of developing one, 2 publish data online, and 2 have a different type of registry. The data collected as part of the RAP is typically stored in the national database, but data from other measurement providers is rarely included. Some countries reported difficulties with sharing data from private companies due to General Data Protection Regulation (GDPR) restrictions and consequently, they reported issues with creating maps.

In terms of communication about radon testing, many countries have organised communication efforts to increase the number of tests conducted. These interventions often take place through schools, information sessions, and letter drops, and (limited number of) tests are frequently provided for free as part of these efforts. Some countries evaluate the success of their interventions based on the number of tests distributed, while others measure the effectiveness by the number of returned tests. Some countries have developed videos to help educate people on "how to test", and a few have a designated person who provides personal advice and information related to radon measurements. A few countries also address ethical considerations in their communication efforts.

Most countries provide some form of financial support for radon testing, such as free radon testing for a selected area. The cost of radon testing in EU MS and the UK can range from free to 100 euros (two dosimeters).

Main conclusions related to remediation actions and re-testing:

In the majority of countries, strategies are being developed to facilitate remediation in buildings with high levels of radon. These strategies aim to set the national legislative framework and knowledge base for corrective actions, as well as to involve stakeholders including citizens, building professionals, industry, and authorities. Some countries, however, do not plan to develop any strategy due to low radon activity concentrations indoors in their territory. The main challenge in addressing excessive radon levels and remediation is the lack of contractors, building industry or other companies to perform the remediation.

Support for remedial actions in dwellings, public buildings and workplaces is diverse across countries. It may involve identifying houses suitable for mitigation through measurement campaigns, encouraging citizens to organise remediation through raising awareness and providing financial support, and ensuring an enabling environment for the construction industry through the legislative system and knowledge base for effective corrective action. The

procedure for remedial actions in workplaces involves the employer reducing radon concentration below the RL, monitoring employees, and following notification procedures. Re-testing and effectiveness evaluation after remedial action is also an important part of the process and is supported in several countries.

Most countries recognise the importance of publishing guidelines for remedial actions to provide solutions for house owners when high radon levels are detected. The national guidelines should be tailored to the specific building and geology conditions. As a result, harmonisation of such guidelines on the EU-level is often not feasible. Most countries have either published or are in the process of publishing these guidelines, mostly available online for free. Only two countries stated that such guidelines are not necessarily due to low radon concentrations and one country reported that they will provide recommendations if necessary.

The accreditation or licencing of companies for remediation in buildings is not a common practice. Two countries implemented a registration scheme for radon contractors to promote quality and expertise in radon remediation services. Contractors must follow certain requirements such as participating in training courses, being tax compliant and having public liability insurance. A few countries are planning to develop registers for remediation providers while others publish lists of contractors based on their participation in training courses or the review of work conducted. Other countries have decided not to implement any form of registration, accreditation, or licensing of remediation services. Some countries offer training courses on radon mitigation. One country established criteria for licensing of remediation services, but no company was identified, and the provision was removed from the law.

Remediation costs for radon mitigation vary widely across countries and type of measure implemented, with private dwellings costing from €500 to over €5,000, and public buildings costing from €1,500 to €60,000. Some EU MS offer direct or indirect financial support for remediation, although the experience reported is often the low motivation for the subventions uptake by owners of dwellings. All countries report difficulties finding radon remediation contractors due to the lack of profit for the building sector.

The remediation of buildings with exceeded radon levels is a concern across EU MS and the effectiveness of the corrective action taken must be tested to ensure it remains effective. However, only four EU MS require re-testing after remedial measures are taken, with one country requiring re-testing only if subsidised measures were used. Three countries provide re-testing for free. Only in one country, remediation contractors are required to provide annual information on the effectiveness of their remedial actions to the regulatory body. Studies have been performed to determine the impact of financial support on testing and remediation in countries such as Ireland and Germany as well as in the H2020 project RadoNorm[2].

Main conclusions related to communication and stakeholder engagement

Radon communication is usually led by the coordinator of the RAP or shared among multiple authorities. Communication strategies are not yet in place in all countries, but actions are ongoing, and some countries have developed communication plans. The objective of current communication plans in most EU MS is awareness raising and education regarding radon, with only a minority of strategies focusing explicitly on behavioural change (e.g., how to test and how to remediate if necessary). Moreover, much communication is based on gut feeling, rather

[2] Further information on the RadoNorm Project at: www.radonorm.eu

than being theory- or evidence-driven. Target groups for communication are often defined in general terms (e.g. general public, workers), although in some cases, specific target groups are identified and are the particular focus of communication action. Most RAPs define a wide range of communication channels (e.g. webpages, seminars, drop-in events, podcasts, videos, leaflets, information days, radio advertisements, phone numbers, notary, interviews, Do It Yourself stories, and paid advertisements), although in practice the diversity of channels used is rather limited. Most countries have not defined assessment criteria to evaluate communication actions but undertake evaluation in different ways. These could include opinion polls, measuring clicks on website or internet readings, the uptake of financial incentives or the number of training courses organised. Significant improvements in radon related communication interventions are expected to be achieved through the H2020 project RadoNorm. In general, it should be noted than there are limits to communication activities if the supporting environment (e.g., contractors, building codes, legal requirements etc.) are not available.

Main conclusions related to education, training, research and development

The implementation of RAPs requires continuous education, training, research and development of relevant stakeholders such as building professionals, measurement professionals, employers and employees, local and regional authorities, schools and health professionals, and the general public. Different education and training programmes are provided through builders' associations, universities, research centers, and government authorities. However, these education and training programmes are often not systematic neither regular. In some countries, radon education is included in the school curriculums, while in others it is included in professional or health training programmes. The International Atomic Energy Agency (IAEA) also provides trainings on radon through its Technical Cooperation projects. Several European countries collaborate in training and education projects in the framework of European funded projects, such as H2020 RadoNorm.

Introduction

The overall objective of the EU-RAP study is to **independently review and assess** in detail the establishment of **national radon action plans** in EU Member States (MS) and the United Kingdom (UK) according to the requirements laid down in Council Directive 2013/59/Euratom – the BSS Directive – with a particular focus on the **practical implementation** of the actions defined in these action plans. The EU-RAP study reviews and assesses, from a neutral perspective, both exposure and risk assessment by EU MS and the UK on the one hand, and radon risk management of EU MS and the UK, on the other hand. It also identifies **good practices** to address the radon related issues together with experts, regulators, local authorities and other stakeholders from EU MS and the UK.

The EU-RAP study review and assessment covers the development of the strategy (radon action plan) and the practical implementation of actions in all EU MS and the UK, including all elements defined in Annex XVIII of the BSS Directive (i.e. the strategy for conducting surveys of indoor radon concentrations, the delineation of areas, the identification of workplaces and buildings with public access where measurements are required, the establishment of reference levels, the assignment of responsibilities, the strategies for reducing radon exposures, the strategies for communication, remediation, financial support, the establishment of long-term goals, etc) and their application.

This final document of the EU-RAP study reports on the results of the study, summarising the analysis of national radon action plans, as established by all EU MS and the UK, the analysis of the practical implementation of the actions defined in the action plans, and the comparative horizontal analysis of the implementation of the national radon action plan by all EU MS and the UK.

The report is structured into seven comprehensive chapters that provide an in-depth examination of the status, implementation, and outcomes of radon action plans in EU Member States and the UK as of January 2023. The present document reports main conclusions in a horizontal and holistic manner, starting with status of RAPs, coordination and improvement mechanisms, strategies for prevention, measurement and testing, remediation and re-testing, communication and engagement and education, training, and research.

Method for review and evaluation of RAPs in EU MS and the UK

The study adopted a holistic methodology to evaluate the practical implementation of national action plans across all EU Member States and the UK. The research was conducted from August 2020 to January 2023 and encompassed a variety of techniques, including online surveys, legal document analysis, group interviews, four regional workshops as part of a horizontal analysis, and a final workshop. The EU-RAP Reference Group was established at the outset of the project to provide guidance and expertise to the research consortium and to validate the findings of the study. The study's approach ensured a thorough and comprehensive evaluation of the implementation of national action plans, regardless of a particular country's level of radon exposure risk.

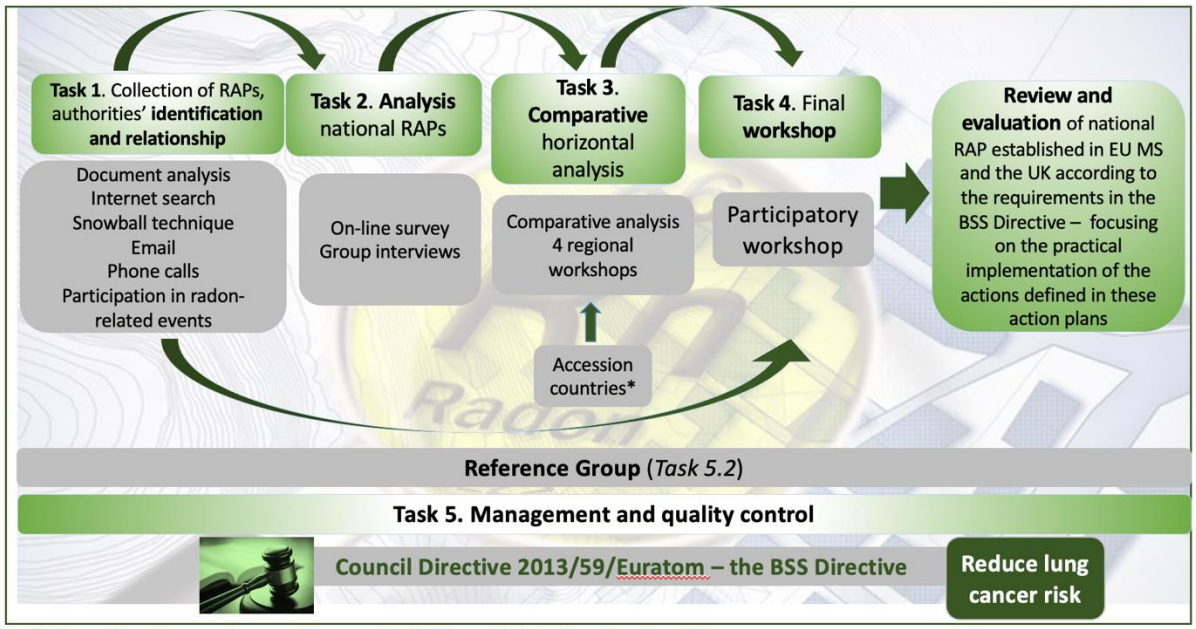
All findings and results were regularly checked, verified and updated through written correspondence with EU MS and the UK. In total, 27 EU MS (Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden) and the UK are included in this data collection.

An **on-line survey** was conducted to identify responsible authorities for different aspects of radon management in all EU MS and the UK. A **legal document review and content analysis** was carried out based on the radon action plans (RAPs) collected radon action plans in all EU MS and the UK. The legal document content analysis findings were discussed with representatives in each EU MS and the UK through **group interviews** to validate the information as well as to respond on and clarify any missing information, particularly related to the implementation phase. Group interviews were conducted on-line in the period between October 2021 and May 2022. **Four regional workshops** were organised inviting representatives of EU MS and the UK in order to examine similarities and differences of RAPs and their implementation and to synthesise practices, challenges and innovative approaches in the implementation of RAPs in EU MS and the UK. The regional workshops were useful to reach a certain degree of generalisation beyond the different countries in the form of a horizontal analysis.
Verification of results and updating the status of national RAPs was undertaken through regular written exchange with national authorities responsible for radon risk management. Country reports were written and sent to all EU MS and the UK for verification. The reports were updated with new information by national authorities in June 2022. In addition, the EU-RAP study findings were presented at events such as the Heads of the European Radiological Protection Competent Authorities (HERCA) workshop (21-23 June 2022 in Lisbon, Portugal) and the final workshop in Brussels (19-20 September 2022 in Brussels, Belgium).

The **EU-RAP Reference Group** (RG) was established at the start of the project as the consultative body to provide advice and expertise to the consortium and to validate the project results.

Following the conclusion of this study, the consortium incorporated key revisions mandated by the Latvian and Lithuanian regulatory frameworks into their respective national legislations at the request of the EC DG Energy. While the successful integration of the regulatory framework into their national legislations is duly acknowledged in the main conclusions, it's important to note that this report does not encompass the legal and content analysis of the Latvian and Lithuanian Radon Action Plans that were approved after January 2023. We would also like to acknowledge that between the conclusion of this study and its publication, numerous other EU Member States introduced and executed various elements of radon action plans within their respective territories. These specific aspects have not been addressed within the scope of this revised version 2 of the study.

Figure 1: Tasks and methods in the EU-RAP projects



* When relevant, accession countries were invited to participate in regional workshops

Results on the RAP strategy and implementation for EU MS and the UK

1. Status of radon action plans in EU MS and the UK in January 2023

Main conclusions related to the status of radon action plans in EU MS and the UK

The findings of the EU-RAP study reveal disparities in the implementation of national radon action plans among the European Union Member States and the United Kingdom as of January 2023. While two countries have only a draft RAP, the remaining countries have established their radon action plans and are currently in varying stages of implementing the practical actions outlined in their strategies.

Table 2 and Figure 2 show the status of approval of the RAPs in the 27 EU MS and the UK, reflecting the situation in January 2023.

Table 2. Status of RAP in the EU MS and the UK, January 2023

Country	Status of RAP	Title of RAP	Publication date	Period
Austria	Approved	National Radon Action Plan	2021	-
Belgium	Approved	National Radon Action Plan	2020	2020-2025
Bulgaria	Approved	National Action Plan to reduce the risk of radon exposure	2018	2018-2022
Croatia	Approved	Radon Action Plan	2019	2019-2024
Cyprus	Approved	National Action Plan for the management of long-term risks due to exposure to radon	2018	2018-2025
Czech Republic	Approved	National Action Plan for control of Public Exposure to Radon	2019	-
Denmark	Approved	Radon Action Plan	2018	-
Estonia	Approved	National Radon Action Plan	2018	2018-2027
Finland	Approved	National Action Plan for the prevention of risks from radon	2020	-
France	Approved	National Action Plan	2020	2020-2024
Germany	Approved	Radon Action Plan for the Sustainable Reduction of Radon Exposure	2019	-
Greece	Approved	National action plan to address the long-term risks from exposure to radon	2020	-
Hungary	Approved	National Radon Action Plan to reduce natural radiation exposure to radon and building materials	2018	2018-2023
Ireland	Approved	National Radon Control Strategy, Phase 2	2019	2019-2024
Italy	Under development	n/a	-	-
Latvia***	Approved	National Radon Action Plan*	2023	2023-2032
Lithuania ***	Approved	Radon Risk Management Plan for 2024-2030**	29 August 2023	2024-2030
Luxembourg	Approved	National Radon Action Plan: long-term risk management due to radon exposure	2021	2021-2028
Malta	Approved	Maltese Radon Action Plan	2020	-
Netherlands	Approved	National Radon Action Programme	2021	-
Poland	Approved	National action plan for long-term risks related to the exposure to radon in buildings designed for human occupancy and in workplaces	2021	-
Portugal	Approved	National Plan for Radon	2022	2022-2026
Romania	Approved	National Radon Action Plan	2018	-
Slovakia	Approved	National Action Radon Plan of the Slovak Republic	2022	2022-2026
Slovenia	Approved	National Radon Program	2020	-
Spain	Ready to be approved	National Radon Action Plan	-	-
Sweden	Approved	National Action Plan for radon	2018	-
UK	Approved	UK National Radon Action Plan	2018	-

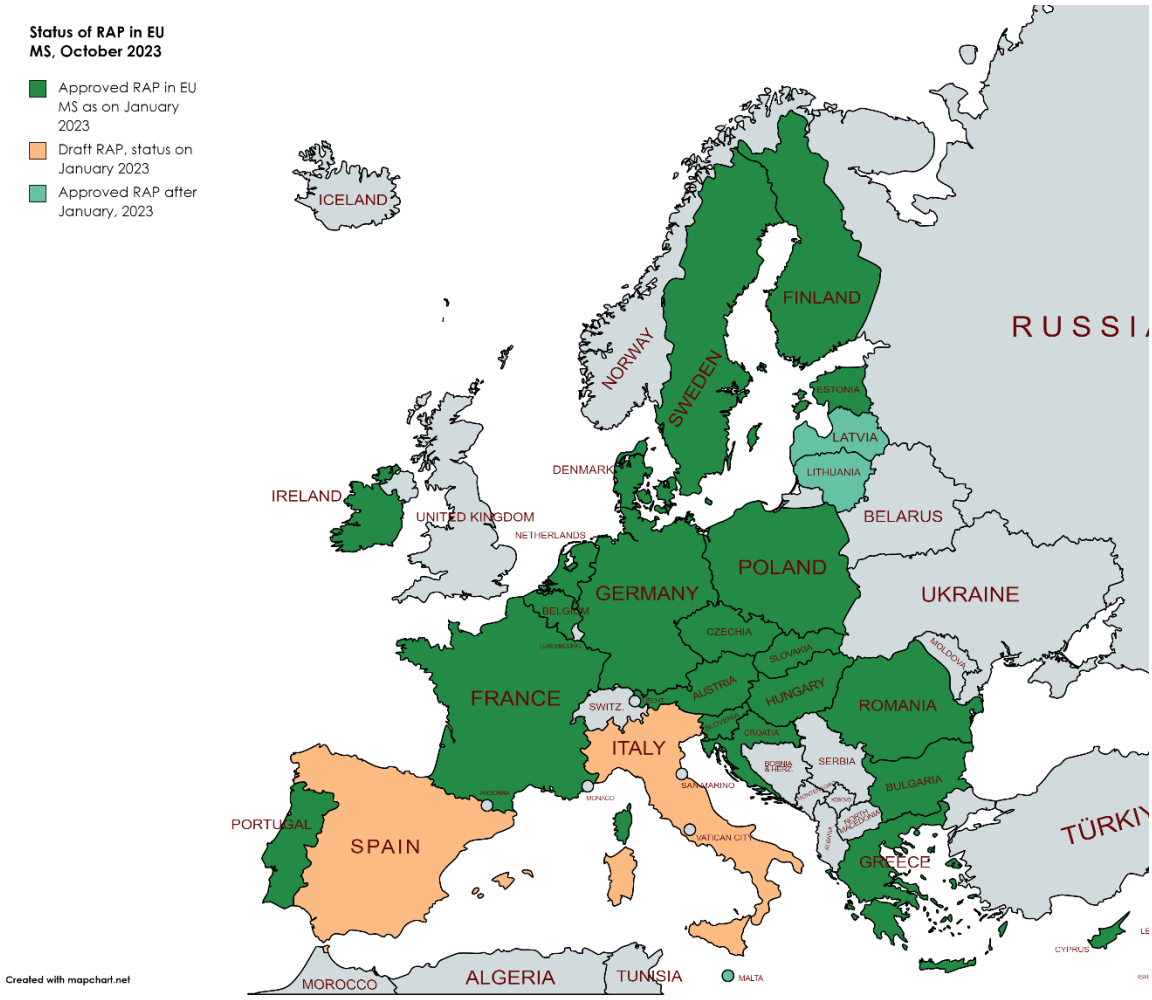
* As of January 2023, the national radon action plan was under development in **Latvia** and was planned to be approved in February 2023. Several documents include actions regarding radon issues. For example,

Environmental Policy Framework S 2021-2027 (accepted by the Cabinet of Ministers, order No.583 31.08.2022.), Informative report "Assessment of radon gas results and future follow-up of ensuring radon gas monitoring in Latvia" (accepted by the Cabinet of Ministers on 03.07.2018.), Cabinet Regulation No.149 "Protection against Ionising Radiation" (adopted on 09.04.2002). Environmental Policy Framework 2021-2027 is a policy planning document in the field of environmental protection and contains "Radiation Safety programme" (Annex 3), which also includes issues of radon gas.

** The interview with the representatives from the Radiation Protection Centre RSC in **Lithuania** in November 2021 identified a number of documents which include radon actions undertaken by the country. These include: 'Lithuanian Hygiene Standard HN73:2018 "Basic Radiation Protection Standards"' (non-official translation in English provided by Lithuanian representatives); 'Order on the Approval of an Exposure Monitoring Program for the population and workers working with sources of ionizing radiation for the year 2017-2023' and 'Indoor radon and estimation of doses due to indoor radon program for 2017-2023'.

***After the conclusion of this study in January 2023, both Latvia and Lithuania incorporated the regulation into their respective national legal frameworks. The table above was updated to reflect the transposition of the EU requirement in the national legislation in these two countries in October 2023.

Figure 2: Status of RAP in EU MS and the UK



2. Coordination of implementation of RAP and continuous improvement at national level

Main conclusions related to coordination of implementation of RAP and continuous improvement at national level

The findings of the study suggest that the responsibility for establishing RAPs varies across countries, with some assigned to nuclear/radiation safety authorities, and others to specific ministries or governmental departments. The mechanisms for collaboration among different actors involved in radon tasks vary, but mostly consist of regular meetings of groups or committees. The lack of resources allocated to organisations responsible for radon and the prioritisation of other topics pose challenges to efficient coordination of radon related tasks. The schedule for review and assessment of RAPs varies among MS, ranging from 2 to 10 years, and is mostly based on the degree of completion of actions planned in the RAPs. Few countries have defined indicators for evaluating the effectiveness of RAPs, but many are working to define such indicators in the short and long term.

Responsibilities: Coordination and mechanisms of collaboration of RAPs

Establishing of RAPs in EU MS is a responsibility of nuclear/radiation safety authorities or specific ministries in charge of different portfolios depending on the country. In most EU MS, there are different institutional actors with responsibilities on radon matters but often there is just one key department or person coordinating the RAP. Depending on the size of the country and the relevance of radon, the number of persons involved in radon tasks may range from 1 to more than 15 scattered across departments and organisations and working mostly part-time on radon.

The mechanisms of collaboration between different actors are mostly based on regular meetings of groups or committees which bring together representatives from different ministries, radiation protection authorities, regional authorities, radon professionals, etc. The collaboration among institutions requires sufficient resources as well as a clear identification of the responsible entities or persons. The lack of resources allocated to organisations responsible for radon or the prioritisation of topics other than radon are challenges to an efficient radon coordination. In a few cases the collaboration mechanisms involve local actors, such as local decision authorities, despite playing a significant role for improving the awareness of local populations and facilitating testing and mitigation actions at local level. International collaboration within the radon field is established among several countries, for instance, in Nordic countries.

Table 3. Owner and mechanisms of collaboration per EU MS and the UK

Owner and mechanisms of collaboration per EU MS and the UK (*status on January, 2023)*		
Country	**Owner of RAP**	**Mechanism of collaboration**
Austria	Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology	Working Group (WG) for existing exposure situations (3-5 meetings annual). Austrian radon network (20-30 institutions, first meeting 16/9/2021)
Belgium	Nuclear Safety Regulator (FANC)	Regular meetings with municipalities, regional authorities, provinces, trade unions, services for prevention and protection at work; bilateral contacts; WG in the framework of annual campaign
Bulgaria	Council of Ministries	National Coordination Council for the preparation and implementation (28 district coordination councils; Chamber of Engineers in Investment Design; experts from regional health inspectorates; all relevant agencies: Ministry of Health; Ministry of Regional Development and Public Work; Ministry of Labour and Social Policy)
Croatia	Ministry of the Interior, Civil Protection Directorate, Radiological and Nuclear Safety Sector*	Group for monitoring the implementation of the RAP with 4 ministries (health; construction and planning; environment and energy; science and education) and experts established in 2018. Meetings twice a year (except in 2020).
Cyprus	Ministry of Labour, Welfare and Social Insurance	Technical Committee (Ministries, journalists, professional associations, etc) foreseen in RAP but not established as it is not justified due to the results of the measurements
Czech Republic	State Office for Nuclear Safety (SÚJB)	Yearly cooperation agreements between designated ministries (interior; environment; industry and trade; regional development; finance; agriculture; not signed by ministry of health) and SÚJB for implementation. One meeting a year (last day in May) with up to 10 people. Collaboration with regional authorities – one meeting a year with around 32 participants
Denmark	Ministry of the Interior and Housing	For development of strategy: collaboration with Ministry of Health; Danish Health Authority and Radiation Protection (SIS). Partnership between Hosing and Planning Agency under Ministry of the Interior and Housing; Bolius (NGO) and Landowners' Investment Fund monitoring group for the implementation of the action plan.
Estonia	Ministry of the Environment	Coordination between Ministry of the Environment with the Ministry of Economic Affairs and Communications, the Ministry of Social Affairs, the Ministry of Education and Research, and the Ministry of Finance. Also, the Environmental Board involved.
Finland	Ministry of Social Affairs and Health	Steering Group - officials' radon working group with members from the Ministry of Social Affairs and Health (chair), the Ministry of the Environment, Valvira (National Supervisory Authority for Welfare and Health), the Health and Welfare Licensing and Inspectorate, the Regional Health Protection Authority, the Occupational Safety and Health Administration, the Association of Municipalities and Radiation and Nuclear Safety Authority (STUK). Stakeholder consultation on-line and one day meeting (with 3 sub-groups)

France	Nuclear Safety Regulator (ASN)	Governance ensured by a group of director generals (Risk Prevention, Housing, Health, Labour, ASN) Steering Committee responsible for drawing up, monitoring, and evaluating the actions; WG to monitor and coordinate communication and awareness raising activities.
Germany	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)	Steering Group chaired by BMUV presenting results and progress to the expert committee on radiation protection of the federal state committee for nuclear energy.
Greece	Greek Atomic Energy Commission (EEAE)	RAP Working Group with 3 sub-working groups with representatives of relevant and cooperating bodies (Ministry of Education -Technical Chamber of Greece -Ministry of Health) involved in individual projects.
Hungary	National Public Health Centre	Consultations with responsible ministries, research institutes, universities, and experts in preparatory phase. No permanent collaboration mechanism. Meetings on an ad hoc basis.
Ireland	Department of Environment, Climate and Communications	Inter-agency Group tasked by the Government whose Terms of Reference (ToR) sets out the purpose of the Coordination Group (consisting of 7 agencies and 5 government departments and approx. 24 individuals invited to the meetings); National Radon Control Strategy Coordination Group; subgroups of the coordination group
Italy	Ministry of Health and Ministry of Ecological Transition	Technical Working Group (representatives of Ministries, State Regions Conference, INAIL, ISIN and ISS) for development of RAP National Radon Observatory (same as Technical WG but with regions and autonomous provinces)
Latvia	Ministry of Environmental Protection and Regional Development coordinates radon activities	A working group consisting of 12 institutions (ministries, universities, research institutions, etc) was established in 2015 to prepare the report on "*Assessment of radon gas results and future follow-up ensuring radon gas monitoring in Latvia"* (July 2018). The National radon action plan states, that the working group coordinates issues related to radon, including rising awareness in society of the effects and risks of radon gas, improve knowledge of protective measures and ensure additional measurements and repeated assessment of the situation.
Lithuania	Ministry of Health Care responsible for radon activities. Radiation Protection Centre RSC: regulatory authority to implement these activities.	Radiation Protection Centre RSC is a regulatory authority to implement activities set in the Lithuanian Radon Risk Management Action Plan for 2024-2030 in collaboration with local authorities in some measures.
Luxembourg	Government of Luxembourg	Steering Committee chaired by the Radiation Protection Division for the follow-up; 4-5 bilateral meetings with approx. 4 administrations.
Malta	Commission for the Protection from Ionising and Non-Ionising Radiation (RPC)	Radon Working Party (RWP) with 6 members from RPC and 1 from University
Poland	Ministry of Health	Panel for the nation action plan for radon exposure: Chief Sanitary Inspectorate, different ministries; National Atomic Energy Agency, research institutes and universities.
Portugal	Portuguese Environment Agency (APA)	Sectorial working groups for implementation Every action identifies the entities involved in the implementation

Romania	National Commission for Nuclear Activities Control (CNCAN)	Interministerial working committee (health; regional development and public administration; research and innovation; environment) to monitor implementation. Meetings twice a year up to 15 people. Reports published on CNCAN website.
Slovakia	Ministry of Health	Interdepartmental Commission for Radon Protection with ministries (health; transport and construction; environment; education, science research and sports) for development of RAP. Working group for implementation launched in 2000 (Public Health Office; ministries above mentioned; ministry of agriculture and rural development, ministry of economy, regional public authorities) : responsibilities for implementation to be defined - around 20 participants
Slovenia	Slovenian Radiation Protection Administration	Consultation with ministries involved in radon for the development of RAP.
Spain	Ministry of Health	Interministerial WG for the development of RAP National Action Plan Committee for the implementation for the RAP (including autonomous communities and local entities)
Sweden	Radiation Safety Authority (SSM)	Steering Group coordinated by managers from SSM in collaboration with Swedish Work Environment Authority; National Board of Housing, Building and Planning; Public Health Agency and Geological Survey of Sweden. Radon group (analysts) collaborate on radon implementation and report to the steering group on how the work is progressing.
The Netherlands	Ministry of Infrastructure and Water	WG (every 2 weeks during preparation of RAP and now for implementation, once a month)
UK	UK Health Security Agency (UK HSA)	Historical collaboration between government departments and agencies; Memorandum of Understanding (MoU) within each of the 4 countries within Great Britain

Reviews and assessments of RAPs

The schedule to review RAPs varies among MS and ranges from 2 to 10 years. In some cases, the schedule to review is not specified in the plan and the interviewees pointed out that the review would be undertaken when needed. However, the question remains open on what could be considered as a need and who signals this. In most cases, the owner of the RAP also acts as a reviewer. When this is not the case, the reviewer is not defined, the different organisations involved in the RAP are responsible also for reviewing the plan or independent experts are planned to be appointed as reviewers.

A few countries have already a set of criteria or indicators which facilitate the review of their national radon action plans. The review of RAPs is mostly based on the degree of completion of the actions planned in the RAPs. Few countries have defined indicators helping assessment of RAP's effectiveness, which may include:

- Number of measurements conducted in dwellings and workplaces;
- Number of awareness raising activities;
- Share of remediated buildings reported;
- Assessment of the cost effectiveness of the interventions;
- Findings of the actual inspections programme;
- Number of courses held and attendance at radon prevention training;
- Etc.

Several countries are working to define effectiveness indicators in the short and long-term (e.g., Austria, Germany). However, there is not yet a common set of criteria or indicators to measure the effectiveness of the different elements of the RAP. Bochicchio et al. (2022) summarise the activities undertaken by HERCA on effectiveness indicators. The HERCA working group on Natural Radiation Sources decided that "*a list of indicators is useful, but selection and applications depend on national circumstances; the need for description of which input data are required was identified. HERCA will not endorse a harmonized list of indicators that must be used as these may be quite different depending on countries' prevailing circumstances, available resources, etc. HERCA representatives concluded that, at the moment, no need for a harmonized European list is foreseen. Instead, the exchange about indicators will be continued in coming meetings*". (HERCA, 2023)

The interest to establish a set of indicators to evaluate the RAPs and the need to recognise the differences in the context of RAPs and incorporate country specificities is shared among all countries. For some authorities consulted during the EU-RAP study, the guiding questions used in the EU-RAP project to assess the implementation phase for each of the 14 items defined in Annex XVIII of the Council Directive 2013/59/Euratom and education and training (see Annex 1) proved to be a useful mechanism to help countries evaluate the effectiveness of the actions included in the corresponding RAP.

3. Elements for preventing indoor radon exposure

This section reports on the following particular elements which are part of the radon exposure prevention: 1. Reference levels and delineation of radon priority areas; 2. Radon prevention in new buildings; 3. Prevention of radon after building reconstruction: challenges and good practices; 4. Engagement and communication as part of the prevention and 5. Links with other programmes.

Main conclusions related to elements for preventing indoor radon exposures

The majority of countries have established their radon reference level (RL) at 300 Bq/m^3, while only a few set it at a lower value. The setting of RLs considers manageability and some countries have also established supporting levels. The process of defining radon priority areas (RPAs) is ongoing in some countries and involves technical, scientific and socio-economic considerations. Cooperation with the building sector is essential in protecting against radon exposure, and protective measures are required in most countries, though the requirements differ. The execution of protective measures relies on the building code in each country and may involve requirements in building permits or simply the dissemination of information. The prevention of radon exposure during building reconstruction is important for indoor air quality. Some countries regulate radon during the building reconstruction process, but the regulations vary. In a few countries, building measurements are taken before or after reconstruction, particularly in school facilities, to ensure radon protection. The EU-RAP study revealed that there is a need for improvement in the communication of preventive measures and alternative technologies for radon exposure prevention in new builds. While some countries have successful practices, such as communication campaigns for prevention at workplaces in RPAs, the communication of prevention actions in new builds is limited and mainly conveyed through technical documents. The information on natural radionuclides in

construction materials is not widely communicated, with only a few countries publishing lists of products publicly. Communication with the building industry and producers is not consistent, although there have been attempts of collaboration in some countries. Nevertheless, the study highlights the importance of stakeholder engagement and decision making practices in radon exposure prevention in all countries.

There is currently a lack of systematic links between RAPs and other related programmes, such as energy saving, indoor air quality, cancer programmes, anti-smoking programmes, lung cancer screening or the Europe's Beating Cancer Plan The cooperation between programmes is either ad hoc and the result of the initiative of other programmes and actors or remains only on strategic level. Most EU MS are considering or preparing such programmes, however their implementation may only occur in future RAPs. There are some good practices such as including radon in an indoor air quality measurement campaign or in an indoor air quality and energy saving action plans. Overall, there is a need to further explore the counter effects of implementing energy efficiency measures which may lead to increasing indoor radon levels, and to connect cancer programmes with RAPs.

Reference levels and delineation of radon priority areas

In this document, the following concepts are used: **radon prone area** and **radon priority area**. A radon prone area refers to the geological characteristics of a region whilst radon priority area refers to specific area in which radon concentration is expected to exceed the relevant national reference level in a significant number of buildings. Participants at the EU-RAP workshops pointed out that the term radon prone area may not be accurate and may be a challenge for communication. Hence, the term radon priority area was advised to be used instead of radon prone area. In addition, some countries use the term radon precautionary area to indicate high radon concentration expected in significantly more buildings than in the national average.

Despite their differing geological conditions, most countries did not set the reference level (RL) below 300 Bq/m^3. Radon-prone countries are already struggling with 300Bq/m^3 and therefore, in this light, it is not feasible to lower RL. In line with this, most countries use manageability for setting RLs.
Some countries consider supporting levels (e.g., intervention level, target level, etc) whilst others do not. An example is the Netherlands, where the latest survey shows that the annual average indoor radon concentration is 16 Bq/m^3 and has a RL of 100 Bq/m^3 for all dwellings, buildings with public access and workplaces and a target level set at 20 Bq/m^3. In the UK, the target level in dwellings for radon remediation and the level above which those at higher individual risk (e.g. smokers and ex-smokers) should seriously consider action is set at 100 Bq/m^3. In Ireland, target levels are not used. Instead, it is recommended that, following radon remediation, radon concentrations should be well below the RL of 200 Bq/m^3 for dwellings and 300 Bq/m^3 for workplaces. Different levels may be used as operational quantities, facilitating the decision-making within the frame of optimisation around the RL. There are advantages and disadvantages of linking the RL with the radon exposure at work. The use of different numbers (RL, action level or target level) might be confusing to the public and the use of one value seems to be preferred by most participants of the EU-RAP workshops. Table 4 presents RLs and supporting levels per country.

Table 4. Reference levels in EU MS and the UK

Reference levels per EU MS and the UK (*status on January, 2023)*		
Country	**Reference level**	**Supporting levels**
Austria	300 Bq/m^3 for all buildings*	/
Belgium	300 Bq/m^3 for all buildings	Target level/design level 100 Bq/m3 Intervention level 600 Bq/m3 Legal level of radon exposure at workplaces is 600 kBqh/m3 per year
Bulgaria	300 Bq/m^3 for all buildings	/
Croatia	300 Bq/m^3 for all buildings	/
Cyprus	300 Bq/m^3 for all buildings	/
Czech Republic	300 Bq/m^3 for all buildings	If annual average of radon concentration indoors above 3,000 Bq/m^3: level unacceptable by law and owner is obliged to take action to reduce Rn level
Denmark	100 Bq/m^3 for all buildings not covered by provisions for new build	Limit: 100 Bq/m^3 for new buildings
Estonia	300 Bq/m^3 200 Bq/m^3 for schools and preschools	Regulation for "design level" for new buildings under development: 300 Bq/m^3
Finland	300 Bq/m^3 for dwellings, workplaces, public buildings and schools 200Bq/m^3 for new buildings	/
France	300 Bq/m^3 for all buildings	Action levels for buildings with public access: above 300 Bq/m^3 (action required), if above 1000 Bq/m^3 or above 300 Bq/m^3 after remediation (apply reinforced actions)
Germany	300 Bq/m^3 for all buildings	/
Greece	300 Bq/m^3 for all buildings	/
Hungary	300 Bq/m^3 for all buildings	/
Ireland	workplaces 300 Bq/m^3 dwellings, schools 200 Bq/m^3 (advised) long-stay institutions 200 Bq/m^3 areas within long-stay institutions which are clearly workplaces 300 Bq/m^3	200 Bq/m^3 is an advisory level, but for simplicity, the term RL used
Italy	300 Bq/m^3 for all buildings	200 Bq/m^3 for dwellings used to promote corrective action in radon priority areas RL for dwellings built after 2024 will be 200 Bq/m^3
Latvia	200 Bq/m^3 for dwellings and 400 Bq/m^3 for workplaces	/
Lithuania	300 Bq/m^3 for all buildings	/
Luxembourg	300 Bq/m^3 for all buildings	/
Malta	300 Bq/m^3 for all buildings	/
Poland	300 Bq/m^3 for all buildings	/
Portugal	300 Bq/m^3 for all buildings	250 Bq/m^3, for decision on frequency of measurement at workplaces; reduced value of RL to cover seasonal variation effect
Romania	300 Bq/m^3 for all buildings	/
Slovakia	300 Bq/m^3 for all buildings	/
Slovenia	300 Bq/m^3 for all buildings	/

Spain	300 Bq/m^3 for long-stay public buildings, school, pre-school, dwellings 300 Bq/m^3 for workplaces	
Sweden	200 Bq/m^3 for all buildings	For new buildings 200 Bq/m^3 is considered as a strict limit.
The Netherlands	100 Bq/m^3 for all buildings	Target level 20 Bq/m^3
UK	300 Bq/m^3 for workplaces 200 Bq/m^3 for dwellings	Target level for remediation and as a point above which those at higher individual risk, such as smokers and ex-smokers, should seriously consider radon reduction is at 100 Bq/m^3

While most countries have already defined radon priority areas (RPAs), in some countries, it is considered too early to designate RPAs, as data is still being gathered (e.g., Italy, Greece, Bulgaria). The conditions and situations are different across the MS and the criteria for delineation can be different. Some countries (Cyprus, Malta, and the Netherlands) do not plan to delineate RPAs due to their geology and climate. In Latvia, the criteria for RPA are defined in the RAP and according to these criteria no such areas have been identified in Latvia. Finland considers all the country as a RPA. However, criteria for delineation vary among the MS depending on the local situation. Thus, a RPA in one MS may not be a RPA in another MS. In some specific cases this may be even different among regions in one country.

The delineation of RPAs is based not only on a technical or radiological consideration, but also on socio-economic issues. A regular review of the delineation of radon prone areas is not a priority at this stage of implementation of national RAPs and may depend on provisions in RAP. However, an update (e.g., every 10 years) is advisable and is put in practice in most MS.

Preventing radon ingress into new buildings

Since almost all the exposure from radon is received indoors (i.e., homes, offices) the cooperation with the building sector is crucial. Provisions for protection of buildings from radon from soil should be included in the building code. In most MS (e.g., Austria, Czech Republic, Spain), the building code is available describing the required procedure of anti- radon building protection. In others, the "radon part" of the building code is still being prepared and not yet approved.

In the majority of MS, protective measures are required. In some countries (e.g., Germany, Czech Republic) the preventive measures should be always applied when building a house. Other countries require this obligation only in designated areas, e.g., in Spain and Austria this applies to radon priority areas whereas in Belgium this applies to Wallonia region. In the UK, in locations where 10% of houses are expected to exceed the RL, it is required to build a passive sump. In locations where 1% (Scotland and Northern Ireland) or 3% (England and Wales) of houses are expected to exceed the RL, build-in membranes are used). In some EU MS, measures are not required and only information about radon is provided (e.g., Lithuania, Luxembourg).

Specific requirements are implemented according to the building code in some countries. In the Czech Republic and Belgium, radon protective measures are imposed in the building permit. In some cases, the scope and type of the preventive measures are chosen according to the radon concentration in the soil (e. g. Czech Republic, Bulgaria, Hungary, Croatia, Estonia). In Finland and Poland, radon itself is not covered in the building code and the requirements are focused on separate technical elements of the building, such as ventilation or foundation structure. These requirements enable preventive measures to be implemented.

In several countries (e.g. Finland, Ireland, UK) preventive passive measures are implemented during the building process if necessary. In Hungary, this process is foreseen.

In some member states, guidelines on radon prevention in buildings are considered unnecessary (e.g. Cyprus, Malta, where no excessive radon levels have yet been detected) while in others the guidelines are under development (e.g. Greece, Romania).

An important part of radon prevention in new buildings is checking the radon levels after construction. In this case, measurements are mandatory before occupation of the building in some countries (e.g. Spain, Finland) whilst in others the measurements before occupation are under consideration (Austria). In Bulgaria the effectiveness of preventive measures is evaluated. In some MS (e.g. Czech Republic), radon activity concentration measurements are mandatory in schools and kindergartens before using the building. In Ireland radon measurement is required in new schools by the Department of Education. In Italy, the testing is mandatory in all public buildings in radon priority areas; while in the UK all workplaces in radon priority areas must have risks due to radon assessed. In other countries (e.g. UK, Czech Republic) testing is recommended for new dwellings after the building is built and during the first year of usage.

Checking the radon levels in existing buildings is undertaken in the UK and Ireland, with the inclusion of radon activity concentration measurement in the conveyancing process. In some countries, using of this tool is under consideration (Austria, Cyprus).

Besides the building code itself, other important publications could be helpful when building a new building, such as building standards, which are ready or being developed in Estonia, Germany, Czech Republic, Austria, Belgium, or different brochures with technical solutions online (Belgium, Czech Republic). Moreover, the standard DIN/TS 18117-1 on Construction and ventilation measures for radon protection in buildings was recently published in Germany.

Prevention of radon during building reconstruction

Radon is an indoor air quality issue, and as such should be considered together with other air quality issues and can result in increased radon levels. Therefore, not only new buildings but also the reconstruction process of buildings is important from the point of view of radon protection. In only a few MS, the law regulates radon in the process of building reconstruction. In some MS, buildings are measured before reconstructions (in the Czech Republic under special conditions), or school facilities are measured after energy refurbishment (e.g. the Czech Republic).

Communication and stakeholder engagement in radon exposure prevention

Preventive measures and alternative technologies to prevent radon ingress in new build are communicated systematically to the building industry and owners. In Ireland, all dwellings built after 1998 in high radon areas must be fitted with radon preventive measures, namely a radon membrane and a standby radon sump. The standby sump can be activated if high radon concentrations are found in the building.

Another good practice is the memorandum of understanding (MoU) between the Ministry of Infrastructure and Water Management and the industry, through which industry committed

itself to not increase radon in dwellings due to building materials in the Netherlands. The MoU ended in 2015 when the Ministry of Infrastructure and Water Management sent the results of the National Institute of Public Health and the Environment (RIVM) survey (Smetsers et al., 2016) to the Parliament. The building industry committed itself to self-regulate that the building and construction materials used would not result in increase of indoor radiation exposure. The government committed itself to commission RIVM to periodically monitor indoor exposure in newly built dwellings.

In general, the EU-RAP study identified the following specific aspects in communication and stakeholder engagement that contribute to radon prevention:

- Communication about radon in general

Communication interventions are focused on presenting factual information about radon and its health effects. It is often communicated as the "second-leading cause of lung cancer death". In some MS, increased ventilation is promoted in RPAs through the media.

- Communication about prevention in new build

The communication of prevention actions is rather scarce. Building codes, if established, are communicated mainly through technical documents. Building authorities are targeted by communication interventions, e.g. in Slovakia.

- Communication about NORM in construction material

Most of the countries have yet to systematically communicate the information on NORM in construction material. Some MS publish a list of products in public documents or on the internet. A European report to assist EU MS implement article 75 of the Council Directive 2013/59/ Euratom (2013) should facilitate in this respect.

- Engagement with stakeholders

Communication with producers and the building industry is not systematic. However, there are some attempts of collaborations e.g. in Denmark or Estonia where guidance material is developed together with industry.

Links with other programmes as a prevention from radon exposures

RAPs could be preferably linked with other related issues and corresponding programmes such as programmes on energy saving and indoor air quality, cancer programme, anti-smoking programme, lung cancer screening or the European Commission (2021) Europe's Beating Cancer Plan (Action 17)[3]. Most EU MS are considering or preparing such programmes, however they may be implemented only in the next RAPs.

In general, the EU-RAP study showed that there are no systematic links with other relevant programmes at this time, and that most of corresponding programmes are linked ad hoc. There are many attempts to connect energy saving programmes with radon prevention programmes, however these are not systematic. The cooperation between programmes is either ad hoc and the result of the initiative of other programmes and actors (e.g. invitations to events or mentions of radon in the corresponding programme) or remains only on strategic level. In Sweden, radon measurements are part of the energy declaration for buildings but are not mandatory. In Ireland, radon is a recommendation included in building energy rating reports for home energy performance. Also links with indoor air quality programmes are rather scarce and weak. There are some good practices, for instance in Austria where radon is part of an indoor air quality (IAQ) measurement campaign. Radon is included in an IAQ & energy saving ten-year action plan for public buildings in Finland. IAQ should include radon concentrations when energy-

[3] https://health.ec.europa.eu/system/files/2022-02/eu_cancer-plan_en_0.pdf

saving interventions such as renovations or window replacements are carried out in public buildings on RPA in Slovenia.

There is a need to further explore the counter effects of implementing energy efficiency measures which may lead to increasing indoor radon levels. For instance, studies on radon concentrations in new, energy saving buildings are conducted, e.g. in Luxembourg.

In addition, cancer programmes are not sufficiently connected to RAPs. Europe's Beating Cancer Plan[2] refer also to exposure to radon which may be an opportunity to cover radon in future cancer programmes.

At regional workshops EU MS discussed how to significantly consider radon in relevant corresponding programmes, particularly for energy saving and IAQ programmes. They indicated that there is a lack of human resources, however connections with people responsible for other programmes may be beneficial. An idea could be to contact energy agencies dealing with energy efficiency to raise awareness of the counter effects of implementing energy efficiency measures compared to the increasing exposure to radon. Also, the connection of energy saving programmes with European programmes e.g. European Green Deal can be seen as an opportunity.

4. Measurements and testing of radon in dwellings, workplaces and public spaces

This section describes the measurements and testing of radon in dwellings, workplaces and public spaces as assessed in all EU MS and the UK. In particular it reports on 1. Guidance on methods and tools for measurement of indoor radon activity concentration; 2. Guidance on methods for measurement of mass activity concentration of natural radionuclides in building material; 3. Guidance on methods for radon exhalation and radon in water management; 4. Criteria for accreditation/licensing of measurement services; 5. Measurements at workplaces; 6. Actions if elevated radon levels found; 7. Effective dose calculation; 8. Radon surveys; 9. Communication aspects related to testing and 10. Costs related to testing.

Main conclusions related to measurements and testing of radon in dwellings, workplaces and public indoor spaces

Measurement of indoor radon concentration can be divided into two groups, measurement in dwellings and measurement at workplaces. National guidance, i.e. measurement protocol, is implemented in 20 while 5 countries are still developing their protocols. Measurement guidance is rarely part of RAPs. The main method for indoor radon measurement is passive track etched detectors in diffusion chambers. The duration of measurement can vary from 30 days to 1 year, with the heating season being the preferred time for measurement. A graded approach to indoor radon measurement is recommended, where detailed measurement is carried out if the initial results exceed the RL. Many countries have already adopted this approach in their measurement protocols.

In summary, guidance on the method of measurement of radon exhalation from building materials is not yet developed or implemented in EU MS and the UK. Some countries have conducted surveys with no significant radon exhalation from building material found. Radon in water is regulated under the Council Directive 2013/51/Euratom of 22 October 2013, but measurement methods and guidance are available in 17 countries with a protocol being developed in 3 countries. Radon in water is part of the RAP in a few countries.

The criteria for accreditation/licensing of measurement services vary among different countries. Some countries require accreditation in compliance with ISO/IEC 17025, while others focus on national proficiency testing. In some countries, the recognition process involves both accreditation and compliance with a specific measurement protocol. Accredited laboratories are often listed in a public database. In at least one EU MS, there is a legal requirement for a radiation protection specialist to be a member of the staff, leading to a lack of available measurement services. The participants at the EU-RAP workshops agreed that defining a minimum set of rules and requirements for providers of measurement services would increase reliability and public confidence in the results.

Radon measurements in all workplaces at a country territory are legally required in 5 countries. Identification of workplaces where the radon measurement will be obligatory is ongoing in 3 countries. In few countries the employer is responsible for assessment of health risks, including radon, for employees. Some countries prioritise radon measurement in high-risk workplaces such as water treatment facilities, underground workplaces and public buildings with long-term stay. Since the priority of radon measurement at work is connected to the delineation of radon priority areas, the measurements are on a voluntary basis in

countries without delineated areas. However, priority for measurements is given to school and preschool facilities, public buildings and underground workplaces. Some countries also use exemptions based on time spent at the workplace, with the allowed duration ranging from 10 to 100 hours per year.

Most countries have established procedures for employers to follow if elevated radon levels are detected in the workplace. If the radon level exceeds the RL, the employer must optimise or reduce the levels. Some countries provide more support to employers. In some countries verification measurements after remediation is implemented. If despite the remediation, the RL remains exceeded, the workplace is notified, and workers' effective doses is assessed. The employer is responsible for employee radon exposure optimisation and the property owner must optimise radiation protection in public access premises and dwellings.

Calculating the effective dose from radon exposure is complex and considers variables such as seasonal and diurnal variation, occupancy time, and radioactive progenies contribution. In most domestic homes and some workplaces, average radon levels are used to assess the hazard, but in complex cases, an effective dose analysis may be conducted. 15 EU countries have adopted the ICRP Publication 137 dose conversion coefficient, while implementation is under discussion in 6 countries. The UK uses the ICRP Publication 65 conversion convention, and Sweden has not formally adopted the ICRP 137 coefficient. Malta chose not to adopt any coefficient due to low radon levels, and information was not provided by 4 countries.

There are significant differences in the strategies for conducting indoor radon measurements in EU MS and the UK, including the frequency of measurements and target areas. Some countries have reduced the number of measurements campaigns carried out each year, while others recognise the need for further measurements. Countries with long-standing radon programmes have representative radon survey results which are around 20-30 years old and some are updating their surveys. Most countries prefer to conduct long-term (over 6 months) measurements using passive track detectors. There is limited information on the number of detectors per building. An identified common challenge in some countries is the low interest from citizens to measure radon in their homes and the low return rate of detectors for evaluation.

The EU MS and the UK vary in how they manage radon related data. 17 countries have a national radon database, while 3 are in the process of developing one, 2 publish data online, and 2 have a different type of registry. The data collected as part of the RAP is typically stored in the national database, but data from other measurement providers is rarely included. Some countries reported difficulties with sharing data from private companies due to General Data Protection Regulation (GDPR) restrictions and consequently, they reported issues with creating maps.

In terms of communication about radon testing, many countries have organised communication efforts to increase the number of tests conducted. These interventions often take place through schools, information sessions, and letter drops, and tests are frequently provided for free as part of these efforts. Some countries evaluate the success of their interventions based on the number of tests distributed, while others measure the effectiveness by the number of returned tests. Some countries have developed videos to help educate people on "how to test", and a few have a designated person who provides personal advice

and information related to radon measurements. A few countries also address ethical considerations in their communication efforts.

Most countries provide some form of financial support for radon testing, such as free radon testing. The cost of radon testing in EU MS and the UK can range from free to 100 euros.

Guidance on methods and tools for measurement of indoor radon activity concentration
Measurement of indoor radon can be divided into two groups: measurement in dwellings and measurement at workplaces. National guidance, i.e. measurement protocol, is implemented in 20 countries, 3 of them reported that they implement ISO 11665 standards as national measurement protocols, i.e. Estonia, Greece and France (only in buildings with public access). Measurement protocols are being developed in 5 countries, e.g. Croatia, Italy, Slovakia. Germany, in the case of dwellings, and the Netherlands, have recommendations for measurement rather than national measurement protocols. Countries with very low average radon concentration indoors in buildings across their territory do not consider the development of national guidance for the moment until deemed necessary (e.g. Cyprus, Malta).

Guidance on measurement is rarely part of the RAP. Normally, the main principles of indoor radon measurements are described together with the mainly used measurement techniques in the RAP. All countries use passive track etched detectors contained within diffusion chamber as the main method for indoor radon measurement. As radon levels are often lower during the day than at night, continuous monitors are used to confirm RL exceedance during working hours, e.g. in Denmark, Finland, Czech Republic. In Denmark, it is considered advisable to use both digital and passive monitors in places where they have a central ventilation system with a day and night cycles. In Finland, if the results exceed the RL and the ventilation is operated according to working hours, continuous radon measurement for 168 hours must be carried out at workplaces. The Czech Republic requires in the measurement protocol that only results made by metrologically verified detector/monitor are accepted.

The duration of measurement varies from 30 days up to 1 year. The heating season is the preferred period of the year for indoor radon measurement. Ireland requires that only the results of a radon measurement carried out in accordance with the EPA's radon measurement protocol be compared with the RL.

The participants at the EU-RAP workshops agreed on the benefits of a graded approach in measurement indoor radon – to carry out measurement during the heating season and if the results are below the RL, further measurement is not necessary until changes affecting radon concentration appears in the building/workplaces. If the results are above RL, further and more detailed measurement is required. Many countries have this approach already implemented in their measurement protocols.

Guidance on methods for measurement of mass activity concentration of natural radionuclides in building material
Measurement of mass activity concentration of natural radionuclides in building material has a very long tradition in some countries, e.g. Finland, Sweden or Czech Republic. 19 countries have implemented either the national guidance or European standard (CEN TS 17216:2018).
The RAPs do not provide details on the measurement protocol. Some EU MS expressed during the regional workshops that content of natural radionuclides in building materials is out of the scope of the RAP. Germany has national recommendations, the enforcement of which is up to

the federal states. In 3 countries (i.e. Croatia, Hungary, Portugal) measurement protocol is currently being developed.

Guidance on methods for radon exhalation and radon in water management

Guidance on a method of measurement of radon exhalation from building material is not developed, nor implemented in any of the EU MS and the UK. Estonia plans to conduct survey of radon exhalation rate for building materials with elevated content of natural radionuclides. Results of a German study undertaken in the past did not reveal any building material with significant radon exhalation (e.g. >>20 Bq/m^3). Participants of the regional workshops stated that limitation of content of natural radionuclides via gamma spectrometry measurement is considered sufficient, e.g., Austria stated that the Austrian standard ensures no significant radon exhalation but was repealed in April 2022.

Radon in water is mentioned only as a possible source of radon indoors in the RAPs. It was stated by many of representatives of the EU MS and the UK that the radioactivity in drinking water is subject of the implementation of the drinking water directive (Council Directive 2013/51/Euratom of 22 October 2013 laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption) and therefore, it is not part of RAP. However, measurement methods are available, and guidance is implemented in 17 countries while measurement protocol is currently being developed in 3 countries (i.e. Croatia, Hungary, Portugal).

Criteria for accreditation/licensing of measurement services

Accreditation is defined here as the official approval given by an organisation stating that somebody/something has achieved a required standard. We point out in this study the broader meaning of accreditation beyond meeting the requirements of ISO/IEC 17025. Licensing is often understood as an official process in which the authority responsible for licensing issues a set of rules and conditions under which the provider may be licensed.

Most countries require measurement providers to meet certain conditions to be recognised. The recognition has various designations, e.g. accreditation, licensing, validation, registration, attestation, approval. Conditions to become recognised vary across countries. In some countries, the process is connected with successful accreditation of the provider of measurement service in compliance with ISO 17025, e.g. Bulgaria, Portugal, Austria. Some other countries require national proficiency testing, e.g. Ireland, UK, Poland. The Swedish approach combines both, accreditation according to ISO 17025 and compliance with Swedish Radiation Safety authority's measurement protocol. Accredited laboratories are often listed in a database of providers published on topical web pages, e.g. Czech Republic (online list of license holders), France (list of measurement services in buildings with public access on ASN webpage), Belgium (FANC website).

At least one EU MS noted that as a result of having a legal requirement requesting the measurement laboratory to have a radiation protection specialist as a member of the staff, no measurement service is available in the country. At least 2 countries do have approval of providers of determination of the effective dose, i.e. Denmark, Finland. Participants at the EU-RAP workshops agreed that defining a minimum set of rules and requirements for providers of measurement services increases reliability of radon measurement and public confidence in the results.

Measurements at workplaces

Radon measurements in all workplaces in the country territory is required in 5 countries while identification of workplaces where the radon measurement will be obligatory is ongoing in 3 countries (Hungary, Malta, Denmark). Sweden, Ireland, Portugal, Germany, and Bulgaria apply a graded approach to give priority to those workplaces located in priority areas or to priority workplaces. In the UK and France, the employer is legally responsible for the assessment of health risks for employees including radon. In the UK, measurement of indoor radon should be carried out in RPAs. In France, the assessment of radon risk is required everywhere in underground and ground-floor workplaces, not only in RPAs. This assessment may require measurements.

Several countries require radon measurement at specific types of workplaces regardless their location - most of the countries require measurement in water treatment facilities and underground workplaces (such as mines, tourist caves); spas, jails, wineries, tunnels, i.e. workplaces with higher probability of elevated radon concentration. Six countries require measurement in buildings of public interest, school and preschool facilities, e.g. Slovenia, Slovakia, Romania.

Obligatory measurement at workplaces on priority areas as required by the Directive 2013/59/EURATOM is strongly connected to the delineation of priority areas. Some countries have not finished delineation of priority areas; therefore, measurement at workplaces is currently on a voluntary basis (e.g. Bulgaria). Most countries reported that priority is given to school and preschool facilities, public buildings with long term stay of public and underground workplaces where the exposure is expected to be very high during the planning of measurement campaigns.

Some countries apply special criteria for selection of buildings hosting workplaces where measurement is or is not required, e.g. Czech Republic and Slovakia do not require measurement in workplace located on RPAs if the building was built after the implementation of legal framework considering radon while Finland considers all territory with highly permeable gravel or sandy soil to be a RPA and all workplaces located in such areas should be measured.

Some of the countries use exemption from measurement based on the time spent at a workplace location, e.g. UK, Czech Republic, Finland, Ireland. Duration of stay of the workers vary country to country and is in the range from 10 to 100 hours per year.

Actions if elevated radon levels detected

Most of the countries have already established processes for the employers to follow if the workplace exceeds the RL. Some of the countries reported very low radon activity concentration measured and therefore, they see no need for establishing a procedure to deal with radon levels higher than the RL, e.g. Malta, Latvia. The majority of countries specify details of these procedures in the RAP and in some cases, like in Finland, they are specified in legal framework.

Most of the countries require optimisation or reduction of radon levels if the RL is exceeded. If despite remediation radon levels remain higher than the RL, the workplace is notified (e.g. Sweden, Belgium); moreover, the effective doses received by workers are required to be assessed in some countries (e.g. Austria, Bulgaria, etc.). EU MS differ in the extent of support

provided to the employer in case of high radon levels. For instance, in Lithuania and Hungary with the case-by-case support is provided by the regulator on a case-by-case basis. In the UK and Sweden there is an established regulatory system and a system of guidelines. Moreover, the Swedish Radiation Safety Authority provides support by e-mail and/or telephone but there is no financial support for measurement and mitigation activities from the authorities or private companies. Employers are responsible for radon exposure optimisation of employees. In the case of premises to which the public has access and in the case of dwellings, the property owner must optimise the radiation protection by taking measures so that the radon level is kept as low as possible and reasonable.

Differences are also found in the extent of measurement required if the RL is exceeded, e.g. Slovenia recommends carrying out measurement of radon progenies and gamma dose rate of building material. A verification measurement after implementation of remediation is required in some countries, e.g. Austria, Czech Republic, while not required in others, e.g. Croatia.

Effective dose calculation

The concern with radon is the assessment of the effective radiation dose delivered to the occupant, but this is complex, depending on many parameters influencing the dose delivered to the sensitive cells. Once the measurement results are available, they are compared to the RL. If despite the remedial measures the radon concentration in the workplace remains above the RL, then it can be appropriate to conduct an effective dose assessment. Indeed, the effective dose calculation has been found to be a sensitive topic for some EU MS, particularly the implementation of the new radon dose conversion coefficient published in the ICRP Publication 137. 15 countries already implement these coefficients (Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Italy, Luxembourg, Romania, Slovakia and Slovenia) while implementation is under discussion in 6 countries (Germany, Ireland, Poland, Portugal, Spain, the Netherlands). The ICRP Publication 65 dose conversion convention is being used in the UK. In Sweden the ICRP137 dose conversion coefficient is not formally adopted. Malta decided not to implement any of the above due to prevailing very low radon concentration in their territory. Four countries did not provide this information. Table 5 presents dose coefficients applied in each EU MS and the UK as of January 2023.

Table 5. Dose coefficients applied

Dose coefficients applied per EU MS and the UK (*status on January, 2023)*	
Country	**Dose coefficient**
Austria	ICRP137
Belgium	ICRP137
Bulgaria	ICRP137
Croatia	/
Cyprus	ICRP137
Czech Republic	ICRP137
Denmark	ICRP137
Estonia	ICRP137
Finland	ICRP137
France	New order will include ICRP137 and will be applicable in January 2024
Germany	Currently the ICRP65, ICRP137 under discussion
Greece	ICRP137
Hungary	ICRP137
Ireland	ICRP137 under discussion
Italy	ICRP137
Latvia	/

Lithuania	ICRP137
Luxembourg	ICRP137
Malta	no need to implement due to low radon
Poland	waiting for final decision on which DCF will be used
Portugal	currently ICRP65, ICRP137 under discussion
Romania	ICRP137
Slovakia	ICRP137
Slovenia	ICRP137
Spain	Dose coefficients based on ICRP 103 recommendations will be applied.
Sweden	ICRP137 not formally implemented, but reference to ICRP115 and 103.
The Netherlands	currently the ICRP65, ICRP137 under discussion
UK	ICRP65

Radon surveys

There are great differences in the strategies for conducting indoor radon measurements in the different countries as well as different density of radon measurements (as can be seen in the European Radon Atlas[4]). Some of the countries reduce the number of measurements carried out each year, whilst in others there is a recognised need for further measurements, e.g. to identify radon priority areas.

Countries with a long history of radon programmes have representative radon survey results which are around 20-30 years old. Some of these countries decided recently to carry out a new representative survey to obtain information on changes of average indoor radon, which may be the result of new building technologies and revisions to radon related legal framework, e.g. Czech Republic, Spain, Slovakia, Ireland. At least one local survey has been carried out in all of the EU MS and the UK.

Some countries prefer to continuously carry out local surveys, e.g. focused on priority areas, or areas with insufficient data, or specific type of buildings, rather than investing money in a large national survey, e.g. Slovenia, Ireland, France. Some countries also reported the low interest from citizens to measure radon in their homes (and become part of the study) and a low return rate of detectors for evaluation, e.g. Greece, Bulgaria, Ireland.

Management of data

With regards to the management of collected radon exposure related data, 17 countries have implemented a national radon database, 4 countries did not provide data for the report (e.g. Latvia), 3 countries reported that the national database is under development (e.g. Italy, Hungary), 2 countries publish data online (Denmark, Croatia) and 2 countries have another type of registry (Luxembourg, Poland).

Usually, data collected within the remit of the RAP are stored in the national database; rarely the data from other providers of measurement are also stored in the national database (e.g. Romania, Slovenia). Finland pointed out during the regional workshop that private companies collect results which might be worthy for the national radon database and there is an ongoing discussion on possibilities to include them. Further details are presented in Table 6.

[4] https://remon.jrc.ec.europa.eu/About/Atlas-of-Natural-Radiation/Digital-Atlas/Indoor-radon-AM/Indoor-radon-concentration

Countries also reported GDPR issues when sharing data from private companies to the national radon database (e.g. Finland) or when developing maps. Table 6 summarises data management and status of radon surveys per EU MS and the UK.

Table 6. Data management and status of radon surveys

Data management and status of radon surveys in EU MS and the UK (*status on January, 2023*)		
Country	**Data management**	**Survey**
Austria	Data stored and used for modelling	Representative survey 2013-2019 local surveys are considered
Belgium	Data managed in ArcGis, new database will be developed	Representative survey 1995-2000 (random selection of 20 households in every municipality) Regular measurement surveys conducted every year; several local surveys conducted since late 1980s
Bulgaria	Data provided in the form of map, national radon database established	Representative survey 2015-2016 (100 detectors per district, 28 districts measured); National detailed survey ongoing district by district with more detectors than in 2016; survey on specific workplaces is ongoing; support of the IAEA when conducting pilot study in 2012/13.
Croatia	Data provided in the form of online map Database to be developed	Radon survey planned, currently no accredited laboratory to perform measurement. Representative radon survey in 10x10 km grid carried out in 2012 with 3 measurements in each; several local surveys carried out in the past; survey in schools and kindergartens. 1st national survey carried out in 2003/05.
Cyprus	The database exists and is not fully available for public at present.	Completed representative survey by 2021 (more than 1,000 measurements - between 9-12 months) Several surveys have been carried out between 2004 and 2012.
Czech Republic	Separate databases for radon and NORM, new comprehensive national database under development.	Representative radon survey carried out in 1993, new representative survey started recently; several local surveys in homes, schools and kindergartens; representative survey of radon in soil carried out or ongoing.
Denmark	Current discussion on management of data collected by other parties (University, NGO). Single information point online.	Representative survey in dwellings published in 2001, new one is being planned; survey in new buildings 2019; representative survey at workplaces published in 1987 and 2001
Estonia	Recently upgraded database exists; work in progress on checking errors in old data.	Since 1980s several national surveys carried out in dwellings, childcare facilities, workplaces, some of them representative to certain level, new study in progress using 10x10 km grid, at least 15 measurements per grid.
Finland	STUK maintains a register on the radon concentrations in dwellings, other premises used by people and workplaces. The results made by other laboratories in dwellings are not available.	National surveys and representative survey in dwellings exist from 1991 and 2006; special sample surveys carried out several times in the past; survey on radon at work and leisure time carried out in 2000-2001. Representative survey at workplaces in progress.
France	National centralised database managed by IRSN and Ministry of Health	In dwellings: Representative study conducted from 1982 and 2003; local targeted surveys performed and ongoing where sufficient data are missing, a survey on indoor air quality including radon was carried out in 600 dwellings in 2022 (analysis pending), national measurement campaign planned; detectors are provided for free to the inhabitants during local targeted surveys. In workplaces: measurements in the case of persistent overrun results after remediation in buildings with public access located in prone areas: the results of measurements are collected in a separate database managed by the Ministry of Health. Dwellings + workplaces + buildings with public access (under construction): all the results of radon detectors provided by accredited laboratories. The results will be made available to the administration, and later to the general public (action from the RAP)
Germany	Data collected in standardized federal database	National and regional surveys (indoor and soil gas) were carried out during around 1980 to around 2005 Representative survey of radon concentration in dwellings was recently carried out. Local surveys performed by federal states (various scopes and measurement methods used).
Greece	Radon database in phase of filling with data.	Representative radon survey in progress.

Data management and status of radon surveys in EU MS and the UK (*status on January, 2023*)		
Country	**Data management**	**Survey**
Hungary	Radon database under development	Representative radon survey in progress; several small scale and 2 large surveys (1993/94 and 1994-2000) were carried out;
Ireland	National radon data is held by EPA. A national database is under consideration.	A comprehensive national radon measurement surveys carried out during 1990s, published 2002 (geographic weighted survey). Subsequent national surveys in 2015 (geographic weighted) and 2017 (population weighted); local surveys (not representative) connected with specific radon projects
Italy	To be developed	National survey in 1989-1998; several local surveys (dwellings, schools, workplaces); second proxy representative radon survey was carried out.
Latvia	/Results from large scale survey (2016-2017) and previous assessments is held by Radiation Safety Centre of State Environmental Service.	Large scale radon survey carried out 2016-2017 and planned to be repeated in 2030/31.
Lithuania	Data provided in the form of national radon map. National radon database established by Radiation Protection Centre RSC.	Radon surveys on various scales starting in 1986, approximately 3,200 measurements made in dwellings and workshops.
Luxembourg	Results from dwellings measurement are sent to the Administration of the Land Registry.	Between the years 1991-2020, more than 5,000 measurements have been carried out; strategy for measurement at workplaces ongoing.
Malta	Radon database exists.	Four studies exist, 1st carried out 1994/95, short term measurement, 2nd 1997/98, long term measurement, 3rd carried out in 2010, long term, 4th in 2016/18 short term. A national survey of indoor radon levels performed in 2010/11 reported that "the mean annual indoor radon concentration for the Maltese Islands was 32 Bq/m^3".
Poland	The results of these measurements are delivered by the laboratory to the Chief Sanitary Inspectorate which analyzes and archives the data.	National survey is ongoing 10x10 km grid, expected to obtain 34,000 measurements in buildings, part of it in public buildings. Older surveys comprise approx. 10-12 000 measurements obtained by different methods.
Portugal	Radon database will be developed.	The first national study in 1987. In 2020, a new national survey particularly focused on dwellings located in geological units with little or no characterization of radon concentrations was conducted.
Romania	Radon database exists	Several local surveys, some of them supported through the EU projects, were carried out. Radon survey in progress.
Slovakia	Radon database is prepared but data needs to be filled in.	Representative radon survey in 1991; small scale surveys mainly for scientific purposes. New representative radon survey planned to be launched in 2022 to cover public buildings and schools and kindergartens, buildings and underground workplaces.
Slovenia	Radon database exists. Companies measuring under state contract have to report to the database.	3 types of local surveys across the territory also focused on priority areas. 1) survey of public access buildings, including educational, health, cultural buildings (conducted for more than 20 years); 2) dwellings in RPA (done in the last 4 years and based on 24 municipalities with higher radon concentration); 3) 27 municipalities with "middle" concentrations of radon; at the same time the RAP states the frequency of systematic surveys to be annually at least 50 public buildings, 50 dwellings, 150 schools and kindergartens.
Spain	Radon database exists	Several surveys of radon concentration in dwellings were carried out in the past, some of them (particularly in Galicia) connected with epidemiological studies. New studies planned.
Sweden	Municipalities collect data in various formats.	Representative radon survey carried out in 2009, many measurements but not available on the central level.
The Netherlands	/	Nationwide measurement campaigns carried out in dwellings (4 studies, the latest in 2013/14), workplaces and buildings with public access (1 study). Strategy – continue measuring campaigns, areas with elevated radon should be prioritized. Latest survey included also thoron measurement.
UK	National database exists	Representative radon survey in the 1980s, since then many other surveys on local level in approx. 600.000 houses.

Communication aspects related to testing
Most countries organise communication interventions with the objective to stimulate testing, many of them through schools and kindergartens (e.g. Bulgaria), information evenings (e.g. Luxembourg) or letter drops (e.g. UK). Tests are often provided for free as part of the communication interventions (e.g. Estonia). Some countries evaluate the success of the interventions based on the number of tests distributed (e.g. France) and only a few countries measure the effectiveness of the communication with the number of returned tests (e.g. Finland). In some cases, communication materials on "how to test" are developed using videos (e.g. Sweden). In Poland, there is a specific person appointed to provide advice and information related to measurements. Ethical aspects are also addressed in a few cases (e.g. in Germany, there is a consent form with the measurement kit).

Costs related to testing
Most countries provide some form of financial support for radon testing, such as free radon testing in radon priority areas (e.g., in Germany, in general, measurements are not free of charge, however, in the framework of research projects, free measurements are provided for buildings in the target areas of these projects). The cost of radon testing ranges from 0 to 100€. Empirical research has been conducted or is being conducted to assess the effectiveness of financial support in countries like Ireland and Germany, as well as in the framework of H2020 research and innovation project RadoNorm. As part of the RadoNorm project, a dedicated survey is being currently conducted in 15 EU MS which investigates people's views, expectations, and experiences with the state's financial support for measurements and mitigation in dwellings (Perko et al. 2021).

5. Remediation actions and re-testing

This section reports remediation actions and re-testing implementations in EU MS and the UK. It presents results from a study related to 1. Procedures for facilitating remedial actions; 2. Support for facilitating remedial actions; 3. Guidelines for remediation; 4. Accreditation /licensing; 5. Remediation costs and financial support for remediation; and 6. Re-testing.

Main conclusions related to remediation actions and re-testing

In the majority of countries, strategies are being developed to facilitate remediation in buildings with high levels of radon. These strategies aim to set the national legislative framework and knowledge base for corrective actions, as well as to involve stakeholders including citizens, building professionals, industry and authorities. Some countries, however, do not plan to develop any strategy due to low radon activity concentrations indoors in their territory. The main challenge in addressing excessive radon levels and remediation is the lack of contractors, building industry or other companies to perform the remediation.

Support for remedial actions in dwellings, public buildings and workplaces is diverse across countries. It may involve identifying houses suitable for mitigation through measurement campaigns, encouraging citizens to organise remediation through raising awareness and providing financial support, and ensuring an enabling environment for the construction industry through the legislative system and knowledge base for effective corrective action. The procedure for remedial actions in workplaces involves the employer reducing radon concentration below the RL, monitoring employees, and following notification procedures.

Re-testing and effectiveness evaluation after remedial action is also an important part of the process and is supported in several countries.

Most countries recognise the importance of publishing guidelines for remedial actions to provide solutions for house owners when high radon levels are detected. The national guidelines should be tailored to the specific building and geology conditions. As a result, harmonisation of such guidelines on the EU-level is often not feasible. Most countries have either published or are in the process of publishing these guidelines, mostly available online for free. Only two countries stated that such guidelines are not necessary due to low radon concentrations and one country reported that they will provide recommendations if necessary.

The accreditation or licencing of companies for remediation in buildings is not a common practice. Two countries implemented a registration scheme for radon contractors to promote quality and expertise in radon remediation services. Contractors have to follow certain requirements such as participating in training courses, being tax compliant and having public liability insurance. A few countries are planning to develop registers for remediation providers while others publish lists of contractors based on their participation in training courses or the review of work conducted. Other countries have decided not to implement any form of registration, accreditation, or licensing of remediation services. Some countries offer training courses on radon mitigation. One country established criteria for licensing of remediation services but no company was identified and the provision was removed from the law.

Remediation costs for radon mitigation vary widely across countries and type of measure implemented, with private dwellings costing from €500 to over €5,000, and public buildings costing from €1,500 to €60,000. Some EU MS offer direct or indirect financial support for remediation, although the experience reported is often the low motivation for the subventions uptake by owners of dwellings. All countries report difficulties finding radon remediation contractors due to the lack of profit for the building sector.

The remediation of buildings with exceeded radon levels is a concern across EU MS and the effectiveness of the corrective action taken must be tested to ensure it remains effective. However, only four EU MS require re-testing after remedial measures are taken, with one country requiring re-testing only if subsidised measures were used. Three countries provide re-testing for free. Only in one country, remediation contractors are required to provide annual information on the effectiveness of their remedial actions to the regulatory body. Studies are underway to determine the impact of financial support on testing and remediation in countries such as Ireland and Germany as well as in the H2020 project RadoNorm[5]..

Strategies for facilitating remedial actions

The strategy of radon protection has two equally important parts, prevention, and mitigation. Mitigation reduces the significant individual exposure of the occupants of buildings with high radon levels, but it does not greatly contribute to reducing the collective dose or exposure of the general population. The availability and accessibility of effective remedial actions is the main challenge for citizens living in excessive radon activity concentration. Therefore, the

[5] Further information on the RadoNorm Project at: www.radonorm.eu

majority of European countries are developing procedures for facilitating remediation in inhabitable buildings, at workplaces and in buildings with public access.
These strategies are directed to setting the legislative environment and the necessary knowledge base concerning the corrective actions and to involve different stakeholders – citizen themselves, building professionals, industry and authorities.
There are several countries which do not plan to develop any strategies on reduction of radon levels because of low values of radon activity concentrations indoors in their respecting states (e.g. Cyprus, Malta).

Support for facilitating remedial actions in dwellings, public buildings and workplaces
Support for facilitating remedial actions is provided in the following areas:

- support for measurement to recognise the buildings with elevated radon levels;
- support to citizens - possible clients (to encourage them to perform mitigation);
- support for remediation (to ensure easy remediation).

Firstly, the houses suitable for mitigation need to be identified. For this purpose, measurement campaigns are organised. Some of these measurements are provided for free (e.g. Czech Republic, United Kingdom). Campaigns are accompanied by massive and focused communication, including hotlines (Ireland), media advertisement, ad-hoc actions (Radon week, Ireland – National Ploughing Championship), etc.

Secondly, after high radon levels are confirmed, citizens are encouraged to organise remediation. The support is provided in different ways. Awareness concerning remedial actions must be raised up (Denmark, Finland, Lithuania, Luxembourg) and list of service providers must be available, ideally online (Greece, Hungary). Several EU MS support severely affected buildings. In the Czech Republic, there is a monetary support for schools and kindergartens with average radon levels > 300 Bq/m^3 during the working time, or for private houses with average radon levels > 1000 Bq/m^3. In some countries, the financial support is foreseen (Estonia, Portugal, Romania, Slovakia) or under consideration (Germany, dwellings).

Some EU MS require owners of radon-affected properties to facilitate remedial actions (e.g. Finland, Slovakia, schools in the Czech Republic). In Finland, the responsibility to measure radon indoor and to take a corrective action if needed is assigned to the owner, occupier and/or developer of a building. If the owner fails to take action, the municipal health protection authority may require taking necessary measures to identify, eliminate or limit the health risk and the factors leading to it. In Slovakia, the owner of a building in which the reference level of volumetric radon activity exceeds 300 Bq/ m3 in a calendar year, is obliged to make remedial actions within one year at the latest to ensure that the annual average radon concentration during the stay of the occupants does not exceed the RL. In the Czech Republic, subsidies for remedial actions are available and schools and kindergarten are compensated when radon concentration exceeds 300 Bq/m^3 during the stay of kids and students. The Ministry of Finance subsidises remediation at schools and kindergartens at a maximum of 60,000 € if other conditions are met.

Thirdly, another important way to support corrective action is to ensure an enabling environment for the construction industry in this area, both in terms of the legislative system and the knowledge base for effective corrective action, including training. Some countries focus on development and publication of effective technical corrective actions (e.g. Denmark, Belgium, Finland, Italy, Poland, Spain, Sweden), some issue and promote guidelines for remedial actions (Bulgaria, Greece, Portugal). The majority of EU MS organise training for

builders, designers, companies (Portugal, Romania), publish case studies (Romania) or encourage a close co-operation with the building sector.

Regarding the workplaces, there is a standard procedure for facilitating remedial actions in most of the EU MS and the UK. Firstly, the employer is required to take optimized corrective action to reduce radon concentration below the RL. If after implementation of the corrective action the concentration remains above the RL, the employer should follow the notification procedure. If the annual effective dose is <=6 mSv, the employer is responsible to follow procedures for monitoring employees and informing the regulator. In case the annual effective dose is above 6 mSv workers' exposure should be treated as planned exposure situation. In addition, the obligations of the employer to carry out measurement after implementing remedial measure is different among countries. For instance, in Croatia there is no obligation to measure after remedial actions. In the Czech Republic, the confirmation of radon concentration reduction is carried out as an annual measurement and dose calculation.

Re-testing and effectiveness evaluating after remedial action is important part of the remediation process. The support in this point is used in Belgium, Czech Republic, Ireland and Slovenia.

Guidelines for remediation

Guidelines for remedial actions need to be published in parallel to or even before the large radon measurement survey is carried out. It is important to provide solutions to the house owners if high radon levels are found. The majority of EU MS understand this necessity of preparing the guidelines. The rule is that national guidelines should be preferably matched to the prevailing national building and geology conditions. If guidelines exist in the country, some information on remediation is available online for free. Most of the countries are on the way of finishing the guidelines and making them known (mostly online). Only two countries (Latvia, Malta) indicated that such guidelines are not necessary, due to prevailing low radon concentrations. In Lithuania the responsible authorities reported that they will provide recommendations if necessary.

Accreditation /licensing

Accreditation of providers of remedial measures is not implemented in any of the EU MS, nor the UK. Ireland implements registration of radon contractors to promote quality and expertise in radon remediation services. To be registered, the contractor has to follow the registration scheme, part of which is successful participation in a radon remediation training course, tax compliance and public liability insurance. To maintain registration, the contractor has to report annually anonymised data in relation to the provision of radon remediation services to the EPA, Ireland. List of registered contractors is published on the EPA's website. Similar approach is implemented also in the Italian legal framework.

Greece, Hungary, Portugal and Romania are the countries planning to develop registers for providers of remediation services. Some countries, e.g. Austria, Belgium, publish a list of contractors on RAP related web pages based on successful participation in training courses (Austria) or based on the review of work conducted (Belgium).

The other countries decided not to implement any sort of registration, accreditation or licensing of remediation services. In some of these countries training courses on radon mitigation are available, e.g. in the UK or Finland.
Prevailing low interest of building sector in radon remediation was mentioned during EU-RAP regional and final workshops. Luxembourg reported that criteria for licensing of remediation services are established in the law, but no company was identified, therefore, the provision was taken out of the law. Companies received a certificate for participation in the training course organised in 2017 and the Directorate recommends companies which can undertake remediation works.

Remediation costs and financial support for remediation

Most countries provide some form of financial support for radon mitigation, such as tax deductions or covering part of the remediation costs incurred by citizens. In some countries, such support is not yet foreseen or will be considered once the radon priority areas have been defined.

Remediation costs vary largely among EU MS depending on interventions:

- from 500 € to more than 5,000 € for private dwellings (e.g. in the Czech Republic, the average cost for remediation per dwelling is 7,000-8,000 €, but it may vary depending on the remedial measures used).
- from 1,500 € to 60,000 € for public buildings (e.g. the maximum subsidy by the Ministry of Finance in the Czech Republic for schools is 60,000€[6]).

Financial support options, direct or indirect, for remediation are available in some EU MS. The indirect support may be related to specific criteria of eligibility for householders (e.g. support for remediation for people above 65 years old in Ireland with eligibility criteria not related to radon) or linked to other programmes (e.g. energy efficiency in Luxembourg). In Sweden, there is a tax deduction in case of remediation whereas in Finland, the government grants tax credit for all household expenses, including radon renovation work. The maximum credit is 2,250€ and the average remediation cost is 2,300€.

It has been discussed at the regional workshops as well as at the final workshop that most of the countries have problems finding radon remediation contractors. Representatives at the workshops identified the low profit as the main reason for the lack of motivation to provide remediation services, especially for private dwellings.

The empirical research conducted in Ireland in 2018 on the effectiveness of financial support in a high radon area in which free radon testing was offered in conjunction with a 50% grant toward necessary remedial work shows a very low uptake of grants from the citizens (EPA internal report). Free post-remediation testing service is available for those householders that have tested above the RL and remediated (about 70-100 people per year). Behavioural research trials to assess different communication approaches providing financial support to inform a

[6] This subsidy is provided only to schools, kindergartens and buildings used for the long-term residence of children and young people younger than 18 years old. The conditions for the application are the following: the RL is exceeded in the habitable rooms intended for the residence of children during the presence of children, the building permit for the building was issued before 28.2.1991 (first legislation in the Czech Republic protecting buildings from radon came in force), the future use of the building should be a school. The project and budget must be submitted with the application for the subsidy. It must be proved by measurement that the implemented remedial measure reduced the radon concentration during the presence of children below RL.

proposed national grant scheme is being undertaken at the moment of writing. This trial involves writing to approximately 3,000 people and the estimated response rate is from 700 - 1,500 people. At least 1,400 dosimeters will be distributed (30€/dosimeter approximately). Behavioural researchers have designed the communication to be tested and results will be available in 2023. The results of this work may help to inform the design of a national grant scheme.

Re-testing

The effectiveness of the installed corrective action should always be tested, otherwise it is not possible to ensure whether the remediation continues to be operating. Four EU MS reported they require re-testing after remedial measures. One of them (Czech Republic) requires re-testing only in case of subsidised remedial measures. Three countries provide re-testing for free. In Ireland, remediation contractors are required, as part of the registration scheme, to provide anonymised information on remedial actions conducted annually to the EPA. In addition, free radon measurements are provided to dwellings to test for radon following remediation work.

6. Reaching out: Communication and stakeholder engagement

Main conclusions related to communication and stakeholder engagement

Radon communication is usually led by the coordinator of the RAP or shared among multiple authorities. Communication strategies are not yet in place in all countries, but actions are ongoing and some countries have developed communication plans. The objective of current communication plans in most EU MS is awareness raising and education regarding radon, with only a minotiry of strategies focusing explicitly on behavioural change (e.g. how to test and how to remediate if necessary). Moreover, much communication is based on gut feeling, rather than being theory- or evidence-driven. Target groups for communication are often defined in general terms (e.g. general public, workers), although in some cases, specific target groups are identified and are the particular focus of communication action. Most RAPs define a wide range of communication channels (e.g. webpages, seminars, drop-in events, podcasts, videos, leaflets, information days, radio advertisements, phone numbers, notary, interviews, Do it Yourself stories, and paid advertisements), although in practice the diversity of channels used is rather limited. Most countries have not defined assessment criteria to evaluate communication actions but undertake evaluation in different ways. These could include opinion polls, measuring clicks on website or internet readings, the uptake of financial incentives or the number of training courses organised. Significant improvements in radon related communication interventions is expected to be achieved through the H2020 project RadoNorm. In general, it should be noted than there are limits to communication activities if the supporting environment (e.g. contractors, building codes, legal requirements etc.) are not available.

Radon communication is mostly coordinated by the RAP owner and in some cases the responsibility is shared among several authorities. Communication strategies are not yet developed in all countries. However, communication actions on radon are ongoing although not systematic nor planned. In cases where there is a communication strategy, annual communication plans are developed, ensuring certain flexibility to respond to societal needs

(e.g. Belgium issued media releases in order to warn for potential radon exposure due to working from home during covid-19 pandemic). In other countries, communication strategies and plans are also developed by regional or local authorities to address the local context and better target communication (e.g. Germany, Portugal, Sweden). In some countries, stakeholders (e.g. medical professionals in Austria, regional authorities in the Czech Republic or the University of Pannonia in Hungary) are involved in radon communication.

The objective of current communication plans in most EU MS is awareness raising and education regarding radon, with only a minority of strategies focusing explicitly on behavioural change (e.g. how to test and how to remediate in the case of Germany and Ireland). Moreover, much communication is based on gut feeling, rather than being theory- or evidence-driven. A few countries engaged communication experts to help authorities in preparing the communication strategy and investigated a baseline of existing knowledge, attitudes, views and behaviour related to radon mitigation in populations under radon risk, using a methodologically sound approach (i.e. clear and representative sampling, data collection, analysis and interpretation of data).

Target groups for communication are often defined in general terms (e.g. general public, workers), although in some cases, specific target groups are identified and are the particular focus of communication actions: e.g. Austria defines multipliers (e.g. medical personnel, building experts, etc) who can effectively pass on their knowledge to the population. In other countries the following target groups, among others, are explicitly identified: in Belgium trade unions; in Cyprus construction industry; in Estonia decision-makers at local level; in Hungary law-enforcers; in Lithuania engineers and builders; in Luxembourg new companies; in Portugal health professionals; in Slovakia civic associations; in the UK solicitors, purchasers, and law society.

Most RAPs define a wide range of communication channels, although in practice the diversity of channels used is rather limited. Within these channels, the use of webpages or sub-webpages dedicated to radon is frequent. In some cases, the use of communication channels is adapted to the different target audiences. A few examples of channels include:

- the use of cartoons for children in schools in Slovenia;
- radon seminars for local authorities in Estonia;
- local “drop-in events” where householders with high radon levels are invited to attend a session and obtain individual face-to-face advice about radon risks and remediation;
- letter drops by the radon industry in the UK;
- podcasts in Sweden;
- videos in Slovakia and Poland;
- leaflets for workers in Portugal;
- information days in Luxembourg;
- meetings with residents in Lithuania;
- radio advertisements on local stations in Ireland;
- dedicated radon phone number in some federal states of Germany;
- notary during house purchasing process in France through the transmission of a risk assessment document;
- interviews for specific magazines in Finland;
- “do it yourself” (DIY) stories in Denmark where real people explain their experience in buying and selling homes with radon, how to use radon detectors or how they have solved radon mitigation problems, among others;

- advertising banner at the on-line meteorological service in Denmark;
- paid advertisements on twitter in Belgium.

Most countries have not defined assessment criteria to evaluate communication actions but undertake evaluation in different ways. These could include opinion polls, measuring clicks on website or internet readings, the uptake of financial incentives or the number of training courses organised. Comparing the results of communication interventions, for example, through opinion polls, before and after the intervention, is barely considered.

General Data Protection Regulation (GDPR) remains a challenging issue in many countries (e.g. for sharing measurement data), particularly finding the balance between openness and transparency and personal data protection (e.g. how to present radon surveys on maps; which data can be collected and shared in databases; feedback information from measurements in dwellings and remediation). The solutions adopted by some countries include using an informed consent form for measurements, showing information on a specific administrative level (e.g. city or communal level) or having two different sets of databases with aggregated information on measurements, one for the public and another for authorities.

Social science methods from health communication, behavioural or social psychology or risk communication are barely considered when designing communication actions. However, some countries have considered implementing science-based communication interventions, as follows:

- Nudge actions are conducted in collaboration with libraries in Wexford county, Ireland;
- Collaboration is established with behavioural scientists in Ireland;
- Social scientists test the understanding of radon maps in Ireland;
- Research on risk communication and risk perception is ongoing in Germany;
- Citizen science projects are ongoing for measurements in Friuli, Italy and are also being developed in the context of the H2020 research project RadoNorm[7] (Martell et al., 2021);
- Methodologically sound public surveys are being developed in the context of H2020 research project RadoNorm in 15 EU MS (Perko et al., 2021).

A study supported by the Bundesamt für Strahlenschutz (German Federal Office for Radiation Protection) investigated whether targeted risk messages are an effective means for radon online risk communication. The results of the study do not show a statistical difference between groups exposed to different types of information. However, the study informed authorities that on-line communication is a complex and multidimensional process which has to be approached based on evidence (Dametto et al., 2023).

A significant improvement in communication related to radon is expected to be achieved through the H2020 project RadoNorm. The following points summarise main findings from the RadoNorm project related to the messages that authorities should communicate (Apers et al., 2023; Geysmans et al., 2022).

- how to remediate, where to get reliable contractors and how much remediation costs;
- actions to be taken after receiving results of measurements and the actual remediation works;

[7] Further information at: https://www.radonorm.eu

- the difference between passive and active dosimeters and how and when to use them;
- the importance of diagnostics;
- clear framing of health effects of radon and lung cancer given the controversies related to the formulation of radon as "*second leading cause of lung cancer*";
- where and how to apply for state incentives to remediate;
- how much energy per year is used for ventilation in the remediated house and the associated costs;
- countries with "radon spas" should take the controversy of radon "as a cure" and "as carcinogen" into account when communicating about radon.

Based on the RadoNorm results, authorities should also be attentive to the type of messages used in radon communication. The use of narratives (human stories) instead of informative content in information campaigns is more effective. Furthermore, the focus should be on social norms (e.g. remediation becomes desirable in your social network), self-efficacy (e.g. ability to find understandable information and useful resources to take actions) and moral norms (e.g. it is a moral responsibility to take care for the residents of a dwelling) instead of knowledge.
In general, it should be noted than there are limits to communication campaigns if the supporting environment (e.g. contractors, building codes, legal requirements etc.) are not available.

7. Education, training, research and development for implementation of RAPs

Main conclusions related to education, training, research and development

The implementation of RAPs requires continuous education, training, research and development of relevant stakeholders such as building professionals, measurement professionals, employers and employees, local and regional authorities, schools and health professionals, and the general public. Different education and training programmes are provided through builders' associations, universities, research centers, and government authorities. However, these education and training programmes are often not systematic neither regular. In some countries, radon education is included in the school curriculums, while in others it is included in professional or health training programmes. The International Atomic Energy Agency (IAEA) also provides training on radon through its Technical Cooperation projects. Several European countries collaborate in training and education projects in the framework of European funded projects, such as H2020 RadoNorm.

Whilst education, training and research and development are not specified in Annex XVIII of the Council Directive 2013/59/Euratom, educated and trained stakeholders are essential for the implementation of RAPs and this has been explored as part of this study. Relevant stakeholders for education and training include: building professionals and workers in the building industry, professionals who conduct measurements, employers and employees in potentially affected workplaces, local and regional authorities, schools, high schools, universities, health professionals and lay citizens.

Education and training for building professionals
Training courses, seminars or lectures for building professionals and workers in the building industry are or will be organised in most countries by or in collaboration with builders' associations, construction industry, research centres or universities. For these courses, training materials are often available online in the form of guidelines, instructions, booklets, videos or case studies. A certificate of attendance is usually provided and, in a few cases, an accreditation.

Education and training for measurement professionals
Few countries organise training courses targeted for professionals conducting measurement surveys or for inspection officials and even fewer training courses are organised which focus on radon remediation.

Education and training for employers and employees
In some countries, the authorities provide information to employers on how to analyse the risk of radon, how to measure radon and how to remediate in case the levels are too high. In Slovenia, for example, an accredited training programme is organised for exposed workers (e.g. tourist guides in caves).

Education and training for authorities
In several countries, responsible authorities also organise online or in-person training events for local administrations or annual workshops for regional administrations.

Radon in school curriculums
Radon is not systematically included in schools or high education institutions but depends on the interest of the teacher, the school or the faculty. Radon could be included in natural sciences courses (e.g. physics, civil engineering, geology) or architecture. Radon specific workshops or information days are organised at schools in an ad hoc manner. It is worth mentioning a few examples where radon has been the focus of training materials. For instance, Slovenian authorities prepare and send a flyer devoted to radon in the form of a cartoon, to pupils of primary and secondary schools. In Poland, the content of lectures on radon are prepared by Nofer Institute of Occupation Medicine for primary, and secondary schools as well as medical and technical universities and some selected fields of study. In Denmark, a Radon Renovation course is offered at Aalborg University and is open to consultants, executors, building material suppliers, professional building owners, measurement companies, etc. to measure radon, plan and carry out renovations of buildings.

Education and training for health professionals
Health professionals might also be the target group for training courses on health, radon and the environment. For instance, in Finland, the safety authority STUK organises a yearly lecture on indoor radon for future local health protection authority workers. Training is also organised by an organisation on tuberculosis and pulmonary diseases for health care professionals in tobacco cessation skills. In Ireland radon is a topic in a series of a e-learning modules on cancer reduction behaviour for health and social care professionals.

Education of general public and citizen science
Information material on radon is available for the general public. In Ireland and Italy, citizen science initiatives have been launched on radon. In addition, the European research project

RadoNorm has also launched pilot citizen science initiatives in four countries – France, Hungary, Ireland and Norway.[8]

Education and training through IAEA technical cooperation projects

The IAEA has an important role in providing training on radon through technical cooperation projects. Several countries participated at the IAEA regional project "development and implementation of national programmes for the control of radon exposure of the population" (e.g. Bulgaria, Cyprus, Estonia, Malta) or had expert missions (e.g. radon at workplaces in Romania). Some countries indicated that support from IAEA is essential to organise workshops, like "training the trainers" (e.g. in Croatia, Malta), develop reports (e.g. Malta) or develop e-learning materials (e.g. Slovakia).

Other education and training programmes and research projects

The collaboration among European countries and the support from the European Commission is also considered essential in the field of training and education in radon. The LIFE project "learning radon: professional qualification and social awareness as a strategy for reducing radon exposure" (2022-2025) is an example of the collaboration between the Portuguese Environment Agency (APA), the National Laboratory of Civil Engineering at the University of Coimbra in Portugal and the University of Cantabria in Spain. The objectives are two-fold: a) to develop a procedure to recognize professionals and/or entities as building remediation service providers and b) to define training courses needed and the targeted audiences.

The H2020 RadoNorm project: *Managing risk from radon and NORM exposure situations to assure effective radiation protection based on improved scientific evidence and social considerations*, which started in September 2020 will be finished in August 2025, offers training courses. A dedicated Education & Training work package in the RadoNorm project aims to organise the education and training program focusing on Ph.D. students and early career researchers and also authorities and other experts in the field of radon risk management. For instance in 2021 five courses were held: "Interdisciplinary radiation research on radon" organised by BfS (Germany), "The art of public opinion survey analysis: surveying the public on Radon and Norm" organised by the University of Antwerp and SCK-CEN (Belgium), "Naturally occurring radionuclides in work and natural environment – establishing the problem definition, finding sources and exposure assessment" organised by GIG (Poland), "NORM impact assessment toolkit: from microorganisms to human cells" organised by the University of Aveiro and University of Porto (Portugal) and "Cellular effects of high and low LET ionising radiation – introduction to radiation biology" organised by Stockholm University (Sweden). (Kulka U. et al., 2022).

Research and development needs are included as chapters in the RAPs in two EU MS (Estonia and Slovenia).

Main recommendations related to education and training were also collected at the regional and the final workshops included:

- Systematically collect existing education and activities or develop an education and training inventory per country and at European level;
- Promote international collaboration on harmonised education and training programmes in EU MS;

[8] See www.radonorm.eu for further information.

- Offer education and training accredited courses for remediators;
- Collect and make available online training materials on radon;
- Support citizen science projects on radon;
- Develop European training courses for all aspects of radon management with the support of the European Commission;
- Search for IAEA support to develop training courses on radon prevention and remediation for constructors and building professionals.

References

Apers, S.; Vandebosch, H. and Perko, T. (2023) Clearing the air: A systematic review of mass media campaigns to increase indoor radon testing and remediation. Communications, 2023. https://doi.org/10.1515/commun-2021-0141

Bochicchio, F.; Fenton, D.; Fonseca, H.; García-Talavera, M.; Jaunet, P.; Long, S.; Olsen, B.; Mrdakovic Popic, J.; Ringer, W. National Radon Action Plans in Europe and Need of Effectiveness Indicators: An Overview of HERCA Activities. *Int. J. Environ. Res. Public Health* 2022, *19*, 4114. https://doi.org/10.3390/ijerph19074114

Diego Dametto, Britta Oertel, Christiane Pölzl-Viol & Christoph Böhmert (2023) Is targeting the solution? Evidence from an experiment on radon risk communication, Journal of Risk Research, doi: 10.1080/13669877.2023.2176913

EURATOM. 2013. Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. http://data.europa.eu/eli/dir/2013/59/oj.

Geysmans, R.; Perko, T.; Keser, M.; Pölzl-Viol, C.; Fojtíková, I.; Mihók, P. (2022) Cure or Carcinogen? A Framing Analysis of European Radon Spa Websites. International Journal of Public Health 2022 (67): 1604559. doi: 10.3389/ijph.2022.1604559.

HERCA (2023): Workshop on National Radon Action Plans; Proceedings from the HERCA workshop, 21-23 June 2022, Lisbon, Portugal

Kulka, U.; Birschwilks, M.; Fevrier, L.; Madas, B.; Salomaa, S.; Froňka,A.; Perko, T.; Wojcik, A. and Železnik, N. (2022) RadoNorm – towards effective radiation protection based on improved scientific evidence and social considerations – focus on RADON and NORM, EPJ Nuclear Sci. Technol. 8, 38, Published by EDP Sciences. https://doi.org/10.1051/epjn/2022031

Martell, M.; Perko, T.; Tomkiv, Y.; Long, S.; Dowdall, A.; Kenens, J. (2021) Evaluation of citizen science contributions to radon research. Journal of Environmental Radioactivity, 237. https://doi.org/10.1016/j.jenvrad.2021.106685

Monahan, E.; Murphy, P.; Long, S.; Dowdall, A. (2022) The effectiveness of passive sumps and static cowls in reducing radon levels in new build Irish dwellings. Journal of Environmental Radioactivity (248) 106866, https://doi.org/10.1016/j.jenvrad.2022.106866.

Perko, T.; Turcanu, C.; Hoti, F.; Thijssen, P.; Muric, M. (2021) RadoNorm pilot study report from public opinion survey, Belgium 2020-2021. Development of a modular questionnaire for investigating societal aspects of radon and NORM. Available at www.radonorm.eu.

Smetsers, R.C.G.M. (Ronald); Blaauboer, R.O. (Roelf); Dekkers, S.A.J. (Fieke) (2016) Ingredients for a Dutch radon action plan, based on a national survey in more than 2500 dwellings. Journal of Environmental Radioactivity 165, 93-102. https://doi.org/10.1016/j.jenvrad.2016.09.008.

Annex 1: Guiding questions for the national RAPs analysis

(1) Strategy for conducting surveys

… of indoor radon concentrations or soil gas concentrations for the purpose of estimating the distribution of indoor radon concentrations, for the management of measurement data and for the establishment of other relevant parameters (such as soil and rock types, permeability and radium-226 content of rock or soil). Annex XVIII (1)
Additional document used for guiding questions: IAEA (2019) Design and Conduct of Indoor Radon Surveys, Safety Report Series No 98; IAEA (2018) Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation, Safety Standard Series No SSG-32; IAEA Flowchart for the Development of a National Radon Action Plan https://www.iaea.org/sites/default/files/18/03/final-radon.pdf

Strategy

Does the RAP define or include information regarding:

- the strategy for conducting surveys of indoor radon concentration for the purpose of estimating distribution of indoor radon concentration?
- the strategy for conducting surveys of soil gas concentration for the purpose of estimating distribution of indoor radon concentration?
- the strategy for management of measurement data?
- the strategy for establishment of other relevant parameters allowing to estimate distribution of indoor radon concentration?

Implementation

Has the EU MS (or the UK) implemented:

- a representative survey of indoor radon concentration?
- surveys of indoor radon concentration (local/national)?
- surveys of soil gas measurement?
- surveys of other parameters relevant to radon indoors measurement?
- measured data management (national radon database)?
- or considered any indicators to measure the effectiveness of this element?

(2) Approach, data and criteria used for the delineation of areas

… or for the definition of other parameters that can be used as specific indicators of situations with potentially high exposure to radon. data and for the establishment of other relevant parameters (such as soil and rock types, permeability and radium-226 content of rock or soil). Annex XVIII (2)
Additional document used for guiding questions: Council Directive 2013/59/EURATOM, article 54, 103(3)

Strategy

Does the RAP define or include information regarding:

- the approach used for delineation of areas with potentially high exposure to radon?
- the data used for the delineation of areas with potentially high exposure to radon?
- the criteria used for the delineation of areas with potentially high exposure to radon?
- the approach used for the definition of other parameters (others than delineation the radon prone areas) used as specific indicators of situations with potentially high exposure?
- the data used for the definition of other parameters (others than delineation the radon prone areas) used as specific indicators of situations with potentially high exposure?

- the criteria used for the definition of other parameters (others than delineation the radon prone areas) used as specific indicators of situations with potentially high exposure?

Implementation
Has the EU MS (or the UK) implemented in practice:
- the existence of areas with potentially high exposure to radon in the country?
- the special regime on these areas?
- or considered any indicators to measure the effectiveness of this element?

(3) Identification of types of workplaces and buildings with public access

… such as schools, underground workplaces, and those in certain areas, where measurements are required, on the basis of a risk assessment, considering for instance occupancy hours. Annex XVIII (3)
Additional document used for guiding questions: Council Directive 2013/59/EURATOM, article 54; IAEA (2018) Occupational Radiation Protection, General Safety Guide GSG-7
Strategy
Does the RAP define or include information regarding:
- the identification of types of workplaces where radon measurements are required?
- the identification of buildings with public access where radon measurements are required?
- the identification of schools where radon measurements are required?

Implementation
Has the EU MS (or the UK) implemented:
- recommendations of / requirements for workplaces measurements?
- recommendations of / requirements for buildings with public access (except schools) measurements?
- recommendations of / requirements for schools' measurements?
- a definition of or specific classification for underground workplace?
- any actions after identifying high levels of radon at workplace (before or after remediation)?
- or considered the need for specific arrangements or advice to assess the radon risk to those working from home? If yes, can you provide a link to the where the advice is published or communicated? times?
- or considered any indicators to measure the effectiveness of this element?

(4) Reference levels for dwellings and workplaces

… The basis for the establishment of reference levels for dwellings and workplaces. If applicable, the basis for the establishment of different reference levels for different uses of buildings (dwellings, buildings with public access, workplaces) as well as for existing and for new buildings. (4)
Additional document used for guiding questions: Council Directive 2013/59/EURATOM, article 74 and 54; World Health Organisation (WHO) handbook on indoor radon: a public health perspective (2009)
Strategy
Does the RAP define or include information regarding:
- the basis for the establishment of reference levels for dwellings and/or workplaces (incl. buildings with public access)?

- the basis for the establishment of supporting types of levels, e.g. target level, action level, limit, …? And how are these defined?

Implementation
Has the EU MS (or the UK) implemented:
- the national reference level for dwellings?
- the national reference level for workplaces?
- the national reference level for buildings with public access?
- the national reference level for existing/new dwellings?
- the supporting types of levels, e.g. target level, action level, limit, etc?
- specific arrangements for low occupancy workplaces?
- any evaluation or modification of the reference levels?
- or plan to implement the new International Commission on Radiological Protection (ICRP) dose conversion factors?
- or considered any indicators to measure the effectiveness of reference levels?

(5) Assignment of responsibilities

… (governmental and non-governmental), coordination mechanisms and available resources for implementation of the action plan. Annex XVIII (5)
This element is reported in deliverable 1.1 (2021) which was sent to all responsible authorities in the 27 MS and the UK. Deliverable 1.1 was submitted to EC on 2021-11-04.
Additional document used for guiding questions: European Union (2020) PM^2 project management methodology. Available at: https://europa.eu/pm2/ and https://ec.europa.eu/isa2/solutions/open-pm2_en
The following questions are investigated for the strategy development and the implementation phases.
Strategy
Does the RAP define or include information regarding:
- Owner of the strategy (acts as the sponsor, chairs the steering committee, accepts the objectives, mobilise resources, provides leadership and strategic direction, monitors progress regularly)?
- Mechanisms for collaboration (working groups, commissions, etc) among different organisations, authorities, etc for the development of the strategy?
- If so, which organisations or authorities are part of this mechanism?

Implementation
Has the EU MS (or the UK) implemented:
- Mechanisms for collaboration (working groups, commissions, interministerial committees, specific agreement, etc) among different organisations, authorities, etc for the follow-up or implementation of the strategy?
- If so, which organisations or authorities are part of this mechanism?
- How are the roles and responsibilities of the different organisations involved in the implementation of the strategy defined?
- Human or technical resources for the implementation of the action plan[9]?

[9] Financial resources are considered under the "financial support" section.

(6) Strategy for reducing radon exposure

… in dwellings and for giving priority to addressing the situations identified under point 2. Annex XVIII (6)

Additional document used for guiding questions: Council Directive 2013/59/EURATOM, article 74 (2); IAEA (2018) Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation, Safety Standard Series No SSG-32; IAEA Flowchart for the Development of a National Radon Action Plan https://www.iaea.org/sites/default/files/18/03/final-radon.pdf

Strategy

Does the RAP define or include information regarding:

- a strategy for reducing radon exposure in dwellings?
- a strategy for giving priority to addressing the situations identified under point 2 (i.e. areas and/or situation with potentially high exposure to radon)?

Implementation

Has the EU MS (or the UK) implemented:

- actions related to radon priority areas being realised?
- requirements on mitigations defined on radon priority areas?
- requirements on preventive measures defined on radon priority areas?
- actions related to radon priority areas being realised?
- or considered any indicators to measure the effectiveness of reducing radon exposure?

(7) Post construction remedial action

… Strategy for facilitating post construction remedial action. Annex XVIII (7)

Additional document used for guiding questions: Council Directive 2013/59/EURATOM, article 74; WHO (2018) Handbook on indoor radon: a public health perspective; IAEA (2018) Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation, Safety Standard Series No SSG-32; IAEA Flowchart for the Development of a National Radon Action Plan https://www.iaea.org/sites/default/files/18/03/final-radon.pdf

Strategy

Does the RAP define or include information regarding:

- a strategy for post construction remedial action execution?
- planned procedures facilitating remedial actions in existing buildings?

Implementation

Has the EU MS (or the UK) implemented:

- existing policy/policies for facilitating post construction remedial action?
- existing methods and tools (e.g. building code) for facilitating post construction remedial action?
- or considered any indicators to measure the effectiveness of this element?

(8) New buildings & building material

… Strategy, including methods and tools, for preventing radon ingress in new buildings, including identification of building materials with significant radon exhalation. Annex XVIII (8)

Additional document used for guiding questions: Council Directive 2013/59/EURATOM, article 103 (2); IAEA (2018) Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation, Safety Standard Series No SSG-32; IAEA Flowchart

for the Development of a National Radon Action Plan https://www.iaea.org/sites/default/files/18/03/final-radon.pdf

Strategy

Does the RAP define or include information regarding:

- a strategy for preventing radon ingress into new buildings?
- methods and tools for preventing radon ingress into new buildings?
- information about building material with significant radon exhalation (e.g. identification, dealing with)?

Implementation

Has the EU MS (or the UK) implemented:

- existing procedures/legislation for preventing radon ingress into new buildings?
- existing methods and tools (e.g. building code) for preventing radon ingress into new buildings?
- existing methods and tools for dealing with building material with significant radon exhalation?
- any measurements in new buildings? Any measurements when change of ownership of a building?
- any measure to assign responsibility in case of potential problems due to radon in new buildings?
- or considered any indicators to measure the effectiveness of this element?

(9) Reviews of the action plan

… Schedules for reviews of the action plan. Annex XVIII (9)

Additional document used for guiding questions: Axelos (2017) Managing successful project with PRINCE2

Strategy

Does the RAP define or include information regarding:

- Schedules/frequency of the review of the RAP?
- Criteria to be met on how the plan is reviewed (e.g. cost, time scales, quality, scope, benefits, risks)?
- Who is/are the reviewer/s of RAP?

Implementation

Has the EU MS (or the UK) implemented a review of the action plan and if so:

- When it was undertaken?
- Criteria used for the review (e.g. cost, time scales, quality, scope, benefits, risks)?
- Review results?
- Who was/were the reviewer/s?

(10) Strategy for communication and stakeholder engagement

… to increase public awareness and inform local decision makers, employers and employees of the risks of radon, including in relation to smoking. Annex XVIII (10)

Communication and engagement questions relate to the requirement in Article 102 of BSS which states: "*Member States shall provide as appropriate for the involvement of stakeholders in decisions regarding the development and implementation of strategies managing exposure situations*".

Additional document used for guiding questions is: European Commission; "*Communication EU research and innovation guidance for project participants*" (2014) available from (last accessed May 2021)

https://ec.europa.eu/research/participants/data/ref/h2020/other/gm/h2020-guide-comm_en.pdf

The General Data Protection Regulation (EU) 2016/679 (GDPR) is a regulation in EU law on data protection and privacy in the European Union (EU) and the European Economic Area (EEA).

Strategy

Does the RAP define or include information regarding:

- communication goals and specific and measurable objectives to increase public awareness and inform of the risks of radon?
- relevant target groups (local decision makers, employers and employees among others)?
- messages related to the risks of radon, including in relation to smoking?
- different channels, means and events to communicate (one-way, like press releases, websites, manuals, newsletters, etc or two-way, like group discussions, meetings, workshops, conferences, etc)?
- ways of measuring communication efforts and impact (indicators such as number of articles in the press, number of people asking for more information, website visits, increased knowledge, behavioural change, etc)?
- resources to be allocated (timeline, professional communicators involved and funding) to communication?
- involvement of stakeholders in decisions regarding the development of the RAP?
- GDPR issues

Implementation

How has the EU MS (or the UK) implemented the above in practice? This is:

- communication goals and specific and measurable objectives previously defined to increase public awareness and inform of the risks of radon?
- relevant target groups (local decision makers, employers and employees among others) addressed in communication activities?
- messages used related to the risks of radon, including in relation to smoking?
- different channels, means and activities that have been used or are used to communicate (one-way, like press releases, dedicated radon websites, manuals, newsletters, etc or two-way, like group discussions, meetings, workshops, conferences, etc)?
- ways of measuring communication efforts and impact (public opinion surveys, indicators such as number of articles in the press, number of people asking for more information, website visits, etc)?
- resources allocated (timeline, professional communicators involved and funding) to communication?
- involvement of stakeholders in decisions regarding the implementation of the RAP?
- collaboration with professional communicators (e.g. marketing companies) to increase awareness?
- GDPR issues

(11) Methods and tools for measurements and remedial measures

… Guidance on methods and tools for measurements and remedial measures. Criteria for the accreditation of measurement and remediation services shall also be considered. Annex XVIII (11)

Additional document used for guiding questions: IAEA (2018) Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation, Safety Standard Series

No SSG-32; WHO (2018) Handbook on indoor radon: a public health perspective; IAEA Flowchart for the Development of a National Radon Action Plan https://www.iaea.org/sites/default/files/18/03/final-radon.pdf

Strategy

Does the RAP include information on:

- guidance on methods and tools for measurement of (indoor) radon?
- guidance on methods and tools for remedial measures?
- criteria for accreditation[10]/licensing of measurement services?
- criteria for accreditation/licensing of remediation services?

Implementation

Does the EU MS (or the UK) have an:

- existing measurement protocol for radon measurement in dwellings?
- existing measurement protocol for radon measurement at workplaces?
- existing measurement protocol for assessment of radon concentration in water?
- existing measurement protocol for mass activity concentration of natural radionuclides in building material?
- existing measurement protocol for radon exhalation from building material?
- existing accreditation/licensing system of measurement services?
- existing accreditation/licensing system of remedial services?
- Does the EU MS (or the UK) consider new protocols or accreditations?

(12) Financial support

… for radon surveys and for remedial measures, in particular for private dwellings with very high radon concentrations. Annex XVIII, (12)

Additional document used for guiding questions: European Commission; *"Financial guidelines for applicants"(2017*).

Strategy

Does the RAP include information on:

- Estimated budget allocated (total and %) to conduct radon surveys? If so, are there eligibility criteria?
- Are private dwellings with very high radon concentrations mentioned specifically?
- Estimated budget allocated (total and %) to remedial actions? If so, are there eligibility criteria?
- Are private dwellings with very high radon concentrations mentioned specifically?

Implementation

- How is the financial burden shared among stakeholders?
- How is the financial burden divided into public and private buildings?
- What are the average remediation costs for standard dwellings?
- What are the average remediation costs for standard large buildings?

(13) Long-term goals in terms of reducing lung cancer risk

… attributable to radon exposure (for smokers and non- smokers). Annex XVIII (13)

[10] Accreditation is defined here as the official approval given by an organisation stating that somebody/something has achieved a required standard. We point out in this study the broader meaning of accreditation beyond meeting the requirements of ISO/IEC 17025.

Additional document used for guiding questions: European Commission (2021) Europe's Beating Cancer Plan (Action 17)

Strategy

Does the RAP define or include information regarding:

- the reduction of lung cancer expected?
- the number of dwellings where radon exposure will be reduced?

Implementation

Does the EU MS (or the UK) monitor the reduction of lung cancer?

Does the EU MS (or the UK) evaluate the number of dwellings where radon exposure has been reduced?

(14) Other related issues and corresponding programmes

… Where appropriate, consideration of other related issues and corresponding programmes such as programmes on energy saving and indoor air quality. Annex XVIII (14)

Additional document used for guiding questions: European Commission (2021) Europe's Beating Cancer Plan (Action 17)

Strategy

To what extent does the RAP define or include information regarding links planned with:

- Energy saving programmes or issues?
- Indoor air quality?
- Cancer programme?
- Anti-smoking programme?
- Lung cancer screening?

Implementation

How is the connection to the following programmes or issues implemented (e.g. actions, campaigns, activities, etc):

- Energy saving programmes or issues?
- Indoor air quality?
- Cancer programme?
- Anti-smoking programme?
- Lung cancer screening?

(15) Education & training programmes

Additional document used for guiding questions: consultation with EUTERP Foundation[11] Board members

Strategy

Does the RAP plan future activities/work/approaches regarding:

- Training courses or training plans for professionals and workers in the construction industry (e.g. engineers, architects, those workers executing the building work, etc)?
- Training courses or training plans for professionals who carry out radon measurements?
- Training courses for workers in potentially affected workplaces?
- Training courses or training plans for those with responsibility for radon (e.g. competent authorities, local authorities)?
- The inclusion of radon in schools?
- The inclusion of radon in relevant degree programmes at higher education institutions?

[11] EUTERP: Training and Education in Radiation Protection (http://euterp.eu/index.asp)

- Accreditation of radon courses?
- Training materials or training tools and applications on radon?

Implementation

How has the EU MS (or the UK) implemented:

- Training courses or training plans for professionals and workers in the construction industry (e.g. engineers, architects, those workers executing the building work, etc)?
- Training courses for workers in potentially affected workplaces?
- Training courses or training plans for professionals who carry out radon measurements?
- Training courses or training plans for those with responsibility for radon (e.g. competent authorities, local authorities)?
- The inclusion of radon in schools or higher education institutions as part of the curricula?
- Accreditation of radon courses?
- Training materials or training tools and applications on radon?

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