16ENV10 MetroRADON

Deliverable D9

Evidence of contributions to the European Council Directive on Radiation Protection 2013/59/EURATOM (EU BSS) and to new or improved international standards and recommendations and examples of early uptake of project outputs by end-users

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Due date: May 2020
Submission: November 2020

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

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Abstract

This document reports contributions to the legislative implementation process of the European Radiation Protection Directive (EU BSS) into national legislation and to new or improved international technical standards and recommendations with a specific focus on ISO/TC85/SC2, CENELEC/TC45, IEC/TC45, IAEA Nuclear Data, CEN/TC351/WG3, CCRI and EURAMET TC-IR.

Additionally, examples of early uptake of project outputs by stakeholders, organisations, regulators, authorities and end users are given.

This report documents deliverable D9 concluding in particular the results of activities A6.1.3, A6.1.6, A6.1.7, A6.1.8 and A6.1.9 of the MetroRADON JRP.

1 Introduction

1.1 Contribution to the implementation of the European Council Directive on Radiation Protection 2013/59/EURATOM (EU-BSS)

The results of this joint research contribute effectively to improving the decisions about defining radon priority areas, as required by the EU-BSS, Art. 103 'Radon action plan'. These are, largely, political decisions given their economical and possibly political impact (cf. requirements in Art. 54 of action related to workplaces in radon priority areas). However, decisions are guided by scientific reasoning, to which this project contributes. Most partners of this JRP are involved in the decision making process on a scientific level; therefore, direct interaction between the project and ongoing discussions about implementation of the EU-BSS significant contributions have been made during the project and will be made in future. The generation of a Radon Hazard Index and the development of new calibration procedures and reference sources help national regulators and radiation protection authorities in identifying radon priority areas for their national radon action plans according to the requirements of the EU-BSS. The European Commission will profit from the harmonization steps taken in this project that will ensure comparability across Europe.

1.2 Contribution to public health

Radon is estimated to cause between 3 % and 14 % of all lung cancer cases, depending on the average radon level in the country (WHO, Fact sheet N°291, 2014). For Europe, this corresponds to about 15 000 to 20 000 people per year dying of lung cancer caused by radon progeny exposure. The output of this project improves the radiation protection and public health due to reliable radon measurements. This will provide a basis for effective radon mitigation and prevention against radon progeny induced lung cancer in Europe. A significant improvement in radiological protection reducing the radon exposure of thousands of Europeans every year has a tremendous social and sociological impact. Providing reliable, traceable measurements and calibrations for radon, especially at low activity concentrations, strengthen the confidence of the public with regard to radiation protection of citizens. Where necessary, measures can be taken to ensure radiation safety, which will in turn reduce the risk for radon induced lung cancer.

1.3 Contribution to the environment

The development of Radon Hazard Index maps that identify and visualize radon priority areas help authorities with zoning, spatial and infrastructure planning, therefore reducing the risk of lung cancer in the population and overall public health.

Precautionary measures can be taken in planning and construction of housing development and construction of new buildings, reducing the number of refurbishments of buildings and infrastructure as well as saving building materials and reducing waste.

According to the EU Drinking Water Directive Council Directive 2015/1787 of 6 October 2015 amending Annexes II and III to Council Directive 98/83/EC on the quality of water intended for human consumption, knowledge of radon prone areas will help with planning safe drinking water treatment and production plants.

1.4 Economic contribution

The implementation of the Council Directive 2013/59/EURATOM (EU-BSS), as far as the protection against the risks of radon inhalation is concerned, entails Europe-wide costs in the order of at least € 1 bn, depending on the envisaged reference levels for indoor radon. Some fraction of the existing houses in Europe will need to be sanitized, with associated costs in the order of € 10 000 per house. Economically effective approaches facilitates by reliable radon measurements and mapping, with the potential to save hundreds of millions of Euros.

Based on the methods developed in the project, areas and buildings, which are (potentially or actually) affected by radon, can be more precisely identified and hence the cost of precautions and building measures minimized.

Healthcare costs will decrease, if counteractive measures against radon are properly implemented. The average cost of treatment of one lung cancer patient is about € 50 000, and the five years survival rate following the therapy is very low: 21 % female and 15 % male. Much more important than to save treatment costs, is therefore to prevent lung cancer itself and hence to save lives.

Technical problems with unexpected high indoor radon levels with associated high follow-up costs can be significantly reduced, because precautions against radon in buildings are much more effective and cheaper if they are implemented at an early stage of building activities, e.g. at construction of the building.

The competitiveness of the European building industry and measurement instrumentation manufacturers will be supported, because the implementation of the EU-BSS requires the application and validation of measurement and calibration methods to establish radon-safe buildings. The development of such methods and instruments means a competitive advantage. To verify these methods, reliable calibrations of measurement instruments and measurements of radon concentrations in houses and dwellings are supported by this JRP by the establishment of newly accredited calibration and testing laboratories.

1.5 Contribution to international research and development

An interlaboratory comparison of activity per unit volume of ^{222}Rn was organized within the framework of this JRP under the auspices of EURAMET. Samples were made available to the participants by LNE-LNHB.

The reference measurement method is defined solid angle alpha counting (DSA) with a frozen disc source of ^{222}Rn which is a primary measurement method. This method was used by two laboratories. Other methods such as comparison by a scintillation cell with ^{222}Rn extracted from standard ^{226}Ra solution or comparison by a scintillation cell with ^{222}Rn in glass ampoules previously measured with a NaI(Tl) detector, were used by other participants. Another laboratory used the liquid scintillation counting method.

All results are consistent, within the uncertainties. No outliers were identified by the Grubbs test.

It is anticipated that international organizations such as IAEA and WHO will integrate the results and outcomes of the project on radon metrology, traceability of radon calibration, and defining radon priority areas into their Safety Guides and Radon Handbook, respectively.

Additionally, knowledge gathered within project can be used and transferred to the future research and development work related to metrology and quality assurance of thoron (^{220}Rn) measurements.

2 Interested and registered stakeholders and collaborators, industrial companies and end-users

2.1 Collaborators and stakeholders

The JRP consortium made a compilation of relevant stakeholders and collaborators and assigned adequate and appropriate channels of information (email newsletter, JRP homepage and Researchgate) to each stakeholder and group of stakeholders. AGES with the help of the WP leaders has monitored and updated the

stakeholder involvement plan at 6 monthly intervals. 28 registered stakeholders from industry, universities and organizations, and 9 collaborators have been affiliated to the JRP (Tab. 2.1).

These registered industry stakeholders and in total about 260 additional stakeholders and newsletter recipients from industry, national authorities, research institutes and associations have received six newsletters reporting the work done and progress within the project. This action creates a huge impact and stimulates effectively the networking of MetroRADON within the radon community.

Most of these parties are continuously working in standardization organisations and at European and national radiation protection regulators. Therefore, they are contributing effectively to the EU BSS implementation into national legislation and to new or improved technical standards and recommendations.

Tab. 2.1. Registered MetroRADON stakeholders and collaborators

Collaborator or stakeholder	Type of organisation	Organisation	Location
stakeholder	Industry - SME	Airthings AS	Norway
stakeholder	Industry - SME	Eurofins Radonlab	Norway
stakeholder	Industry - SME	GT-Analytic SARL	France
stakeholder	Industry - SME	SARAD GmbH	Germany
stakeholder	Industry - SME	Nofer Institute of Occupational Medicine in Lodz	Poland
stakeholder	Industry - SME	Pylon Electronics Inc.	Canada
stakeholder	Industry - SME	Radonanalys GJAB	Sweden
stakeholder	Industry - SME	DURRIDGE UK Ltd.	United Kingdom
stakeholder	Industry - SME	RADON, v.o.s.	Czech Republic
stakeholder	Industry - SME	CANBERRA PACKARD S.R.L.	Romania
stakeholder	Industry - SME	Algade (LED-DU Laboratory ans DOSIRAD Laboratory)	France
stakeholder	Industry - SME	Radon Check Zuzanna Podgórska	Poland
stakeholder	Industry - SME	U-Series Srl	Italy
stakeholder	Industry - SME	Radosys Atlantic, Ida	Portugal
stakeholder	Industry - SME	RadoSys Ltd.	Hungary
stakeholder	Industry - SME	Instytut Chemii i Techniki Jądrowej (Institute of Nuclear Chemistry and Technology)	Poland
stakeholder	Industry - SME	RadiÖko Ltd	Hungary
stakeholder	Industry - SME	Social Organization for Radioecological Cleanliness	Hungary
stakeholder	Industry - SME	Mi.am srl	Italy
stakeholder	Industry - SME	Studio Lanfranco Cicala	Italy
stakeholder	Industry - SME	Scientific & Technical Centre "Amplituda", LLC	Russian Federation
stakeholder	Industry - SME	ÜHINENUD EKSPERDID	Estonia
stakeholder	Industry - SME	Extratech	Italy
stakeholder	Industry – SME	GIHMM GmbH	Austria
stakeholder	Industry - SME	Radonova Laboratories AB	Sweden
stakeholder	University /academic org.	Institute of Nuclear Physics PAN Laboratory of Radiometric Expertise	Poland
stakeholder	University /academic org.	LabExpoRad, UNIMedical - University of Beira Interior	Portugal
stakeholder	Other	QST/NIRS	Japan

collaborator	University /academic organisation	University of Novi Sad	Serbia
collaborator	University /academic organisation	Universidade de Coimbra	Portugal
collaborator	Industry - SME	Radonova Laboratories AB	Sweden
collaborator	Public research organisation	DiMEILA Centro Ricerche INAIL	Italy
collaborator	University /academic organisation	University of Babes-Bolyai	Romania
collaborator	Other	EURADOS (European Radiation Dosimetry Group)	Europe
collaborator	Public research organisation	National Center for Radiation Protection and Computational Physics – Istituto Superiore di Sanità	Italy
collaborator	University /academic organisation	Universitat Politècnica de Catalunya	Spain
collaborator	Other	LIFE-Respire Consortium	International

2.2 Industry Interest Group

All partners had formed an Industry Interest Group (IIG) consisting of 28 relevant companies manufacturing radon monitors and/or measuring radon concentration (Tab. 2.2). This group had been formed by the end of the first year.

The aim of the group was to keep the industry informed on developments in the project, in particular concerning calibration and validation procedures and measurement methods and to obtain feedback. The shared information has been included for example the novel calibration method for the traceable calibration of radon (^{222}Rn) measurement instruments at low activity concentrations (100 Bq/m^3 to 300 Bq/m^3) with relative uncertainties ≤ 5 % and technical concepts and solutions to reduce thoron-related bias to the radon signal in radon monitors.

An online discussion forum was set up for the Industry Interest Group (IIG) to share results and stimulate communication with and among the IIG. An IIG meeting was held in Brunswick in June 2019 with about 20 participants. In October 2020 two information and training workshops for interested industrial parties had been carried out online: 'New Procedures for Radon Monitoring' (44 participants) and 'Training seminar on new procedures, guidelines and methodologies for radon instrument calibration and measurements' (74 participants). Five members of the IIG participated as industrial exhibitors at the European Radon Week 2020, organized by AGES and BEV in Vienna, February 2020 (see Chapter 3.2).

Some of these group members are working in standardization organisations. Therefore, they are contributing to the practical implementation of the EU BSS and to new or improved standards.

Tab. 2.2. Registered MetroRADON Industry Interest Group members

Company name	Country of the principle office	Contact person/address	role
Airthings AS	Norway	Björn Magne Sundal Wergelandsveien 7 N-0162 Oslo	Industry
Eurofins Radonlab	Norway	Dr. Alexandar Birovljev Eurofins Radonlab AS Gaustadalleen 23 D, 0373 Oslo	Industry
GT-Analytic SARL	France	Jochen Gschnaller 30 rue Grande F-13410 Lambesc	Industry
SARAD GmbH	Germany	Thomas Streil/Teresa Streil SARAD GmbH Wiesbadener Str. 10 01159 Dresden	Industry
Nofer Institute of Occupational Medicine in Lodz	Poland	Katarzyna Walczak Sw. Teresy od Dzieciatka Jezus 8 91-348 Lodz	Industry
Pylon Electronics Inc.	Canada	Charles H. Larocque 147 Colonnade Road, Ottawa, Ontario, Canada K2E7L9	Industry
Radonanalys GJAB	Sweden	Gilbert Jönsson Ideon Science Park SE22370 Lund Sweden	Industry
Radonova Laboratories AB	Sweden	Jose Luis Gutierrez Villanueva Rapsgatan 25 754 50 Uppsala	Industry
DURRIDGE UK Ltd.	UK; USA	Dr. Stephen W. Sadler UK Office DURRIDGE UK Ltd. Sheffield Technology Park Arundel Street Sheffield S1 2NS, UK www.durridge.com	Industry
RADON, v.o.s.	Czech Republic	Matej Neznal Novákových 6, 180 00 Praha 8, Czech Rep	Industry
CANBERRA PACKARD S.R.L.	Romania	Dr. Radu Vasilache Canberra Packard SRL 18 Clejani St., 051036 Bucharest S5	Industry
Algade (LED-DU Laboratory ans DOSIRAD Laboratory)	France	Roselyne Ameon Avenue du Brugeaud 87250 Bessines-sur-Gartempe	Industry
Radon Check Zuzanna Podgórska	Poland	Zuzanna Podgórska Marvina z Wrocimowic 12b/106 PL 03-194 Warsaw	Industry
U-Series Srl	Italy	Massimo Esposito Via Ferrarese, 131 40128 Bologna	Industry
Radosys Atlantic, Ida	Portugal	Paulo Gustavo Alecrim Norte Pinto IPN-C, Rua Pedro Nunes 3030-199 Coimbra	Industry
RadoSys Ltd.	Hungary	Erik Hulber; Vegyész u. 17-25., H-1116 Budapest, Hungary; Website: http://www.radosys.com/index.htm	Industry
Instytut Chemii i Techniki Jądrowej	Poland	ul. Dorodna 16 PL 03-195 Warszawa	Industry

(Institute of Nuclear Chemistry and Technology)		www.ichtj.waw.pl	
RadiÖko Ltd	Hungary	Mr Gergo Bator H-8200 Veszprem Wartha V. str 1/2	Industry
Social Organization for Radioecological Cleanliness	Hungary	Tibor Kovacs H-8200 Veszprem Jozsef A str 7/A	Industry
Mi.am srl	Italy	Dr. Antonio Parravicini Via Alessandro Bolzoni 30 29122 Piacenza	Industry
Studio Lanfranco Cicala	Italy	Lanfranco Cicala Via Abbadesse 41 I-20124 MILANO	Industry
Scientific & Technical Centre "Amplituda", LLC	Russian Federation	Andrey Tsapalov Scientific & Technical Centre "Amplituda", LLC Gen. Alekseeva 15, 124460 Zelonograd Moscow	Industry
ÜHINENUD EKSPERDID	Estonia	Marc Vokk	Industry
Extratech	Italy	Vito Lisanti via Seminario Maggiore No 35 85100 Potenza	Industry
Institute of Nuclear Physics PAN Laboratory of Radiometric Expertise	Poland	Jadwiga Mazur, Krzysztof Kozak Radzikowskiego 152 31-342 Krakow POLAND	Industry
LabExpoRad, UBIMedical - University of Beira Interior	Portugal	Sandra Soares Estrada Municipal, 506 - 6200-284 Covilha	Industry
GIHHM	Austria	Martin Exler Wienerstr. 70 2104 Spillern	Industry
Bertin-Saphymo	Germany-France	Franz Rossler	Industry

2.3 Involved national radiation protection authorities

The JRP partners made contact with and formed a group of national regulators and authorities in EU Member States that are responsible for the implementation of the EU-BSS in their country. This group had been formed by the end of the first year.

The national bodies has been kept informed on developments in the project, especially in particular concerning the definition of radon priority areas, new procedures for radon instrument calibration and methods for radon measurements. Feedback has been sought on how to estimate radon priority areas and harmonize Radon Priority Areas (RPAs) across borders. Information about indoor radon and geogenic radon surveys in Europe has been provided: strategy, methodologies and their potential for used as a basis for implementation for the EU-BSS and methodologies to harmonize indoor data (i.e. seasonal correction, short-term and long-term measurements).

2.4 Involved European and international bodies and organizations

The MetroRADON partners made contact with and formed a group of European and international bodies and associations dealing with radon issues: BIPM, ICRM, ICRU, IAEA, WHO, ERA, COIRA, IRPA and ICRP. This group were formed by the end of the first year.

The international bodies has been kept informed either by email, conference contributions and personal meetings and were asked for feedback on developments in the project, in particular concerning the definition of Radon Priority Areas, new procedures for radon instrument calibration and methods for radon

measurements, results of the on-site inter-comparison exercise, and the validation of traceability of European calibration facilities for radon concentration measurement in air.

3 Contributions via final MetroRADON workshops

3.1 Transport of Radon and Thoron in Polymers

This 2-days workshop was organized by SUBG and took place on 21-22 March 2019 in Sofia. The outcomes and achievements of different groups and researchers engaged in research in this field were reported on the workshop.

3.2 Harmonization of radon measurements methodologies and radon priority areas

This 2-days workshop was organised by AGES and BEV and took place on 25-26 February 2020 in Vienna as part of the "European Radon week 2020", together with the European Commission JRC workshop "Challenges in the implementation of EU-BSS" and the European Radon Association (ERA) workshop on "Radon Research". 124 participants from 29 countries participated on-site or online. The results of WP2, WP3 and WP4 were presented in 23 talks and discussed with the stakeholders in group discussions. In addition an industry exhibition was included. Moreover, a special issue in the Journal European Radon Association (JERA) to collect contributions on the talks given during the European Radon Week 2020 has been launched recently and will be realised spring-summer 2021. Up to now 13 papers have been confirmed to be submitted in the special issue.

3.3 New procedures for radon monitoring

This 1-day workshop was organised by PTB and **plann**ed for May in Berlin. Because of Covid-19 it was postponed to 12 October 2020 and held as a web-conference. The results of WP1, WP2 and WP5 were presented to 44 stakeholders, followed by a round table discussion.

3.4 New procedures, guidelines and methodologies for radon instrument calibration and measurements

This 1-day training seminar was organised by UC and also postponed to 13 October 2020 and held as a web-conference with 74 participants. Results of WP2 and WP5 were presented, specified for the audience of calibration facilities and end-users and with space for questions and discussions.

4 Involved standardization organizations, committees and working groups

4.1 ISO - International Organization for Standardization

- ISO/TC 85/SC 2: Nuclear energy, nuclear technologies, and radiological protection / Radiological protection
- ISO/TC 85/SC 2/WG17: Radioactivity measurements

4.2 IEC – International Electrotechnical Commission

- IEC TC 45/SC 45B Radiation protection instrumentation – WG 10: Radon and radon daughter measuring instruments

4.3 CEN – European Committee for Standarization

- CEN/TC 351/WG 3: Construction products: Assessment of release of dangerous substances/Radiation from construction products

- CEN/TC 430: Nuclear energy, nuclear technologies, and radiological protection

4.4 CENELEC – European Committee for Electrotechnical Standardization

- CENELEC/TC 45B: Radiation protection instrumentation

4.5 National Standardization Organizations

- Austria:
  - ASI Committee 088: Radiation Protection
  - ASI Working group 088.14: Radon
  - OVE TC MR (Austria): Measurement and control engineering
- Czech Republic
  - Office for Standards, Metrology and Testing
- Finland:
  - Finnish Standards Association SFS
- France:
  - AFNOR
- Germany:
  - DKE/GK 851 Aktivitätsmessgeräte für den Strahlenschutz (Radiation Protection Instrumentation: Activity Measuring Instruments)
  - DIN NA 005-53 FBR "Fachbereichsbeirat KOA 03 - Hygiene, Gesundheit und Umweltschutz“
  - DIN "Gemeinschaftsarbeitsausschuss NABau/NHRS, Radongeschütztes Bauen", Group of Experts from building and HVAC industry and Radon Experts
- Hungary:
  - MSZ Magyar Szabványügyi Testület
- Poland:
  - Polish Committee for Standardization, technical committee 246 Radiation Protection
  - Polish Committee for Standardization, technical committee 266 Nuclear Technologies
- Romania:
  - ASRO Technical Committee CT16: Nuclear instrumentation
  - ASRO Technical Committee CT58: Metrology
- Spain
  - Working Group CEN-TC351/WG3/N0265 Determination of radon diffusion coefficient

4.6 Involved international and European technical committees and radiation protection organizations

- BIPM Consultative Committee on Ionizing Radiation CCRI, CCRI(II)
- EC Group of Experts established under Article 31 of the Euratom Treaty
- ERA - European Radon Association
- EURADOS – European Radiation Dosimetry Group
- EURAMET Technical Committee IR - Ionizing Radiation
- EURATOM Article 31 Group of Experts
- HERCA – Heads of the European Radiological Protection Competent Authorities
- IAEA Nuclear Data Section of the Division of Physical & Chemical Sciences (NAPC), Department of Nuclear Sciences & Applications (NA)
- IAEA Radiation Safety & Monitoring Section, Division of Radiation, Transport and Waste Safety, Department of Nuclear Safety & Security
- ICRM International Committee for Radionuclide Metrology
- ICRM Working Group Low-Level Measurement Techniques
- WHO - World Health Organization

4.7 Involved national radiation protection organizations, regulators and authorities

- Austria: ÖVS – Austrian Radiation Protection Association
- Austria: BMNT – Austrian Federal Ministry of Sustainability and Tourism; BMK – Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology
- Czech Republic: State Office for Nuclear Safety
- Czech Republic: National Radiation Protection Institute
- Finland: STUK–Radiation and Nuclear Safety Authority - National radiation protection authority, regulation of radon at workplaces
- Finland: Municipal health authorities - regulate radon in dwellings and public buildings other than work places
- France: IRSN - National Institute for Radioprotection and Nuclear safety
- Germany: FS – German-Swiss Fachverband für Strahlenschutz e.V. (Association of radiation protection experts)
- Hungary: NRIRR; "Frederic Joliot-Curie" - National Research Institute for Radiobiology and Radiohygiene; Ministry of Human Capacities Hungary; Ministry for Innovation and Technology Hungary
- Hungarian Atomic Energy Authority
- Poland: PAA- National Atomic Energy Agency (polish regulator)
- Poland: Ministry of Health
- Poland: The Main Sanitary Inspectorate
- Poland: Radon Centre
- Romania: Romanian National Commission for Nuclear Activities Control (CNCAN)
- Spain: CSN Consejo de Seguridad Nuclear (Spanish Nuclear Safety Council)
- Spain: SEPR Sociedad Española de Protección Radiológica (Spanish Radiological Protection Assocition)

5 Contributions of MetroRADON to relevant standards, regulations and guidelines

5.1 Contribution to standards and technical guidelines

The project's results, output and data of WP1, WP2, WP3, WP4, and WP5 have benefited or will in future benefit international, European and national standards, guidelines and regulations on radon monitoring, measurement, instrument calibration in the fields of radiological protection, construction products, radiation instrumentation and nuclear data by contributions of JRP partners.

Specifically, the JRP's outputs on technical standards, guidelines and regulations improve the metrological traceability requirements of radon measuring instruments (Tab 5.1). The main goal of which are the reduction of uncertainties at instrument calibrations and harmonization of calibration methods at low radon activity concentrations (< 300 Bq/m³ ^{222}Rn). Input will also be given to IEC standard 61577 after the end of the project.

Table 5.1. Contributions to European and international standardization organizations

Standards Committee / Technical Committee / Working Group	JRP Partners involved	Area of impact / activities undertaken by partners related to standard / committee
CEN/TC 351/WG 3: Construction products:	BEV-PTP	BEV-PTP (permanent member) has presented the results at the CEN/TC 351/WG 3 working group meetings with specific focus on future European standards related to standardised harmonised

Assessment of release of dangerous substances		procedures for the evaluation of natural radionuclides' radiation and radon exhalation from building materials and construction products as basis for effective dose assessment and radiation protection.
CENELEC/TC 45B and IEC/SC 45B: Radiation protection instrumentation	BfS, IRSN, CEA, BEV-PTP	BfS, IRSN, CEA and BEV-PTP are members of CENELEC/TC 45B and/or IEC/SC 45B. They have presented the results of the project at the committee meetings. The project has contributed to the development of these standards: ● EN IEC 61577-2 - Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 2: Specific requirements for radon measuring instruments ● EN IEC 61577-3 - Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 3: Specific requirements for radon decay product measuring instruments ● EN IEC 61577-4 - Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 4: Equipment for the production of reference atmospheres containing radon isotopes and their decay products (STAR) ● IEC/TR 61577-5 - Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 5: General properties of radon and radon decay products and their measurement methods
ISO/TC 85/SC 2: Radiological protection and CEN/TC 430	BfS, IRSN, BEV-PTP, STUK	BfS (permanent member), IRSN (permanent member), BEV-PTP (corresponding member) has presented the results at the CEN/TC 430 committee meetings with specific focus on the development of standards for radon monitoring and mapping. The project has contributed to the development of these standards: ISO & EN ISO 11665 Measurement of radioactivity in the environment - Air: ^{222}Rn: ● ISO 11665-4: Integrated measurement method for determining average activity concentration using passive sampling and delayed analysis ● EN ISO 11665-5: Continuous measurement method of the activity concentration ● EN ISO 11665-6: Spot measurement method of the activity concentration ● ISO 11665-8: Methodologies for initial and additional investigations in buildings ● EN ISO 16641 Measurement of radioactivity in the environment - Air - Radon-220: Integrated measurement methods for the determination of the average activity concentration using passive solid-state nuclear track detectors STUK sends statements to ISO standards under preparation that concern radioactivity/nuclear energy via the Finnish Standards Association SFS

5.2 Contributions to European and international organizations

Two project newsletters per year (Jan and July / 2018, 2019, 2020) giving information on the progress and results of MetroRADON were distributed to approx. 250 interested parties, stakeholders and European and international organizations (Tab. 5.2), as well as two mailing lists (more than 300 people total). 65 conference presentations and posters have been held at scientific conferences and 14 papers have been published in peer-reviewed journals, 4 are in preparation. The MetroRADON project was presented at the EURADOS winter school in Poland, February 2019.

Table 5.2. Contributions to European and international organizations and committees

Organization	JRP Partners involved	Area of impact / activities undertaken by partners related to committee
BIPM CCRI	BEV PTP, BFKH, CEA, CMI, IFIN HH, PTB, STUK, VINS	BEV-PTP and all internal partners (permanent members) has presented the results of the project to the committee, and the new radionuclide metrology methods for ^{222}Rn and ^{220}Rn has been recommended to be used in future intercomparisons. The supplemental comparison of BIPM Section CCRI(II) Radioactivity 'EURAMET.RI(II)-S8.Rn-222 has been implemented in the BIPM International Key Comparison Database KCDB (Annex 1).
WHO	AGES, BEV-PTP	WHO is the host of a worldwide radon listserver. WHO was informed about MetroRADON through the MetroRADON newsletter.
IAEA	AGES, BEV-PTB	IAEA is recipient of the MetroRADON newsletter. IAEA was regularly informed about the MetroRADON project.
IAEA-Nuclear Data Section of the Division of Physical & Chemical Sciences (NAPC), Department of Nuclear Sciences & Applications (NA)	CEA	CEA (permanent participant in the Nuclear Data Section) has reported the results of this project and thus support the development of nuclear data for radon isotopes and their progenies. CEA LNE-LNHB was pilot laboratory for the WP1 comparison EURAMET 1475 / BIPM CCRI(II) EURAMET.RI(II)-S8.Rn-222.
International Committee for Radionuclide Metrology (ICRM)	BEV-PTP, all internal partners	BEV-PTP (ICRM vice president Franz Josef Maringer) and all internal partners have presented the project's results and publish scientific papers at the ICRM conferences. Advances within the project have been presented biannually at the ICRM conferences, WG LLRMT (working group on low-level radionuclide measurement techniques). The ICRM will produce guidelines in the according working groups regarding

		low-level radon measurement techniques, including uncertainty calculation and ensuring traceability.
EURAMET Technical Committee - Ionising Radiation	BEV-PTP, BFKH, CEA, CMI, IFIN HH, PTB, STUK, VINS	BEV-PTP and all internal partners (permanent members) has presented the results and advances within the project annually at the EURAMET TC-IR meetings to promote uptake of the project's outcomes and to create impact on the future work and research programme. The EURAMET Ionizing Radiation (RI) Comparison 1475 'Rn-222 intercomparison in the frame of MetroRADON' has been carried out in MetroRADON WP1 (Annex 1). MetroRADON coordinator will submit to EURAMET the deliverables D7 'Validation report on the traceability of primary and secondary radon calibration facilities in Europe' and D8 'Guideline and recommendations on calibration and measurement procedures for the determination of radon concentration in air'.
EURADOS – European Radiation Dosimetry Group	PTB, BEV-PTP, AGES	PTB initiated the establishment of the WG3 (Environmental Dosimetry) sub group S3 'Radon Monitoring'. The specific objectives of EURADOS WG3-S3 are • to harmonize the activities of experts in the field of radon activity concentration measurements and related dose assessments, • provide support in the usage of the radon/-progeny dose conversion factors published by ICRP in dose assessment at homes and at workplaces, • to establish and support radon intercomparisons open to experts in metrology and in field measurements and • to support knowledge transfer and scientific cooperation in the field of environmental dosimetry where radon is of interest. BEV-PTP presented the MetroRADON project at the EURADOS winter school in Poland, February 2019.
HERCA - Heads of the European Radiological Protection Competent Authorities	AGES	AGES has presented the MetroRADON project at the HERCA meeting in September 2018.
EC JRC working group for the European Atlas of Natural Radiation (EANR)	AGES, BEV-PTP, BfS	MetroRADON partners presented MetroRADON and first results at the 2nd international workshop on the European Atlas of Natural Radiation (IWEANR) and are members in the JRC EANR expert group.
ERA – European Radon Association	AGES, BEV-PTP	The MetroRADON newsletter was disseminated to all members of ERA; AGES has presented MetroRADON to the Executive Committee of ERA; the European Radon Week of ERA, EC JRC and MEtroRADON had been organized by AGES and BEV-PTB in Vienna, February 2020.

5.3 Contributions to International Standards

5.3.1 ISO

BfS and IRSN (both permanent ISO member) contributed continuously with relevant results and data of WP1, WP3 and WP5 at the committee meetings TC 85/SC2/WG17 with specific focus on the development of standards for radon monitoring, measurement, instrument calibration and radon mapping. They contributed continuously with results from to the preparation of ISO 11665 Series 'Measurement of radioactivity in the environment — Air: radon-222': discussion of possible revision; working draft to discuss; preparation for publication; setting new work item proposals.

ISO 11665-4:	Measurement of radioactivity in the environment — Air: radon-222 — Part 4: Integrated measurement method for determining average activity concentration using passive sampling and delayed analysis
ISO 11665-8:	Measurement of radioactivity in the environment — Air: radon-222 — Part 8: Methodologies for initial and additional investigations in buildings methods
ISO 11665-7:	Measurement of radioactivity in the environment -- Air: radon-222 - Part 7: Accumulation method for estimating surface exhalation rate; Status report on EMPIR Metrology for Radon
ISO 11665-11:	Measurement of radioactivity in the environment. Air: radon-222. Part 11: Test method for soil gas with sampling at depth.

ISO/WD 22931:	Measurement of radioactivity in the environment - Air: radon-222 - QA/QC for calibration facilities

5.3.2 IEC

IEC TR 61577-2:	BfS and IRSN contributed continuously at IEC/SC45B/WG10 with results from WP2, to the discussion of needed revisions on the IEC TR 61577-2 “Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 2: Specific requirements for radon measuring instruments” concerning the test on the influence of thoron on radon measurement, Annex 7.
IEC TR 61577-5:	BfS and IRSN contributed continuously at IEC/SC45B/WG10 with results from WP1, WP3 and WP5 to the preparation of IEC TR 61577-5 "Radiation protection instrumentation – Radon and radon decay product measuring instruments – Part 5: General properties of radon and radon decay products and their measurement methods", WG 10: Radon and radon daughter measuring instruments.
IEC 61577-6:	BfS and IRSN contributed at IEC/SC45B/WG10 with results of WP3 to the new work item proposal (NWIP): Project IEC 61577-6 "Passive integrating radon measurement systems” by developing a draft.

5.4 Contributions to European Standards

5.4.1 CEN

EN ISO 11665:	Measurement of radioactivity in the environment - Air: ^{222}Rn BfS (permanent member), IRSN (permanent member) and BEV-PTP (corresponding member) have presented the results of WP1, WP3 and WP5 at the CEN/TC 430 committee meetings with specific focus on the development of these standards for radon monitoring and mapping: EN ISO 11665-5: Continuous measurement method of the activity concentration EN ISO 11665-6: Spot measurement method of the activity concentration
EN ISO 16641:	Measurement of radioactivity in the environment - Air - Radon-220: Integrated measurement methods for the determination of the average activity concentration using passive solid-state nuclear track detectors
CEN TR 17113:	Ongoing transformation of the CEN Technical Report TR 17113:2017 “Construction products: Assessment of release of dangerous substances — Radiation from construction products — Dose assessment of emitted gamma radiation” into a CEN Technical Standard (EC Action on CEN TC 351 WG 3 Construction products: Assessment of release of dangerous substances, Radiation from construction products)
EN 17216	Ongoing transformation of TS 17216 ‘Construction products: Assessment of release of dangerous substances – Determination of radium-226, thorium-232 and potassium-40 activity using gamma-ray spectrometry’ into an harmonized technical European standard

5.4.2 CENELEC

CLC/FprTR 62461:	Input to CENELEC/TC 45 Technical Report CLC/FprTR 62461 Radiation protection instrumentation - Determination of uncertainty in measurement - CLC/FprTR 62461:2019.

5.5 Contributions to national standards

5.5.1 Austria

ON S 5280-1: Radon Teil 1: Messtechnische Aufgabenstellungen und Beurteilung (Radon — Part 1: Metrological tasks and evaluation). Austrian Standardization Institute (ASI) – draft (2016) (Annex 2; in German)

ON S 5280-2: Radon Teil 2: Bautechnische Vorsorgemaßnahmen bei Gebäuden (Radon — Part 2: Structurally engineered preventive measures for buildings). Austrian Stadardisation Institute (ASI) – draft (2017) (Annex 3, in German)

5.5.2 Finland

STUK contributed to the following relevant to radon measurements (only in Finnish and Swedish):

- STUK Regulation S/3/2019 on activities causing exposure to natural radioactivity
- STUK Regulation S/6/2018 on measurements of radioactivity

5.5.3 France

LNHB provides radon standards 'Supply and/or calibration of radioactive gas sources' - H-3, Kr-85, Xe-133, Rn-222 (http://www.lnhb.fr/services-en/supply-and-calibration-of-radioactive-gas-sources/).

5.5.4 Germany

- Adoption of the standards assigned to the ISO 11665 series of standards into the national body of rules
- Adoption of the standards assigned to the IEC 61577 series of standards into the national body of rules
- DIN/TS 18117 Vornorm, Entwurf, Bauliche und lüftungstechnische Maßnahmen zum Radonschutz - Teil 1: Begriffe, Grundlagen und Beschreibung von Maßnahmen (Pre-standard, draft. Structural and ventilation measures for radon protection - Part 1: Terms, principles and description of measures)

5.5.5 Hungary

- Adoption of the standards assigned to the ISO 11665 series of standards into the national body of rules (MSZ EN ISO 11665)
- Adoption of the standards assigned to the IEC 61577 series of standards into the national body of rules (MSZ EN 61577)

5.6 Contributions to regulations and guidelines

IAEA SSG-32: Input to the revised IAEA Specific Safety Guide No. SSG-32 'Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation', jointly sponsored by the IAEA, WHO. BEV-PTB and other JRP partners support the IAEA radon section.

ICRM 2019: Input to ICRM guidelines on radon metrology. BEV_PTB and other JRP partners presented the progress and the interim results of the JRP in the ICRM Low Level Radionuclide Metrology Techniques Working Group at the 22nd International Conference on Radionuclide Metrology and its Applications, at the University of Salamanca (May 2019, Annex 4).

EURAMET 1475: Input to a EURAMET standard comparison report. EURAMET comparisons for ^{222}Rn, not involving any Radon chambers, had been carried out about 15 years ago. The JRP comparison for ^{222}Rn and ^{220}Rn, done in WP1, has been successfully established as EURAMET TC IR comparison 1475 and BIPM CCRI(II) supplemental comparison EURAMET.RI(II)-S8.Rn-222. (MetroRADON Deliverable D8)

BGBl. 2020/II/470:	Input to the Austrian Radon Protection Ordinance, CELEX-Nr.: 32013L0059: 470. Verordnung der Bundesministerin für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie über Maßnahmen zum Schutz von Personen vor Gefahren durch Radon (Radonschutzverordnung – RnV) (Annex 5)
BGBl. 2020/I/50:	Input to the Austrian Radiation Protection Act in the field of radon: Bundesgesetz über Maßnahmen zum Schutz vor Gefahren durch ionisierende Strahlung (Strahlenschutzgesetz 2020 - StrSchG 2020);
IAEA SRS-98:	Input to the Safety Reports Series No. 98 “Design and Conduct of Indoor Radon Surveys”, jointly sponsored by IAEA, WHO. AGES contributed to the drafting and reviewing of the report.
EC-RP-N.193:	European Commission: Radiation Protection N. 193 - Radon in Workplaces, DG Energy, 2020. MetroRADON partners participated as observers via HERCA/ERA.
EU - EANR:	European Atlas of Natural Radiation (EANR), Publication Office of the European Union, Luxemburg 2019. MetroRADON partners participated as authors and reviewers to the EANR.
1034/2018:	Input of STUK to the Finish Government Ordinance 1034/2018 on ionizing radiation
1044/2018:	Input of STUK to the Finish Ministry of Social Affairs and Health Ordinance 1044/2018 on ionizing radiation
859/2018:	Input of STIK to the Finish Radiation act 859/2018
D.Lgs.101/2020:	Legislative Decree 101/2020: Input to the Italian radiation protection legislation, transposing the Council Directive 2013/59/EURATOM (EU-BSS). GURI n.201, 12.09.2020 (Title IV, Annex II)
BGBl. I S. 2034, 2020:	Input to the German Radiation Protection Ordinance, Verordnung zum Schutz vor der schädlichen Wirkung ionisierender Strahlung (Strahlenschutzverordnung - StrlSchV)
BMU (2019)	Input to the German Radon Action Plan for the long-term reduction of radon exposure
BfS (2020)	Radon an Arbeitsplätzen in Innenräumen. Leitfaden zu §§ 126 - 132 des Strahlenschutzgesetzes (Radon in indoor workplaces. Guide to Sections 126-132 of the Radiation Protection Act)
HG 526/2018:	Romanian Government Decision no. 526/2018 for the approval of the National Radon Action Plan / Hotărârea Guvernului nr. 526/2018 pentru aprobarea Planului Naţional de Acţiune la Radon, publicată în Monitorul Oficial al României, Partea I nr. 645 din 25.07.2018
RO 185/2019:	Romanian Order no. 185/2019 of the President of the National Commission for the Control of Nuclear Activities/ Ordinul Președintelui Comisiei Naţionale pentru Controlul Activităţilor Nucleare nr. 185/2019 privind aprobarea Metodologiei pentru determinarea concentraţiei de radon în aerul din interiorul clădirilor şi de la locurile de muncă, publicat în Monitorul Oficial, Partea I nr. 655 din 07.08.2019

6 Examples of early uptake of project outputs by end-users

The largest fraction of the average annual effective dose of each European inhabitant from natural sources of ionizing radiation is caused by the inhalation of radon progeny. In large European countries, thousands of lung cancer cases are attributed to indoor radon exposure. The EU BSS, which has been in the process of implementation into national legislation, requires the monitoring of radon levels and the establishment of appropriate precautions against exposure to radon for the protection of the European population. The output of MetroRADON helps end-users both to establish a basic infrastructure so that metrological sound measurements can be made to support the implementation of the EU-BSS and sound decision making for radiological protection.

Key end-users of MetroRADON and stakeholders including those responsible for the transposition of the EU BSS into national law are: regulators, national authorities and policy makers, industrial partners and professionals designing, performing, evaluating and interpreting radon surveys, radon instrument manufacturers, construction and building industry.

Since national radon action plans – a major requirement by the EU BSS (Article 103) – also raise considerable interest beyond the EU, important stakeholders also include those concerned with radon control even if not committed to the EU BSS.

Implementation of the MetroRADON project outcomes to establish a reliable metrological infrastructure for traceable calibrations at low-level radon activity concentrations on the one hand and new metrological methodologies in the field of radon measurements on the other hand benefit stakeholders, regulators and end-users of radon measurement methods. The achievement of traceability for the most commonly used European radon calibration facilities, especially at low radon activity concentrations, significantly reduce calibration uncertainties. As a consequence, field measurements done by metrological end-users in Europe have a higher precision, allowing more appropriate precautions and counter measures against radon exposures to the public. In addition, harmonization and standardization allow the comparison and merging of different existing radon data sets on a European scale.

Examples of early uptake of project uptake and end-user request to MetroRADON partners are shown in Table 6.1.

Table 6.1. Examples of end-user uptakes and requests

Description of uptake /use of project outputs by the end-user	Organisation name(s)	Relevant JRP partner and WP
Request of calibration services for instruments measuring the radon concentration in air	CANBERRA PACKARD S.R.L. (Romania)	CMI, WP5
Request of calibration services for instruments measuring the radon concentration in air	MECRO SYSTEM S.R.L. (Romania)	CMI, WP5

Request of calibration services for instruments measuring the radon concentration in air	RADTECH Solutions S.R.L. (Romania)	CMI, WP5
Traceable measurement of Rn-222 activity concentration in water and instrument calibration	IAEA - International Atomic Energy Agency	BEV-PTP, WP5
Accreditation of the testing laboratory (Annex 6)	Radonova Laboratories AB, Sweden	Radnova, WP5
Organization of trainings for companies performing radon measurements. A textbook on the topic has been written with several exercises. The training will be published as web-based course.	Several finish companies	STUK, WP6
Provision of radon calibration services throughout the project.	Several Finish companies / customers	STUK, WP5
Request of calibration services for instruments measuring the radon concentration in air	CRE ENEA Casaccia, Italy	BfS, WP5
Request of calibration services for instruments measuring the radon concentration in air	MNE Bureau of Metrology Montenegro	BfS, WP5
Request of calibration services for instruments measuring the radon concentration in air	UBB CONSTANTIN COSMA RADON LABORATORY, Babes-Bolyai University, Romania	BfS, WP5
Request of calibration services for instruments measuring the radon concentration in air	SMU Slovak Institute of Metrology, Dept. of Ionizing Radiation, Slovak Republic	BfS, WP5
Request of calibration services for instruments measuring the radon concentration in air	UPC Laboratory of ^{222}Rn studies (LER) of the Institut de Tècniques Energètiques (INTE) of the Universitat Politècnica de Catalunya (UPC), Spain	BfS & SUJCHBO, WP5
Request of calibration services for instruments measuring the radon concentration in air	SSM Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority), Mätning av joniserande strålning (Radiation Measurements), Sweden	BfS, WP5
Request of the national reference values for indoor radon concentrations in European member states (Deliverable 3, Annex 3)	BfS, Germany	JRC, WP3

Accreditation of the testing laboratory (Annex 8)	Laboratory of Environmental Radioactivity, University of Cantabria (LaRUC)	UC, WP5
Declaration of interest in industrial developments and applications based on the invention made within MetroRADON project (Bulg. Pat. Appl. Reg. Nr. 112897) (Annex 9)	AMG Technology Ltd., Bulgaria	SUBG, WP2
Accreditation of the testing laboratory	"Constantin Cosma" Radon Laboratory, Babes-Bolyai University (LiRaCC), Romania	UC, WP5
Request of calibration services for instruments measuring the radon concentration in air	S.C. RadonControl S.A., Romania	CMI, WP5
Information on MetroRADON beneficial results for end-users (Annex 10)	Romanian National Commission for Nuclear Activities Control (CNCAN)	IFIN-HH, WP6
Information on MetroRADON beneficial results for end-users (Annex 10)	S.C. Canberra Packard SRL (Romania)	IFIN-HH, WP6
Information on MetroRADON beneficial results for end-users (Annex 10)	S.C. Mecro System SRL, S.C. Radtech Solutions SRL (Romania)	IFIN-HH, WP6
Information on MetroRADON beneficial results for end-users (Annex 10)	Radoncontrol S.A. (Romania)	IFIN-HH, WP6
Accreditation Certificate 01/04/2020 of the Radon Laboratory LiRaCC (Annex 11)	University Babeş Bolyai (Romania)	IFIN-HH, WP6

7 Patent application

As outcome of the MetroRADON research, a patent application has been submitted for the compensation module design for radon detectors: Pressyanov, D., 2019. Bulg. Pat. Appl. Reg. Nr. 112897, priority: 19.03.2019, WIPO Appl. Reg. Nr. PCT/BG2020/000003.

The temperature dependence of the response of many radon detectors and that introduced by polymer anti-thoron barriers are reciprocal. This can be used to reduce/eliminate the temperature dependence, the thoron interference and the humidity influence.

An interest to this invention was declared from an industrial company (Annex 9).

8 References

IEC 61577-2. Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 2: Specific requirements for radon measuring instruments. Internat. Electrotechn. Commission, Geneva (2014)

IEC 61577-3. Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 3: Specific requirements for radon decay product measuring instruments. Internat. Electrotechn. Commission, Geneva (2011)

IEC 61577-4. Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 4: Equipment for the production of reference atmospheres containing radon isotopes and their decay products (STAR). Internat. Electrotechn. Commission, Geneva (2009)

ISO 11665-4. Measurement of radioactivity in the environment — Air: radon-222 — Part 4: Integrated measurement method for determining average activity concentration using passive sampling and delayed analysis. . International Organization for Standardization, Geneva (2020)

ISO 11665-7. Measurement of radioactivity in the environment -- Air: radon-222 - Part 7: Accumulation method for estimating surface exhalation rate; International Organization for Standardization, Geneva (2012)

ISO 11665-8. Measurement of radioactivity in the environment — Air: radon-222 — Part 8: Methodologies for initial and additional investigations in buildings methods. International Organization for Standardization, Geneva (2019)

ISO/WD 22931: Measurement of radioactivity in the environment - Air: radon-222 - QA/QC for calibration facilities. Working draft. International Organization for Standardization, Geneva (2019)

EN ISO 11665-4. Measurement of radioactivity in the environment - Air: ^{222}Rn: Part 4 - Integrated measurement method for determining average activity concentration using passive sampling and delayed analysis. Working draft. European Committee for Standardization (2020)

EN ISO 11665-5. Measurement of radioactivity in the environment - Air: ^{222}Rn: Part 5 - Continuous measurement method of the activity concentration. European Committee for Standardization (2020)

EN ISO 11665-6. Measurement of radioactivity in the environment - Air: ^{222}Rn: Part 6 - Spot measurement method of the activity concentration. European Committee for Standardization (2020)

EN ISO 11665-8. Measurement of radioactivity in the environment - Air: ^{222}Rn: Part 8 - Methodologies for initial and additional investigations in buildings. Working draft. European Committee for Standardization (2020)

EN ISO 16641. Measurement of radioactivity in the environment - Air - Radon-220: Integrated measurement methods for the determination of the average activity concentration using passive solid-state nuclear track detectors. European Committee for Standardization (2016)

CEN TR 17113. Construction products: Assessment of release of dangerous substances — Radiation from construction products — Dose assessment of emitted gamma radiation. European Committee for Standardization (2017)

CEN TS 17216. Construction products: Assessment of release of dangerous substances – Determination of radium-226, thorium-232 and potassium-40 activity using gamma-ray spectrometry. European Committee for Standardization (2018)

ON S 5280-1. Radon Teil 1: Messtechnische Aufgabenstellungen und Beurteilung (Radon — Part 1: Metrological tasks and evaluation). Working draft. Austrian Standardization Institute (2016)

ON S 5280-1 Teil 2: Radon Teil 2: Bautechnische Vorsorgemaßnahmen bei Gebäuden (Radon — Part 2: Structurally engineered preventive measures for buildings).Working draft. Austrian Standardization Institute (2017)