National Radon Action Plan

MINISTERIO
DE SANIDAD

STUDIES, REPORTS AND RESEARCH COLLECTION
MINISTRY OF HEALTH
2024

Published and distributed by:

General Technical Secretariat
Publications Centre
Paseo del Prado, 18, 28014 Madrid

Publication Identification Number (NIPO):
Legal deposit: pending processing

NATIONAL RADON ACTION PLAN COMMITTEE

Formed in accordance with Article 78 of Royal Decree 1029/2022 of 20 December, approving the Regulation on health protection against the risks arising from exposure to ionising radiation.

Chair: A representative of the Ministry of Health, with the rank of General Director.

Vice-chair: A representative of the Spanish Nuclear Safety Council, with the rank of Technical Director.

Members:

- Eight people appointed to positions with at least the rank of Head of Area or equivalent, representing each of the following ministerial departments: two representatives from the Ministry of Health; two representatives from the Ministry for Ecological Transition and Demographic Challenge; two representatives from the Ministry of Transport, Mobility and Urban Agenda; two representatives from the Ministry of Labour and Social Economy.
- Two representatives of the Spanish Nuclear Safety Council, with at least rank of Head of Area or equivalent.
- One representative from each Autonomous Community and City with a Statute of Autonomy interested in participating, with at least rank of Deputy Director General or equivalent.
- Three representatives from local authorities, appointed by the Spanish Federation of Municipalities and Provinces.

Secretariat: An official appointed by the Ministry of Health, who will not be considered a member of the Committee.

TECHNICAL WORKING GROUP

Spanish Nuclear Safety Council

Inmaculada Simón Cirujano
Marta García Talavera

Ministry for Ecological Transition and Demographic Challenge

Elvira Hernando Velasco

Ministry of Transport, Mobility and Urban Agenda

Isabel Marcos Anasagasti
Eduardo González de Prado

Ministry of Labour and Social Economy

Salvador Martínez Fenoll

Ministry of Health

Covadonga Caballo Diéguez
Margarita Palau Miguel
Montserrat García Gómez
Santiago González Muñoz
Sara Fernández Moreno (TRAGSATEC)

Technical Support

Marian Mendoza García
Salvador Giménez Bru (TRAGSATEC)
Helena García Cortés (TRAGSATEC)

National Radon Action Plan

Approved by the Council of Ministers at its meeting on 9 January 2024, the "Agreement for the approval of the National Radon Action Plan"

CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY OF TERMS, ACRONYMS AND ABBREVIATIONS

BEIR	Biological Effects of Ionising Radiation
BSS	Basic Safety Standards
CIEMAT	Energy, Environment and Technology Research Centre
CSIC	Spanish National Research Council
CSN	Spanish Nuclear Safety Council
CTE	Technical Building Code
ENAC	Spanish National Accreditation Body
ERA	European Radon Association
IARC	International Agency for Research on Cancer
IETcc	Eduardo Torroja Institute for Construction Sciences
ICRP	International Commission on Radiological Protection
IGME	Geological and Mining Institute of Spain
LARUC	Environmental Radioactivity Laboratory of the University of Cantabria
MARNA	Map of Natural Gamma Radiation in Spain
IAEA	International Atomic Energy Agency
WHO	World Health Organization
RADPAR	European Radon Prevention and Remediation Project
RPSRI	Regulation on Health Protection against Ionising Radiations
SEPR	Spanish Society for Radiological Protection
USC	University of Santiago de Compostela
USEPA	United States Environmental Protection Agency
RPTU	Radiation Protection Technical Units

1. Executive summary

Royal Decree 1029/2022, of 20 December, which determines the Regulation on health protection against the risks arising from exposure to ionising radiation, partially transposes into Spanish law the radon-related requirements of 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 repeals Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. This Directive calls on Member States to develop action plans with the ultimate aim of reducing the risk of lung cancer attributable to radon exposure.

There is ample scientific evidence demonstrating the relation between indoor radon exposure and lung cancer. Radon is recognised as a Group 1 human carcinogen by the International Agency for Research on Cancer (IARC). Combined with the fact that a significant proportion of the existing building stock has high radon concentrations, radon exposure is regarded as a public health concern. It is also worth noting that the effects of radon exposure are heightened in smokers, due to the synergy of radon and tobacco.

Radon is produced as a result of the decay of radium (Ra-226), an element of the uranium decay series, which is widespread in rocks and soils, although it is found in higher concentrations in areas of Hercynian geology. From underground, this gas migrates into indoor air in homes and buildings, where it tends to accumulate, although such accumulation can be prevented or mitigated through various construction solutions.

The Government will establish the policy to reduce the risk to public health from indoor radon exposure by approving the National Radon Action Plan. To develop and implement this, the National Radon Action Plan Committee has been created, with its composition detailed in Article 78 of Royal Decree 1029/2022.

The National Radon Action Plan will outline the strategies and the activities to be carried out by the various public authorities to reduce the risk to public health from radon exposure. Therefore, this document aims to quantify the magnitude of the problem, reduce exposure, and enhance research into indoor environments by estimating radon concentration in these spaces and mapping radon potential. It will also determine a methodology for risk assessment in line with regulatory reference levels and provide the foundation for the establishment of remedial and preventive actions, as well as verification and validation procedures and the development of a public guidance document. To achieve this purpose, basic information on radon and its health risks will be compiled, and an analysis of the situation in Spain will be presented, including available data on exposure levels.

2. Introduction

This National Radon Action Plan falls within the regulatory framework of Royal Decree 1029/2022, of 20 December (1), which approves the Regulation on health protection against the risks arising from exposure to ionising radiation. It also falls under the scope of the Strategic Plan for Health and Environment (2), approved on 24 November 2021, in an extraordinary session of the Plenary of the Interterritorial Council of the National Health System and the Sectorial Conference on the Environment. The main aim is to promote environmental settings that enhance public health and reduce the risks associated with environmental factors.

This document has been prepared by the National Radon Action Plan Committee, whose composition is outlined in Article 78 of Royal Decree 1029/2022. The drafting of this National Radon Action Plan complies with Section 2 of Chapter III "Exposure to radon" of Royal Decree 1029/2022, which transposes the provisions of Directive 2013/59/Euratom (49).

Radon (Rn-222) is a radioactive isotope from the noble gas group, which is colourless, odourless and moderately soluble in water and other liquids. It is the decay product of uranium (U-238), which is present in the rocks of the Earth's crust and other environmental compartments, and is a direct descendant of radium (Ra-226).

Radon is released from the ground and enters buildings primarily by diffusion or advection through pores, cracks and fissures in foundations. It can also enter, to a lesser extent, from building materials or tap water. In general, radon concentrations in buildings decrease as one moves away from the ground, although in some occasions, high radon concentrations can be found at higher floors due to the potential contribution of building material, water and because of the chimney effect.

Short-lived radon progeny (Po-218, Pb-214, Bi-214 and Po-214) tend to attach to airborne particles. When inhaled they become trapped in different sections of the respiratory tract, depending on their aerodynamic diameter. The largest contribution to radiation dose comes from alpha particles that impact lung epithelial cells, potentially leading to molecular alterations and, ultimately, to lung cancer. Radon is one of the most significant sources of ionising radiation to which the general population is exposed (3).

Radon was classified as a Group 1 human carcinogen by the IARC (4) and by the United States Environmental Protection Agency (USEPA) (5). The World Health Organization (WHO) estimates that residential radon causes between 3-14% of all lung cancer cases globally (6). Based on these figures, radon is the second leading cause of lung cancer after tobacco and the primary cause in non-smokers.

In Spain, occupational exposure to radon has been generically regulated since 2001 by Title VII of the Regulation on Health Protection against Ionising Radiations, approved by Royal Decree 783/2001, introduced regulations on health protection against exposure to ionising

radiation, although it was not until 2012 that specific guidance was issued to clarify and facilitate the application of this regulation. This came in the form of Instruction IS-33 from the Spanish Nuclear Safety Council (CSN), which outlined the radiological criteria for protection against exposure to natural radiation (BOE No. 22, 26 January 2012 (79)). This framework has been further strengthened by the adoption of the current Regulation on health protection against the risks arising from exposure to ionising radiation (Royal Decree 1029/2022, of 20 December), which transposes European legislation into Spanish law.

In the context of buildings, the DB-HS6 document "Protection against radon" (8) was approved in 2019, which establishes the construction measures that new and refurbished buildings must incorporate in order to meet the reference radon level of 300 Bq/m^3.

Since then, other documents have been published, including the Radon Remediation Guide published as part of the Technical Building Code (CTE, as per its known acronym in Spanish) (7), which is intended as a tool to assist in the designing of radon protection solutions. Moreover, it provides the fundamental concepts necessary to support the correct diagnosis of radon entry pathways, and presents protection strategies, offering criteria for selecting the most appropriate solution in each case. The Radon Remediation Guide, published by the Ministry of Transport, Mobility and Urban Agenda, aims to serve as both an essential tool for designers tasked with developing radon protection solutions in compliance with DB-HS6 and a valuable resource for users of affected buildings. It raises awareness about the potential scope of the various solutions, the different ways radon can infiltrate a building, and the impact of user behaviour on the concentration of this gas.

3. Radon as a Health Risk Factor

Radon is the most significant source of natural ionising radiation exposure for humans (9, 10). It is regarded as the leading cause of lung cancer among non-smokers and the second leading cause among smokers and ex-smokers.

The relation between radon and lung cancer was first identified in uranium mine workers exposed to high concentrations of radon gas (11, 12).

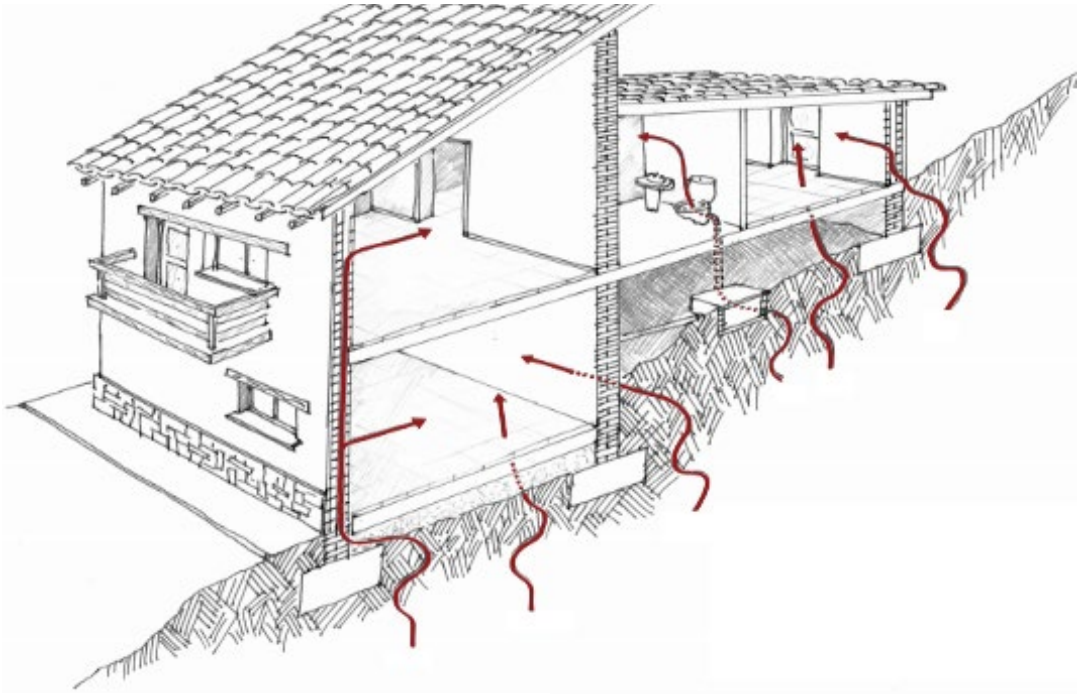
Subsequently, epidemiological studies have been conducted, highlighting the risk produced by the relation between lung cancer and indoor radon exposure. Three notable meta-analyses were carried out in Europe (13, 14), North America (15, 16), and China (17), respectively. Their findings confirmed that radon exposure in dwellings can be considered a risk factor for the development of lung cancer.

Presence of radon in indoor or enclosed environments

Radon occurs naturally underground, and rises to the surface in greater or lesser amounts, depending on the type of soil. Greater amounts of radon are produced in granitic areas compared to clayey or calcareous regions, as granite contains higher levels of uranium and thorium than other soil types, such as sandstone, carbonate, or basaltic soils (18).

Outdoors, radon is quickly diluted to very low concentrations (typically between 5 Bq/m^3 and 15 Bq/m^3) (19) and does not generally represent a significant issue, except in certain anticyclonic conditions where the mixing height is substantially reduced. Indoors, however, radon concentrations can be much higher, especially in locations like mines, caves or water treatment facilities, where ventilation is poor and levels are typically highest. In buildings such as homes, schools, and offices, radon concentrations can range from below 10 Bq/m^3 to over 10,000 Bq/m^3 (6). Radon can enter buildings through the soil on which they are constructed, via building materials, or through groundwater (20) (Figure 1).

Figure 1. Common pathways of radon entry and weak points.



Source: Frutos Vázquez B et al. (2010) (20).

Soil is the main source of radon emissions in nature, due to the concentration of uranium (U-238) found within it. Certain regions of Spain have high radon levels underground and are therefore more likely to high indoor radon concentrations (21).

The primary way radon enters buildings and dwellings is through migration from the ground through cracks in floors and walls, gaps around pipes or cables or small pores in walls. Older or poorly constructed homes are more likely to experience high indoor radon levels, generally due to inadequate insulation from the ground (20, 22).

Another source of radon emissions comes from certain building materials, containing radium (Ra-226). Radon exhaled by these materials can significantly contribute to the overall radon concentration in a dwelling, potentially increasing it by around 10 Bq/m^3 to 20 Bq/m^3 (23). A list of building materials to be considered in relation to emitted gamma radiation is outlined in Annex VI of Royal Decree 1029/2022. High radon concentrations on upper floors are often linked to the use of these materials (24).

Additionally, the use of groundwater from wells or springs for domestic purposes in areas with high radon concentrations can lead to increased radon levels in homes. Radon in water mainly originates from the emanation from the rocks of the aquifer. Once dissolved in groundwater, radon can enter the home through drains or sewage systems, or diffuses into the air from taps and showers when this water is in use (20).

It is important to note that radon concentration in dwellings is not solely dependent on the type of exposure source, various environmental factors also influence radon levels (20), such as:

- Air infiltration due to wind can alter radon concentrations by affecting the ventilation and airflow within the dwelling.
- Higher atmospheric pressure helps to reduce radon entry into dwellings by decreasing the pressure gradient between the ground and the interior of the dwelling. Conversely, a drop in atmospheric pressure may lead to increased radon exhalation from the ground into the dwelling.
- Given that radon is heavier than air, the likelihood of its presence in dwellings is influenced by the height above ground. Consequently, higher radon concentrations tend to occur in ground floors and in basements.
- Environmental humidity and rainfall saturate the soil, this saturation can clog pores, causing radon to dissolve in water, allowing it to move through underground currents, and reduce its exhalation to the surface.
- Temperature affects convective air movements, which influences radon transport. This often results in higher radon concentrations at night compared to daytime, or depending on the season.

Health effects

Radon and lung cancer

The causal relationship between radon and respiratory diseases began to be observed in the 16th century due to the mortality observed in certain groups of miners. It was not until the 19th century that it was discovered that this mortality was due to lung cancer (25).

Following several studies on miners, the USEPA in 1987 established 148 Bq/m^3 as the radon concentration above which abatement measures should be taken in homes; and a year later, the IARC classified radon and its progeny as Group 1 human carcinogens[1].

Also, in 1987, the Committee on the Biological Effects of Ionising Radiation published the results of a detailed analysis of studies on radon in miners and radon in animals, BEIR IV "Biological Effects of Ionizing Radiation", in which the risk of lung cancer is associated with radon exposure (11). An update of the BEIR IV study (called BEIR VI) was published in 1999, indicating that radon is the second leading risk factor for lung cancer after tobacco (12). Eleven cohort studies involving a total of 68,000 miners from Europe, North America, Asia and Australia were considered for this second study.

Studies on miners pointed to the possibility that the risk could appear in the general population due to exposure occurring indoors in dwellings and workplaces. Since then, numerous observational epidemiological studies on residential radon and lung cancer risk have been conducted in different countries, which despite some heterogeneity, have continued to reveal a causal association between long-term residential radon exposure and lung cancer.

There are three pooled analyses that are considered as a reference for the relationship between residential radon and lung cancer: the European pooled analysis, the North American pooled analysis and the Chinese pooled analysis (13, 14, 15, 16, 17). All of them identify an increased risk of lung cancer from residential radon of 16% (95% CI: 5-31%), 11% (95% CI: 0-28%) and 13% (95% CI: 1-36%) respectively (Figure 2). Of the three studies, the European study is the only one that relies on long-term average radon concentration for the detailed assessment of residential radon risks. In contrast, the other two studies are based on the spot measured radon concentration.

All studies note that the risk percentage does not vary with changes in age or gender. They also establish a linear relationship (the higher the exposure, the higher the risk), with no threshold level below which no risk exists. Furthermore, they show that the risk of lung cancer due to radon is much higher in people who smoke or have smoked in their lifetime than in

[1] Industrial processes, chemical compounds or groups thereof that are carcinogenic to humans. The exposure conditions involve exposures proven to be carcinogenic to humans.

those who have never smoked, showing a synergistic effect between radon and tobacco. Radon is now the second leading external cause of lung cancer, after tobacco, and leading cause in non-smokers.

In 2009, following the publication of these studies, the WHO published “Handbook on Indoor Radon: A Public Health Perspective" (25), which presents the results to date of epidemiological studies showing that radon in dwellings increases the risk of lung cancer in the general population, although no other health effects of radon have been demonstrated.

Figure 2. Summary of lung cancer risk from indoor radon based on international pooled analyses combining individual data from several case-control studies.

	Nbr. of studies included	Nbr. of lung cancers	Nbr. of controls	Exposure Window (years)[a]	Percentage increase in risk of lung cancer per 100 Bq/m³ increase in radon concentration	
					Based on measured radon	Based on long-term average radon[b]
Pooled analyses of studies of indoor radon in the home						
European (Darby et al. 2005, 2006)	13	7 148	14 208	5-35	8 (3, 16)	16 (5, 31)
North American (Krewski et al. 2005, 2006)	7	3 662	4 966	5-30	11 (0, 28)	-
Chinese (Lubin et al. 2004)	2	1 050	1 995	5-30	13 (1, 36)	-
Weighted average of above results of pooling studies					10	~20[c]

[a] Considering radon concentrations during the period from 35 to 5 years before the date of diagnosis in cases of lung cancer, or a comparable date for controls.
[b] Adjusted for year-to-year random variation in indoor radon concentration.
Source: World Health Organization (2015) (25).

Studies of radon exposure in Spain

Specific studies on the relationship between residential radon and lung cancer are also available in Spain (Table 1). The first studies carried out in Spain were identified in the regions of Galicia and Cantabria. The Galician studies reported results showing that there is a risk of lung cancer due to radon even at low concentrations, with a strong synergy with tobacco consumption, similar to those found in the European framework. In contrast, the study carried out in Cantabria found no association between radon and lung cancer, possibly because Cantabria, unlike Galicia, is not an area of high radon exposure (26, 27, 28, 29).

Galicia is classified as a residential radon risk area, where more than 20% of the dwellings have indoor radon concentrations measurements in their homes higher than 200 Bq/m^3, hence most studies have focused on this geographical area.

The first study, published in 2002, included 163 cases and 241 controls in the area of Santiago de Compostela (Galicia). The calculated mean radon concentration was 129.5 Bq/m^3 and the geometric mean was 69.3 Bq/m^3; 22.2% of the dwellings studied were exposed to a radon concentration of 148 Bq/m^3 or more. The results showed a risk of 2.73 (95% CI: 1.12-5.48), 2.48 (95% CI: 1.29-6.79) and 2.96 (95% CI: 1.29-6.79) for those exposed to 37-55.1, 55.2-147.9 and 148 Bq/m^3 or more, respectively, taking as reference those exposed to less than 37 Bq/m^3. The results of this study were included in the European pooled analysis (26).

Later, a study conducted in Cantabria in 2007 found no association between residential radon concentrations and lung cancer. The study included 86 cases and 172 controls from Cantabria between January 2002 and August 2003. The average exposure recorded at home was 46.8 Bq/m^3 for cases and 42.9 Bq/m^3 for controls. The results obtained show a risk of 0.95 (95% CI: 0.33-2.65) for those exposed to more than 37 Bq/m^3, taking as a reference those exposed to less than 37 Bq/m^3. The region of Cantabria is characterised by low levels of radon activity, which explains the results obtained from the study (27).

Another study carried out in the areas of Santiago de Compostela and Ourense was published in 2012, involving 349 cases and 513 controls between 2004 and 2008. The results showed that more cases than controls were exposed to high radon concentrations, 18.6% and 20.1% of cases were exposed to 101-147 and >147 Bq/m^3 respectively, compared with 14% and 15% of controls. It was observed that the risk of lung cancer increased with residential radon exposure. The risk was statistically significant above 50 Bq/m^3 with risks of 1.87 (95% CI: 1.21-2.88); 2.25 (95% CI: 1.32-3.84) and 2.21 (95% CI: 1.33-3.69) for those exposed to 50-100 Bq/m^3, 101-147 Bq/m^3, and more than 148 Bq/m^3, compared to those exposed to less than 50 Bq/m^3 respectively (28).

The LCRINS (Lung Cancer Risk in Never Smokers) study began in 2011, with the aim of analysing the association between radon and lung cancer in people defined as never smokers. The first results were published in 2014, involving 192 cases and 329 controls from Galicia and Asturias between 2011 and 2013. 48% of the cases were exposed to >200 Bq/m^3 compared to 29.4% of the controls. The results show a significant risk of 2.42 (95% CI: 1.45-4.06) for non-smokers exposed to >200 Bq/m^3 compared to those exposed to <100 Bq/m^3. In addition, a risk of 1.99 (95% CI: 1.16-3.41) is observed for those exposed to radon concentrations >200 Bq/m^3 and who did not live with smokers. This risk changed to 2.75 (95% CI: 1.44-5.25) for those who were exposed to the same radon concentration, and who have lived between 1 and 35 years with smokers. This is the first study to suggest a possible association between exposure to residential radon and environmental tobacco smoke on lung cancer risk (29). The final results of the research were published in 2019 and it is one of the studies with the largest number of

non-smoking subjects to have their residential radon levels measured, 523 case studies and 892 control. The results showed a significant linear association between radon and lung cancer (30).

In 2020, a study was published combining data from research conducted by the University of Santiago de Compostela (USC), involving more than 3,700 participants (1,842 cases and 1,862 controls). The results showed that the risk of lung cancer increases with exposure to radon even below the levels established by international organisations, with a statistically significant risk of 2.06 (95% CI: 1.61-2.64) at 200 Bq/m^3 and above compared to participants exposed to less than 50 Bq/m^3. In addition, an effect modification was found between radon exposure and tobacco use (31).

A cohort study conducted in Galicia in 2017 linked the association between lung cancer and radon using radon mapping (from a cross-sectional study) and controls from a previous case-control study. Out of a total of 2,127 participants, 1,932 were finally analysed and 24 cases of lung cancer were identified. The relative risk for the category of individuals exposed to 50 Bq/m^3 or more was 1.2 (95% CI: 0.5-2.8), although no statistically significant association between residential radon exposure and lung cancer was observed. However, it seems that with a sample of older individuals, the risk of lung cancer would have been higher (32).

In addition to case-control and cohort studies, an ecological study was conducted in Galicia in 2015 to analyse the correlation between lung cancer mortality and residential radon exposure in Galician municipalities. This study, included 192 municipalities with at least 3 residential radon measurements each. To obtain data on lung cancer mortality, the number of observed deaths was obtained from the Galician Mortality Registry, and then standardised mortality ratios (SMRs) for lung cancer were then calculated for both sexes for the period 1980-2009. Median concentrations of residential radon for each municipality were correlated with lung cancer SMRs and the results showed that the median concentration of residential radon in the municipalities analysed was 75 Bq/m^3, ranging from 40.7 to 154 Bq/m^3. Furthermore, the correlation between lung cancer SMRs and radon concentration was found to be significant for males ($p = 0.023$), concluding that there is an association between residential radon and municipal lung cancer mortality in males, whereas for females this association was not statistically significant ($p = 0.087$) and therefore inconclusive (33).

Table 1. Studies on residential radon and lung cancer in Spain

Author, Year	Type, place	Sample size	Results
Barros-Dios *et al*. 2002	Santiago de Compostela, Galicia. Spain	163 cases and 241 controls	Risks of 2.73 (95% CI: 1.12-5.48); 2.48 (95% CI: 1.29-6.79) and 2.96 (95% CI: 1.29-6.79) for those exposed to 37-55.1; 55.2-147.9 and 148 Bq/m^3 or more, taking as a reference those exposed to less than 37 Bq/m^3
Llorca J *et al*. 2007	Cantabria. Spain	86 cases and 172 controls	Risk of 0.95 (95% CI: 0.33-2.65) for those exposed to >37 Bq/m^3 for those exposed to less than 37 Bq/m^3
Barros-Dios *et al*. 2012	Ourense and Santiago de Compostela, Galicia. Spain	349 cases and 513 controls	Risks of 1.87 (95% CI: 1.21-2.88); 2.25 (95% CI: 1.32-3.84) and 2.21 (95% CI: 1.33-3.69) for those exposed to 50-100, 101-147 and over 148 Bq/m^3 compared to those exposed to less than 50 Bq/m^3 respectively
Torres-Durán M *et al*. 2014	Galicia and Asturias. Spain	192 cases and 329 controls	Never smokers. Risk of 2.42 (95% CI: 1.45-4.06) for those exposed to > 200 Bq/m^3 compared to those exposed < 100 Bq/m^3
Barbosa-Lorenzo *et al*. 2015	Galicia. Spain	Population by Galician municipalities from 1980 to 2009	Significant correlation between SMR for lung cancer in males and radon concentration
Barbosa-Lorenzo *et al*. 2017	Galicia. Spain	1,932 individuals	Risk of 1.2 (95% CI: 0.5-2.8), for those exposed to 50 Bq/m^3 or more
Lorenzo-González M *et al*. 2019	Galicia, Asturias, Castile and Leon, Madrid. Spain	523 cases and 892 controls	Risks of 1.14 (95% CI: 0.80-1.64); 1.25 (95% CI: 0.85-1.85) and 1.73 (95% CI: 1.27-2.35) for those exposed to 101-147; 148-199 and 200 Bq/m^3 or more.
Lorenzo-González M *et al*. 2020	Galicia. Spain	1,842 cases and 1,862 controls	Risks of 1.61 (95% CI: 1.25-2.08); 1.64 (95% CI: 1.25-2.15); 1.81 (95% CI: 1.31-2.45) and 2.06 (95% CI: 1.61-2.64) for those exposed to 51-100; 101-147; 148-199 and more than 199 Bq/m^3.

Residential radon burden of disease

The burden of disease concept refers to the number of radon-induced lung cancers attributable to exposure to residential radon. The WHO estimates that worldwide the average indoor radon concentration is 39 Bq/m^3, and that between 3 and 14% of lung cancer cases worldwide are related to residential radon depending on the average radon concentration in the country concerned. In Europe, radon is responsible for 9% of lung cancer deaths (13), and in Spain, in particular, it is estimated that radon causes about 4% of all lung cancer deaths (35), or about 1,500 deaths per year (34).

In Spain there are few studies that analyse the burden of disease due to residential radon. One of them estimated the percentage of lung cancer deaths that are related to residential radon exposure in Galicia (Table 2). The results estimate that 3-5% of lung cancer mortality is exclusively due to residential radon exposure. The mortality attributable to the combined effect of radon and tobacco is about 22% for those exposed to levels above 148 Bq/m^3. Therefore, using the USEPA action level (148 Bq/m^3), radon would be involved in 25% of lung cancer deaths in Galicia (36).

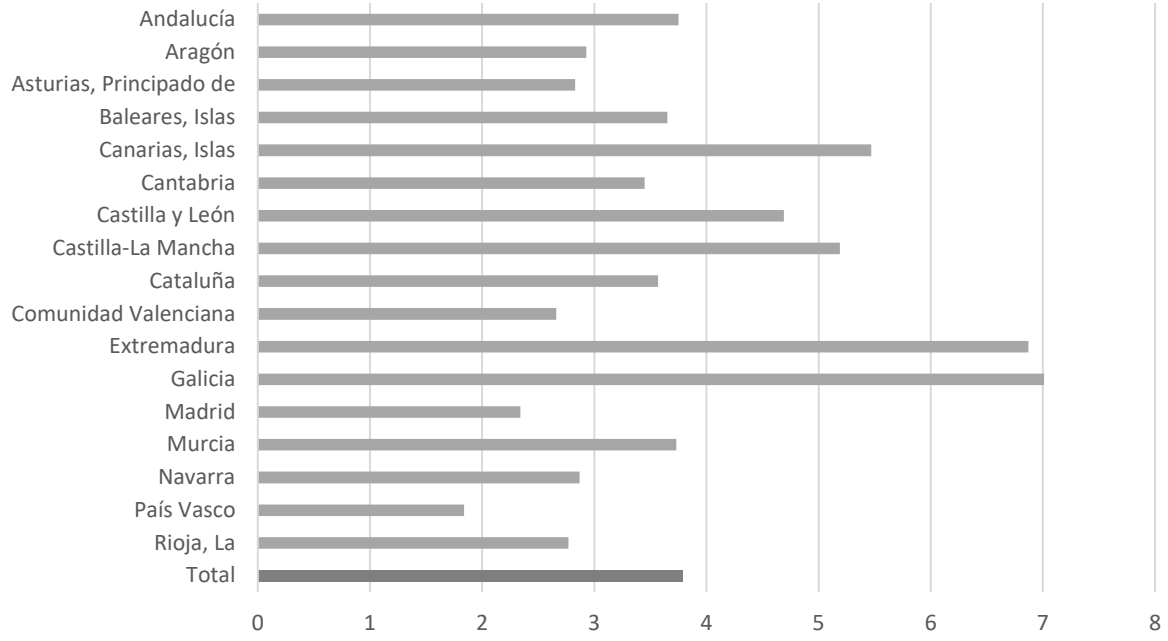
Table 2. Percentage of lung cancer mortality in Galicia attributable to exposure to radon and tobacco.

	37 Bq/m^3		148 Bq/m^3	
	Attributable deaths (%)	No. of deaths	Attributable deaths (%)	No. of deaths
Unexposed - Non-smokers	6.66%	87	7.98%	105
Unexposed – Ex- smokers	14.07%	185	38.78%	509
Unexposed - Smokers	5.30%	70	27.93%	367
Exposed - Non-smokers	4.50%	59	3.29%	43
Exposed – Ex- smokers	31.38%	412	6.61%	87
Exposed - Smokers	39.09%	500	15.41%	202
Total	100%	1,313	100%	1,313

Source: Pérez-Ríos M et al. (2010) (36).

A recently published study estimates the impact of radon on lung cancer mortality in Spain in 2017. For the first time, the study includes a correction for population exposure to radon according to dwelling height. The results show that approximately 4% of all lung cancer deaths in Spain would be related to radon exposure, with large differences between different Autonomous Communities, such as Galicia, where this percentage rises to 7%, or Extremadura with 6.9% (Figure 3). This study also notes that most radon-related deaths occur in men, both smokers and ex-smokers (35).

Figure 3. Percentage of lung cancer mortality attributable to radon exposure by Autonomous Community, 2017.



Source: based on data from Ruano-Raviña A et al. (2021) (35).

Estimates of the burden of disease due to residential radon have been published in other countries such as Germany, Switzerland, France, the United Kingdom, Italy and Portugal (Table 3). Most of them use a similar methodology, based on using the results of the European pooled analysis as an estimate of the lung cancer risk attributable to residential radon. The results vary from 3.3% of lung cancer cases attributable to radon in the United Kingdom to 18-28% in Portugal (37, 38, 39, 40, 41).

Table 3. Estimation of the proportion of cases due to radon in different European countries.

Country	Mean indoor radon concentration [Bq/m^3]	Percentage of lung cancer attributable to radon [%]	Estimated no. of deaths due to radon-induced lung cancer each year
Germany (Menzler *et al*. 2008)	49	5	1,896
Switzerland (Menzler *et al*. 2008)	78	8.3	231
France (Catelinois *et al*. 2006)	89	5	1,234
United Kingdom (Gray *et al*. 2009)	21	3.3	1,089
Italy (Bochicchio *et al*. 2012)	71	10	3,326
Portugal (Veloso B *et al*. 2012)	16-210	18-28	1,533-2,384
Spain (Ruano-Raviña A *et al*. (2021)	--	3.8	838

Source: data adapted from WHO (2015) (25).

There is sufficient scientific evidence to support the link between residential radon exposure in the home and lung cancer. However, there are few studies linking radon exposure to other diseases and more research is still needed in this area. Nevertheless, there are studies in Spain suggesting a causal relationship between residential radon exposure and oesophageal cancer and brain cancer, among others (42, 43). Other countries have investigated the association between residential radon and diseases other than lung cancer. Some of these have found associations between radon exposure and the development of skin cancer (44), acute lymphoblastic leukaemia (45), central nervous system tumours (46) and chronic obstructive pulmonary (COPD) (47). These associations are too weak to be conclusive, but should be taken into account for future studies.

Additional risk factors

Studies to date do not appear to show that gender or age are risk factors associated with radon exposure. However, smoking, place of residence or occupation have been shown to increase the risk of developing lung cancer associated with radon exposure.

Extrinsic (modifiable) factors:

- **Tobacco:** According to the WHO data, radon has a synergistic effect with tobacco on the risk of developing lung cancer. These data show that a smoker's risk of developing lung cancer is up to 25 times higher than that of a non-smoker. This means that if they lived in an area free from this type of gas, their chances of developing cancer would be much lower (25).

An important example is the BEIR VI model, which in addition to the relationship between radon exposure and lung cancer, aimed to demonstrate a synergism between radon exposure and tobacco on lung cancer risk. Based on BEIR VI, the USEPA estimated that at a radon level of 148 Bq/m^3 (4 pCi/L), the risk of inducing cancer in non-smokers is 7 out of 1000, compared to 62 out of 1000 in smokers (12).

Other studies have followed this line showing similar results of this synergy, suggesting a strong interaction between radon exposure and smoking, i. e. smokers have a higher risk of dying from radon-induced lung cancer than non-smokers. On this basis, the European review concludes that most radon-related deaths occurred in people who smoked (13, 14).

Because of this association, various sources have discussed a common policy for the prevention of smoking and radon exposure. It is considered to be a more cost-effective way of reducing the health burden of radon, because residential polices for radon control would be more effective and efficient when combined with tobacco prevention and control. They note that working on both issues simultaneously could reduce the incidence rate in lung cancer; however, according to data is not only not decreasing, but is increasing, particularly in areas where radon levels are known to be high. Coordinated activities for radon and tobacco control are a necessary area of work (48).

- **Occupation:** Studies of underground miner workers exposed to radon, usually at high concentrations, have shown an increased risk of lung cancer (11, 12). Lung cancer rates in miners exposed to radon have been studied using cohort designs. These studies identify workers employed in mines for a certain period of time and follow-up on them, whether they are still working in the mine or not, to determine their vital status at the end of that period.

  Working in enclosed or underground workplaces is also associated with an increased risk of lung cancer when there are high indoor radon concentrations. In the workplace, as in the home, exposure can extend throughout the working day and over years, posing a significant risk.
- **Residential buildings:** As detailed above, there are numerous studies linking residential radon exposure to lung cancer risk. In particular, as an important starting point for this relationship, we can highlight the three pooled analyses (European, North American and Chinese), all of which agree on the risk of lung cancer from residential radon (13, 14, 15, 16, 17). In this case, the location of the dwelling is not as easily modifiable as the characteristics of the dwelling. In this respect, there are remediation measures in dwellings and buildings with the aim of reducing the occupant's exposure to radon.

<u>Intrinsic (non-modifiable) factors:</u>

- **Gender:** There does not appear to be a clear association between sex and radon and cancer risk. However, several studies have found significant correlations of lung cancer

risk with radon exposure in men, but not in women. This could be due to the fact that most studies of residential radon and lung cancer have been carried out mainly in men and that the incidence of lung cancer in Spain is higher in men because of its association with smoking.

A very interesting finding of the ecological study carried out by Barbosa-Lorenzo *et al.* (33) in Galicia is the correlation, close to statistical significance, in women. In this case, a very high percentage of the women included in the study had never smoked. Lung cancer has a peak incidence between the ages of 65 and 70, and in the years included in the analysis hardly any Galician women smoked, which shows that radon could indeed influence the risk of death from lung cancer.

- **Age:** As in the previous case, age has also not been shown to be a risk factor for radon related cancers; there is no higher risk is observed in one age group than in another. What does have an influence is the period of exposure, as increase in exposure time would increase the probability of developing an adverse health effect. In other words, a younger person living under certain radon exposure conditions will spend more time exposed to radon during his or her lifetime than an older person under the same conditions. In this context, age would imply the increased risk of cancer development due to increased exposure time, not age *per se*.

4. Regulatory framework

The National Radon Action Plan is being developed within the regulatory framework of the Royal Decree 1029/2022, of 20 December, approving the Regulation on health protection against the risks arising from exposure to ionising radiation (1), which partially transposes the radon-related requirements of the European Council Directive 2013/59/Euratom of 5 December 2013 (49) laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation (hereinafter Directive 2013/59/Euratom). This Directive, which includes radon, establishes the need for Member States to implement action plans to reduce in the medium and long term the risk of lung cancer attributable to radon exposure. These requirements imply an extension of the scope and level of protection of the current regulatory framework, as well as the introduction of communication and support measures beyond the legal field.

It also falls within the scope of the Strategic Health and Environment Plan (2), approved on 24 November 2021 at an extraordinary meeting of the Plenary of the Interterritorial Council of the National Health System and the Sectoral Conference on the Environment, whose main objective is to promote environmental settings that improve the health of the population and reduce the risks associated to exposure to environmental factors, including exposure to radon.The requirements for protection against radon are laid down in Royal Decree 1029/2022, which approves the Regulation on health protection against the risks arising from exposure to ionising radiation

Article 19 on measures in workplaces states that:

1. For the purposes of radiation protection, and following a prior assessment to determine the nature and magnitude of the radiological risk to exposed workers, the employer shall identify, delimit and classify all workplaces where there is a possibility of receiving effective doses in excess of 1 mSv per official year and shall establish the applicable radiation protection measures. Such measures shall be adapted to the nature of the installations and sources, and to the working conditions and rules, as well as to the magnitude and nature of the risks. The extent, nature and quality of the means of prevention and surveillance must be appropriate to the risks associated with work involving exposure to ionising radiation. The risk of exposure to ionising radiation and the radiological protection measures shall be taken into account, in an integrated manner, in the occupational risk prevention plans, risk assessments and planning of preventive measures established in Law 31/1995, of 8 November, for Occupational Risk Prevention.

2. If there are areas in a workplace where the concentration of radon in the air exceeds the reference level set out in Article 72(a), despite the measures taken in accordance with the principle of optimisation, the employer licensee must:

> (a) Reassess airborne radon indoor concentrations of radon at a frequency to be determined in each case by the Spanish Nuclear Safety Council.

(b) Estimate the annual effective doses due to radon that may be received by workers with access to such areas. These doses shall not be taken into account for compliance with Articles 18 and 22.

(c) Shall classify as workers exposed to radon the workers who are likely to receive an effective dose from exposure to radon in excess of 6 mSv per official year shall be classified as workers exposed to radon.

(d) Shall classify and identify as radon areas aAll places where there is an indoor radon concentration likely to result in an effective dose to workers of more than 6 mSv per official year shall be classified and identified as radon areas.

3. Whenever in any of the workplaces referred to in Article 75(1) there are workers whose annual effective dose due to radon may exceed 6 mSv, the employer licensee shall determine the radiation protection measures. The scope of these measures will depend on the associated risk and, in particular, articles 11, 16, 19(2)(c), 19(2)(d), 23, 24, 25, 31(2), 31(3), 31(4), 32, 36, 39(1), 40(2), 42 and 43 shall apply.

4. In aircraft operating companies where the annual effective dose to the crew because of exposure to cosmic radiation may exceed 6 mSv per official year, the employer shall manage such exposure in accordance with this regulation.

Article 72 lays down the reference levels for existing exposure situations, which are:

(a) For indoor exposure to radon, 300 Bq/m^3, in terms of the annual average activity concentration of radon in air, both for dwellings or buildings open to the publicand for workplaces.

(b) For indoor external exposure to gamma radiation emitted by building materials, shall be 1 mSv per year, in addition to outdoor external exposure.

With regard to the **requirements for radon in workplaces**, Article 75 sets out the employer's obligations in relation to radon exposure:

1. Employers in the following workplaces listed below, shall estimate the annual average activity concentration of radon in air in all areas of the workplace in which workers are required to remain or to which they may access by reason of their work, excluding outdoor areas:

(a) underground workplaces, such as construction sites, tunnels, mines or caves.

(b) places where groundwater is processed, handled or exploited, such as thermal baths and spas.

(c) All workplaces located on the ground floor or basement level in the priority municipalities referred to in Article 79.

2. In the case of workplaces with areas where the annual average activity concentration of radon in air exceeds the reference level of 300 Bq/m^3, the employer shall take appropriate measures to reduce the radon concentrations and/or the exposure, in accordance with the principle of optimisation, after which the annual average activity concentration of radon in air at the workplace shall be reassessed.3. If, despite the measures taken in accordance with paragraph 2, the annual average activity concentrations of radon in air in any of the areas of the workplaces referred to in paragraph 1 continues to exceed, on an annual average basis, the reference level of 300 Bq/m^3, the employer shall comply with Article 19 and other applicable Articles.

The National Radon Action Plan is detailed in Articles 77, 78 and 79:

Article 77. Establishment of the National Radon Action Plan

1. The Government shall establish the policy to reduce the risk to the health of the population due to indoor radon exposure by approving the National Radon Action Plan. The Plan shall be proposed by the Ministry of Health and reviewed every five years.

2. The National Radon Action Plan shall include measures to promote the identification of dwellings, buildings with public access and workplaces where the annual average activity concentration of radon in air exceeds the reference level set out in Article 72(a), for any source of radon ingress, whether soil, water or building materials, and to promote the reduction of the radon concentration therein by technical or other means. The National Radon Action Plan shall cover the aspects set out in Annex VIII.

3. The National Radon Action Plan shall include the strategies to be adopted and the activities to be carried out by the different public bodies in order to reduce the risk to the health of the population due to exposure to radon. In this regard, the Autonomous Communities and Local Authorities, within the scope of their respective competences and within the framework of the National Plan, may draw up their own plans.

Article 78. National Radon Action Plan Committee

1. The National Radon Action Plan Committee is established, attached to the Ministry of Health, and is made up of representatives of the authorities competent in the matters covered by the Plan, with the following composition:

a) Chair: a representative of the Ministry of Health, with the rank of Director General.
b) Vice-chair: a representative of the Spanish Nuclear Safety Council, with the rank of Technical Director.

c) Board members: board members of the Committee shall be:

1º Eight people appointed to positions of at least the rank of Head of Area or equivalent, representing each of the following ministerial departments: two representatives from the Ministry of Health; two representatives from the Ministry for the Ecological Transition and Demographic Challenge; two representatives from the Ministry of Transport, Mobility and Urban Agenda; two representatives from the Ministry of Labour and Social Economy.

2º Two representatives of the Spanish Nuclear Safety Council, with at least rank of Head of Area or equivalent.

3º One representative from each Autonomous Community and City with a Statute of Autonomy interested in participating, with at least the of Deputy Director-General or equivalent.

4º Three representatives from local authorities, appointed by the Spanish Federation of Municipalities and Provinces.

2. The bodies appointing the members of the Committee shall at the same time appoint their alternates, according to the same criteria as those referred to in paragraph 1.

3. The Secretariat of the National Radon Action Plan Committee shall be provided by an official appointed by the Ministry of Health, who shall not be considered a member of the Committee. In the event of absence, vacancy or illness, an official designated by said Ministry shall deputise.

4. The functions of the Committee shall be as follows:

a) To prepare the National Radon Action Plan and submit it to the Ministry of Health for approval by the Government.
b) To update the National Radon Action Plan every five years, in accordance with scientific knowledge and the progress made of the measures included in it, and to submit these updates to the Ministry of Health for approval by the Government.
c) To promote, evaluate and supervise compliance with the action guidelines set out in the Plan.
d) To act as a liaison body between the ministerial departments and their agencies and the regional and local administrations, in order to ensure the coordination of the criteria and policies defined by them.

5. The National Radon Action Plan Committee shall be set up within one month of the entry into force of this Royal Decree and shall meet as necessary to carry out its functions, but at least every two years.

6. The National Radon Action Plan Committee may set up a working group consisting of representatives of the member ministries of the National Radon Action Plan Committee and the Spanish Nuclear Safety Council to discuss and prepare proposals to be submitted to the National Radon Action Plan Committee. This working group may include the participation of experts as it may convene.

7. The National Radon Action Plan Committee may invite as many experts as it deems appropriate to attend its meetings or parts thereof, with the right to speak but not to vote.

8. Without prejudice to the provisions established in this Royal Decree, the functioning of the Committee shall be in accordance with the provisions on collegiate bodies in articles 15 to 22, both inclusive, of Law 40/2015, of 1 October, on the Legal Regime of the Public Sector, with regard to its convening, as well as its system of constitution, the adoption of agreements, the holding of meetings and the substitutions of its members.

9. The meetings of the Committee and the working group may be held both in person and remotely, in the terms provided for in article 17.1 of Law 40/2015, of 1 October.

10. The creation and operation of the Committee and, where appropriate, of the working group, will not entail any increase in public expenditure and shall be covered by the human, technical and budgetary resources of the Ministry of Health.

Article 79. List of local terms of priority action

The Spanish Nuclear Safety Council shall publish, on the basis of the best available information, an instruction containing a nationwide list of municipalities in which a significant number of buildings exceed the reference level set out in Article 72(a). This list will be updated periodically, by means of an Instruction of the Spanish Nuclear Safety Council, depending on the state of progress of the National Radon Action Plan and on the new data available.

Annex VIII constitutes the list of items to be considered in preparing the national action plan to address the long-term risks from radon exposures as referred to in the previous mentioned Articles. The list consists of:

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).

2. Approach, data and criteria used for delineation of areas or for definition of other parameters that can be used as specific indicators of situations with potentially high exposure to radon.

3. Identification of the 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.

4. 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.

5. Assignment of responsibilities (governmental and non-governmental), coordination mechanisms and available resources for implementation of the action plan.

6. Strategy for reducing radon exposure in dwellings and for giving priority to addressing the situations identified under point 2.

7. Strategies to facilitate post-construction remedial action.

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

9. Schedules for reviews of the action plan.

10. Strategy for communication to increase public awareness and inform local decision makers, employers and employees about the risks of radon, including in relation to smoking.

11. Guidance on methods and tools for measurements and remedial measurement. Criteria for the accreditation of measurement and remediation services shall also be considered.

12. Where appropriate, provision of financial support for radon surveys and for remedial measures, in particular for private dwellings with very high radon concentrations.

13. Long-term goals in terms of reducing lung cancer risk attributable to radon exposure (for smokers and non-smokers).

14. When appropriate, consideration of other related issues and corresponding programmes such as programmes on energy saving and indoor air quality.

Likewise, in order to comply with the provisions of article 103.2 of Directive 2013/59/Euratom, Royal Decree 732/2019, of 20 December, which amends the Technical Building Code, approved by Royal Decree 314/2006, of 17 March, has been approved. The Preamble of the

Royal Decree states that "As a consequence of the above and for the partial transposition of this Directive, this Royal Decree introduces a new basic health requirement HS 6, protection against radon gas, which requires that, in buildings located in municipalities where a non-negligible level of risk has been assessed, adequate means must be provided to reduce the foreseeable risk of inadequate exposure to radon from the ground". For this reason, Section HS 6 is further developed in Annex II: Protection against exposure to radon in the Basic Health Document, which sets out the requirements to be met in new buildings and certain interventions in existing buildings to reduce the foreseeable risk of inappropriate exposure to radon from the ground in enclosed spaces. This Royal Decree also partially transposes Article 74 of the Directive for dwellings located in new buildings or in existing buildings undergoing interventions within the scope of the new HS 6 section of the Technical Building Code (CTE), establishing a reference level for the annual average indoor radon concentration of 300 Bq/m^3.

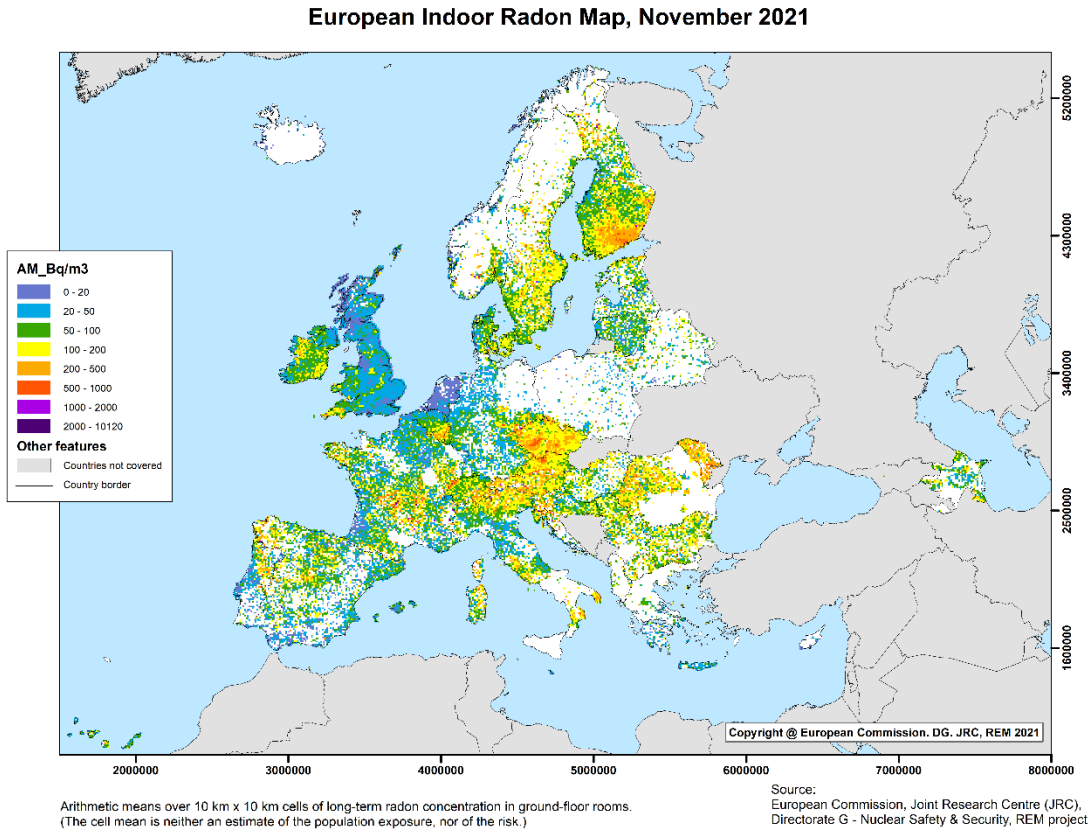
In order to comply with the provisions of Council Directive 2013/51/Euratom of 22 October 2013 laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption, Royal Decree 314/2016, of 29 July, was approved, amending Royal Decree 140/2003, of 7 February, by which health criteria for the quality of water intended for human consumption are established, Royal Decree 1798/2010, of 30 December, regulating the exploitation and marketing of packaged natural mineral and spring water for human consumption, which, in its ninth additional provision, refers to the characterisation of supply areas in terms of radon exposure. This characterisation provides information on the extent and nature of the potential radon exposure of drinking water, which are determined by the geology and hydrology of the area, as well as the radioactivity of the rocks or soil. In this way, "basic criteria are adopted for the protection of the health of the population against the hazards arising from ionising radiation, natural or otherwise, to water for human consumption". Royal Decree 140/2003 has been repealed by Royal Decree 3/2023, of 10 January, which establishes the technical and sanitary criteria for the quality of drinking water, its control and supply, which includes the requirements of Royal Decree 314/2016 on ionising radiation.

5. Diagnosis of the situation

The current European and international situation

Radon exposure in Europe is not homogeneous, nor are the measures currently being implemented in the different European countries (Figure 4). While some countries do not have an action plan, others have well-established national radon action plans with more than 20 years of experience (50).

Figure 4. European radon map.



Source: European Indoor Radon Map, European Commission, DG, JRC, REM 2020 (51).

In Europe, most countries have radon-related bodies or institutions, most notably the Radiation Protection Institute in Ireland and the Radiological Institute for Nuclear Safety in France. Other organisations, such as the European Radon Association (ERA), have also established a European Radon Day on 7 November.

As for other national plans, there are some examples in neighbouring countries. One of these is the National Radon Plan (PNR) developed by Italy in 2002, which includes how to locate buildings with high radon concentrations, the sources of radon and other factors affecting radon concentrations in buildings, how to measure radon concentrations in the air, and how to reduce and avoid high concentrations of radon in the buildings (52). It also provides information, training, qualification and standards, and includes studies and similar actions in

its "Building" axis, adapting them to the situation in the country. In 2005, the PNR was launched through the Project Launch of the National Radon Plan for Lung Cancer Risk Reduction in Italy (acronym PNR-CCM, in Italian) (53), approved by the National Centre for Disease Prevention and Control. In order to give continuity to the activities carried out under the PNR-CCM project, in 2012, the Ministry of Health approved the two-year project National Radon Plan for Lung Cancer Risk Reduction in Italy: Second Implementation Phase (acronym PNR-II) (54).

Another example is France, whose national plan has allowed for regulatory monitoring in construction and application of regulations in the workplace, the provision of tools for radon measurements and training of professionals. France has had a second National Action Plan (2011-2015) for radon risk management with the main aim of reducing exposure in dwellings (55). The country then developed a third National Action Plan (2016-2019) which highlights the need to initiate a global information and awareness raising strategy, to develop tools for information collection and communication, to further improve the reduction of exposure and its health impact, and to manage radon risk in buildings (56). Currently, the National Action Plan 2020-2024 is in force, which is based on three axes: the first focuses on information and awareness about the risk associated with radon and current regulations, the second focuses on improving knowledge, and the third on radon and construction (57).

There are also other countries with a long history in this area, such as Ireland and the Czech Republic, where radon mapping began in the 1980s. Ireland has had radon legislation in place since 1989 and is currently in the second phase of its National Radon Control Strategy. The first phase of its plan (58), involved the identification of existing buildings with high concentrations, the development of preventive measures in newly built dwellings and measures to be taken in existing dwellings. Research, awareness-raising policies and financial support are other measures implemented in this first phase. In the second period (59), which is currently underway, efforts are focused on reducing the number of lung cancer deaths as a result of increased radon exposure and continuing to raise awareness among both the general public and professionals in the construction sector. They emphasise the need for cooperation and an interdepartmental approach (60). The Czech Republic has in place the National Action Plan for Radon Exposure Control, which allows for the monitoring of programmes implemented between 2000 and 2009 and between 2010 and 2019. One of the main objectives of this plan is to ensure that the administration, professionals and the general public are adequately informed, that effective prevention takes place in the construction of buildings, and that existing exposure is efficiently controlled (61).

The United Kingdom (UK) developed its National Radon Action Plan in 2018 (62), a report prepared by representatives of UK government departments and agencies, with input from stakeholders. This report presents the existing monitoring documents that make up the national radon strategy and the national radon action plan and describes its properties and

health risks, its distribution in the UK and routes of exposure, and the assessment of exposure in dwellings, workplaces, new buildings, water supplies and building materials. It also includes the communication strategy on radon to affected groups.

Sweden also has its National Radon Action Plan since 2018 (63) which includes: planning initiatives with subsequent follow-up in order to implement the strategies and activities defined by the action plan, a long-term communication campaign to promote radon measurement and encourage actions to reduce radon concentration, and that public administrations do their utmost to ensure that all dwellings reach the target of a maximum radon concentration of 200 Bq/m^3.

Since 2019 Germany has had its Radon action plan for the sustainable reduction of radon exposure (64), an action plan developed to address the risks of long-term radon exposure, including measures to improve radon detection in buildings and reduce exposure in homes and workplaces. In order to ensure the best possible protection against radon, the Plan emphasises the need to promote research, development, education and training, as well as information on the risks of radon exposure that will enable the public to take voluntary measures such as ventilating more often, or carrying out construction measures. Additionally, it is remarkable that radon protection should be taken into account in quality assurance measures and financial support for construction projects. The Estonian National Radon Action Plan, also approved in 2019 (65), is one of the Annexes to the National Radiation Safety Development Plan for 2018-2017.

In Belgium, the Federal Agency for Nuclear Control (l'Agence fédérale de Contrôle nucléaire, AFCN) has developed the Belgian National Radon Action Plan (2020-2025) (66) which aims to minimise the risks of radon exposure in private and professional buildings, and is structured around: home monitoring, with measurement campaigns in soil and dwellings in collaboration with regional, provincial and municipal authorities in order to produce a detailed radon concentration map of the country; workplace monitoring, with awareness campaigns and workplace measurement in class 2 municipalities; and communication, by developing a communication plan aimed at the population, local authorities, professional sectors and schools, with the objective of providing information about the problem, demonstrating how to address it, promoting radon testing and stimulating prevention in new construction.

With regard to other European radon action plans, Switzerland implemented its Radon Action Plan 2021-2030 (67) in 2020 to ensure the continuation of the radon protection strategy, following the Radon Action Plan 2012-2020 (68). In 2021, countries such as Finland (69) and Austria (70) adopted theirs. And finally, in December 2022 Portugal approved its National Radon Action Plan, prepared by the Portuguese Environment Agency (Agência Portuguesa do Ambiente, APA) (71).

Another relevant initiative carried out in Europe was the "Radon national action plan workshop", which took place in Paris in September 2014. This workshop addressed a number of issues related to the development of radon action plans due to the health risks associated with radon. The following objectives were considered: to reduce the risk of lung cancer attributable to radon exposure in smokers and non-smokers; mapping to increase radon awareness in each country; radon measurements in some work areas; mapping and defining areas prone to high radon concentrations; and organising a radon database (72). These objectives are also included in the different axes of this document, as will be seen below. The first two aims can be found in the "Knowledge and basic infrastructure" axis, the third in the "Workplaces" axis, the fourth in the "Priority action areas" axis and the last in the "Communication and awareness raising" axis.

In October 2014, the HERCA (Heads of the European Radiological Protection Competent Authorities) published the document "HERCA Action Plan in relation to the transposition and implementation of Directive 2013/59/Euratom (Euratom BSS)" which involved representatives from all European countries and is aimed at supporting the process of transposition and implementation of Directive 2013/59/Euratom, identifying the role of HERCA and defining actions in relation to the transposition of the Directive in the different areas, as well as the relations between HERCA and the European Commission in relation to transposition activities (73). In the same year, the first "HERCA workshop on National Radon Action Plans" was held, whose main aims were to facilitate the preparation or updating of action plans by jointly addressing the steps and activities in the implementation of the requirements of the Directive and to provide a forum for European countries to exchange information, experience and challenges. It was concluded that radon is a public health problem, that National Action Plans should be regularly assessed and updated, and that the long-term goal is to reduce the risk of lung cancer. Most of the workshop participants did not have an action plan, and while the national radon programmes presented had been successful, it was noted that certain aspects needed to be reviewed, especially to raise radon awareness and to accelerate the pace of measurement and remediation measures (74). In June 2022, the "2nd HERCA Workshop on Radon National Action Plans" was held with more than 70 participants from 21 European countries and representatives of international organisations, with the aim of exploring the progress made in each country and promoting continuous improvement.

Current situation in Spain

Limiting the risk of radon exposure to the population requires a multidisciplinary approach and the mobilisation of resources at state, regional and local levels, which should be addressed, as recommended by international bodies, through national action plans. The content of the National Radon Action Plan is set out in Annex VIII of Royal Decree 1029/2022

of 20 December approving the Regulation on health protection against the risks arising from exposure to ionising radiation.

In Spain, although actions related to the National Radon Action Plan have been carried out, there is still a long way to go and other policies need to be developed. It should be noted that regulations and standards already exist for both the workplace and for building construction, as described in Chapter 3. The following sections of this chapter describe the current situation in different areas.

Since 1989, several studies have been carried out in Spain to quantify radon concentrations, their distribution and to predict their effects on indoor air in buildings. Of particular note is the MARNA project (Map of Natural Gamma Radiation in Spain, according to its Spanish acronym), a research and development project to evaluate the levels of natural gamma radiation in Spain, in accordance with the guidelines of the International Atomic Energy Agency (IAEA) and the European Union. It is being developed under a collaboration agreement between the Spanish Nuclear Safety Council (CSN) and the public company ENUSA, with the participation of the University of Cantabria, the University of Extremadura, the University of Salamanca, Galician Government and the University of Vigo for the first phases of the project (75).

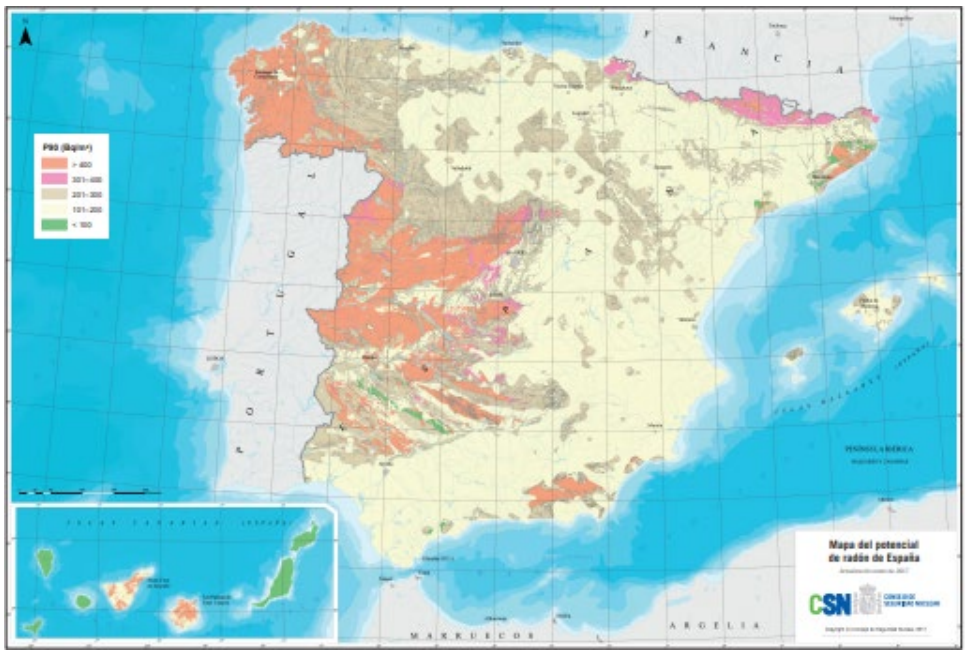
The aim of this project was to have maps of natural radiation, in order to know the levels to which the population is exposed and to be able to evaluate possible increases with respect to the background. The results are useful for epidemiological studies, for the assessment and control of background radiation increases, for the optimisation of site selection of radiation measurement equipment, for estimating absorbed and equivalent dose rates received by the population and for estimating the potential for radon release from a site on the basis of complementary geological and meteorological information. This mapping and zoning of the country based on radon radiological data is so relevant that it is important to keep it updated, which is the aim of the actions under the "Knowledge and infrastructure" axis of this document.

On the basis of the data obtained after the MARNA project, the CSN developed a predictive map of radon exposure (76) which, based on the ambient gamma radiation dose rate, indicates the different probabilities of radon levels in dwellings exceeding certain values. The map was produced by averaging the MARNA survey values on 7x5 km grid. This map divides the territory into three categories of potential exposure: 0-low, 1-medium, and 2-high (21). As a result, priority action areas can be identified and clear and easily enforceable measures need to be targeted to reduce the risk to their populations, as they are the most exposed.

In addition, since the late 80’s, the Spanish Nuclear Safety Council has financed several campaigns to measure radon in dwellings, which in any case have not exceeded 13,000 measurements throughout the country. On the basis of these measurements and a

methodology that incorporates geological and environmental dose rate information, the CSN has developed the radon map of Spain (Figure 5) (77). This map identifies, using the same criteria throughout the national territory, the areas where a significant percentage of residential buildings have concentrations above 300 Bq/m^3, one of the requirements established in Directive 2013/59/Euratom.

Figure 5. Map of radon potential in Spain.



Source: CSN, Radon map of Spain CSN, 2017 (77).

Regulatory framework

Protection against exposure to natural radiation not related the nuclear fuel cycle was first introduced into Spanish legislation by Royal Decree 783/2001, of 6 July 2001, approving the Regulation on Health Protection against Ionising Radiations, as per its acronym in Spanish (RPSRI) (78), amended years later by Royal Decree 1439/2010, of 5 November 2010, amending the Regulation on health protection against ionising radiation, approved by Royal Decree 783/2001, of 6 July 2001. Specifically, Title VII of Royal Decree 783/2001 regulates the exposure of workers to natural sources of radiation, specifically highlighting exposure to radon (Rn-222) and its decay products. Royal Decree 783/2001 was repealed by Royal Decree 1029/2022 in December 2022.

The provisions of the RPSRI are developed in the CSN Instruction 33 (IS-33), which establishes, as a general rule, a reference level of 600 Bq/m^3 of annual average radon concentration in indoor air in workplaces, except for educational centres and workplaces with residential use, where a level of 300 Bq/m^3 is established. In addition, IS-33 includes a list of occupational practices and activities that are required to carry out mandatory radiological studies of radon exposures (79). These work activities are those that take place in underground workplaces (including underground networks, mines, caves visited by tourists, etc.), workplaces where groundwater is exploited or treated (such as groundwater treatment plants or thermal establishments), as well as workplaces located in areas identified as having high radon values. Those whose geological characteristics may generate high amounts of radon or favour its transport within confined areas, e. g. granitic, volcanic or fault-active areas (21, 80).

The reference level for workplaces is also interpreted as an entry level to the occupational radiation protection system. For workplaces where it is demonstrated that it is not reasonably practicable to reduce radon concentrations below the reference level, exposures to radon shall be treated as occupational exposures and therefore the dose limits of the RPSRI shall apply. IS-33 sets out the applicable worker protection measures, with a tiered approach requiring a higher level of control when the annual indoor radon concentration measurement exceeds 1,000 Bq/m^3 (79).

In accordance with this instruction and the RPSRI, the CSN has issued several recommendations in the field of radon exposure control to facilitate compliance with the previous regulations and standards. These can be found in the following Safety Guides:

- Guide GS 11.1 on Guidelines for the competence of laboratories and services for measuring radon in air (89).

- Guide GS 11.2 on the Control of exposure to natural sources of radiation. It recommends a national reference level of 300 Bq/m^3 annual average radon concentration, and a design target level of 100 Bq/m^3 for new buildings or for dwellings

where mitigation actions are to be undertaken. The same reference level applies to long-stay public buildings (e. g. hospitals, nursing homes, etc.) as it does to dwellings, as well as to pre-schools, primary, and secondary schools (81).

- Guide GS 11.4 on Methodology for the assessment of radon exposure in the workplace (82).

Public awareness

According to the World Health Organization, one of the main objectives of the National Plan should be clear and effective communication on the radon problem, an aspect also covered by Royal Decree 1029/2022, which partially transposes Directive 2013/59/Euratom.

Communicating any type of risk to the public involves a number of key steps, including assessing the public´s perception of the risk, using clear and understandable risk messages, and identifying the groups to whom these messages should be addressed.

Radon risk communication campaigns should be designed on the basis of the target groups' perceptions and level of knowledge about radon. On the other hand, having a quantitative baseline assessment of the degree of awareness in society provides the base level from which to evaluate the effectiveness of the actions to be carried out in the National Radon Action Plan.

Although in recent years in Spain the level of public knowledge and awareness of the risks associated with radon has improved, partly due to increased media attention since the adoption of Directive 2013/59/Euratom, there is no evidence that studies have been carried out to date to measure the level of public awareness or sensitivity.

On the other hand, dissemination activities have been carried out by various agents, administrations and public bodies, which have published technical material and provided information on their official websites.

The first such initiatives were launched by the Spanish Nuclear Safety Council in the 1990s. An example of this is the national awareness campaign carried out by the University of Cantabria and the CSN, for which an informative video was produced, reissued and updated on the basis of scientific evidence (83).

It should be noted that for decades, several Spanish universities have focused their research and teaching work on the field of radon; trade unions have also published guides and have launched information campaigns aimed at prevention delegates. Professional societies, such as the Spanish Society for Radiological Protection (SEPR, as per its acronym in Spanish), the Spanish Society of Environmental Health (SESA, as per its acronym in Spanish) or the Spanish Society of Pneumology, have dealt extensively with this issue in their congresses. More recently, following the approval of the regulations in the field of construction in 2019, several professional associations of architects have organised courses and workshops for building professionals.

Radon map of Spain

Radon concentrations in a building are in most cases determined by its geographical location (linked to geology), but due to the large number of factors that influence the radon level it is not possible to predict whether they will be high in each individual case. However, it is possible to make predictions about the areas where dwellings with high radon concentrations are most likely to be found.

The most direct and reliable method to identifying such areas is mapping based on measurements of radon concentration in the indoor air of dwellings. However, mapping from direct measurements requires a large number of measurements and an acceptable density over the entire national territory.

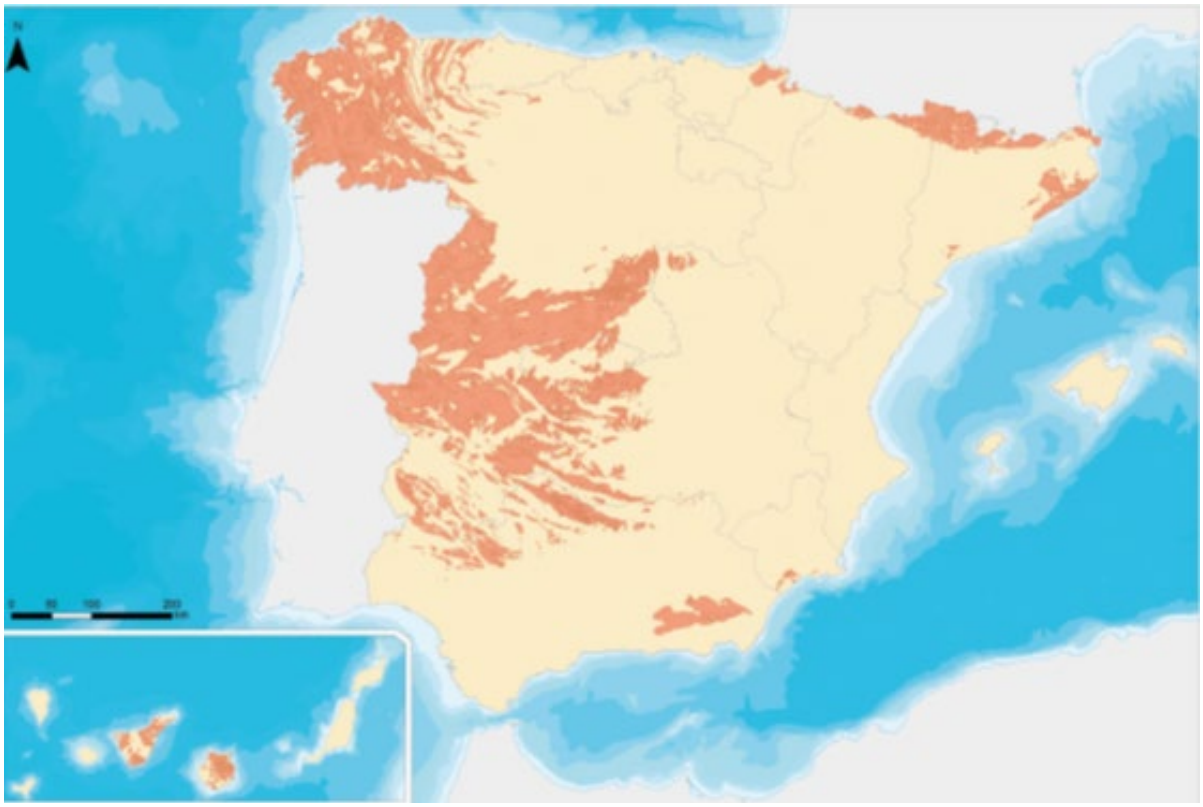
As an alternative, indirect methods have been developed using other magnitudes correlated with radon concentration in dwellings, such as ambient gamma radiation or radon concentration in the soil gas phase. In general, as the soil is the main source of radon in a building, the radon concentration in the soil gas phase is usually a good indicator. This variable in turn depends on the Ra-226 contents of the soil, the underlying rock, the degree of fracturing of the rock formation and the permeability of the soil. Environmental factors, such as barometric pressure or humidity, are not usually included as indicators because of their high variability (21, 76).

The Spanish Nuclear Safety Council (CSN), based on radon measurement campaigns carried out by various universities (University of Cantabria, University of Santiago de Compostela, Autonomous University of Barcelona, University of Las Palmas de Gran Canaria, University of La Laguna), has drawn up a radon map of Spain (Figure 5). This map is based on a hybrid method (84) that combines radon measurements in dwellings available in Spain as of 2017, environmental gamma radiation exposure data from MARNA (75), and lithostratigraphic information (85).

This map categorises the national territory into units of radon potential, defined as the 90th percentile of the distribution of radon measurements in a given geographic area (Figure 6). Specifically, the map identifies areas where more than 10% of buildings may have radon concentrations on the ground or first floor above the reference level of 300 Bq/m^3 established in Article 72 of Royal Decree 1029/2022 in Spanish legislation (units coloured in pink and orange).

The areas on the map with a potential higher than 300 Bq/m³ are considered priority action areas (86), as shown in Figure 6. In total, they represent 17% of the national territory. By Autonomous Community, the percentages of affected areas are as follows: Andalusia, 8%; Aragón, 2%; Asturias, 12%; Canary Islands, 19%; Castile and León, 19%; Castilla-La Mancha, 10%; Catalonia, 16%; Ceuta, 11%; Extremadura, 47%; Galicia, 70%; Madrid, 36%; Murcia, 1%; Navarre, 6%; Basque Country, 2% (77).

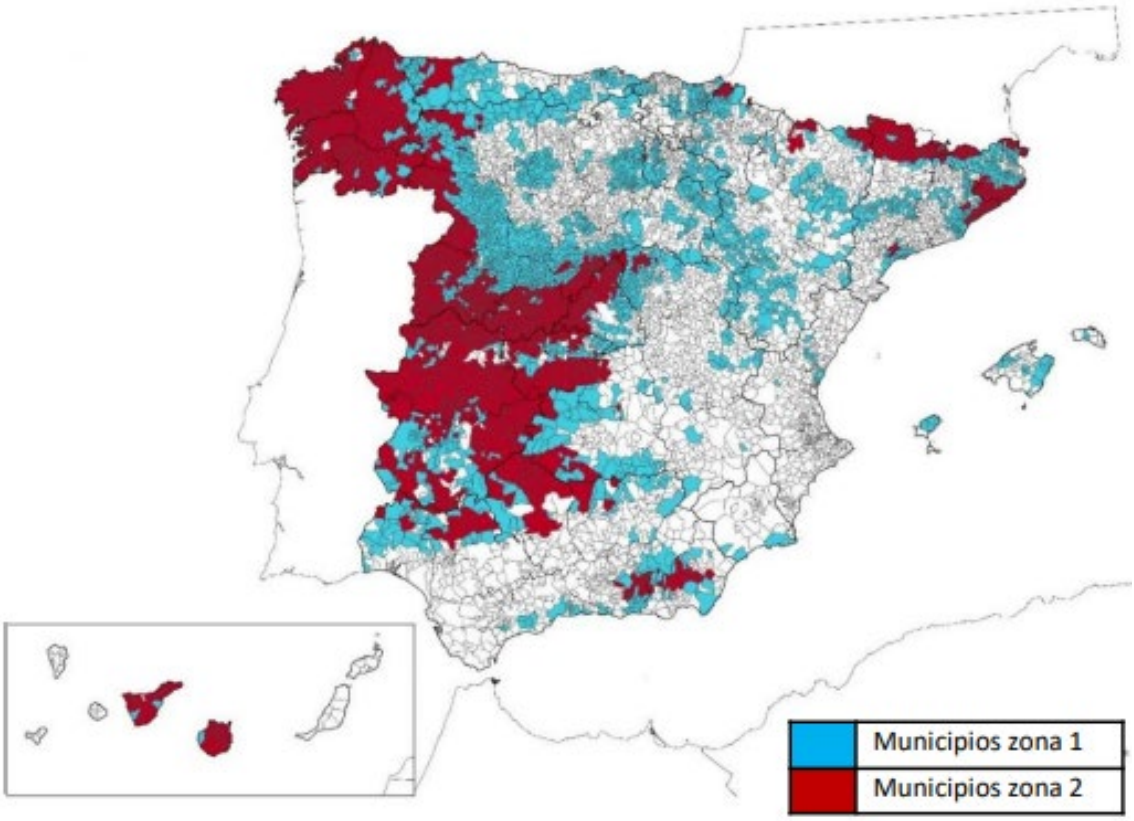
Figure 6. Map of priority action areas.



Source: CSN, National radon potential map of Spain, 2017.

The Technical Building Code (CTE) establishes in the Basic Document HS Health, HS 6 on Protection against exposure to radon a list with the classification of municipalities according to the radon potential (87) (Figure 7). This list, drawn up by the CSN, is based on various studies and maps (77), in which priority action areas have been defined at municipal level. However, these lists may be updated based on new studies or evidence.

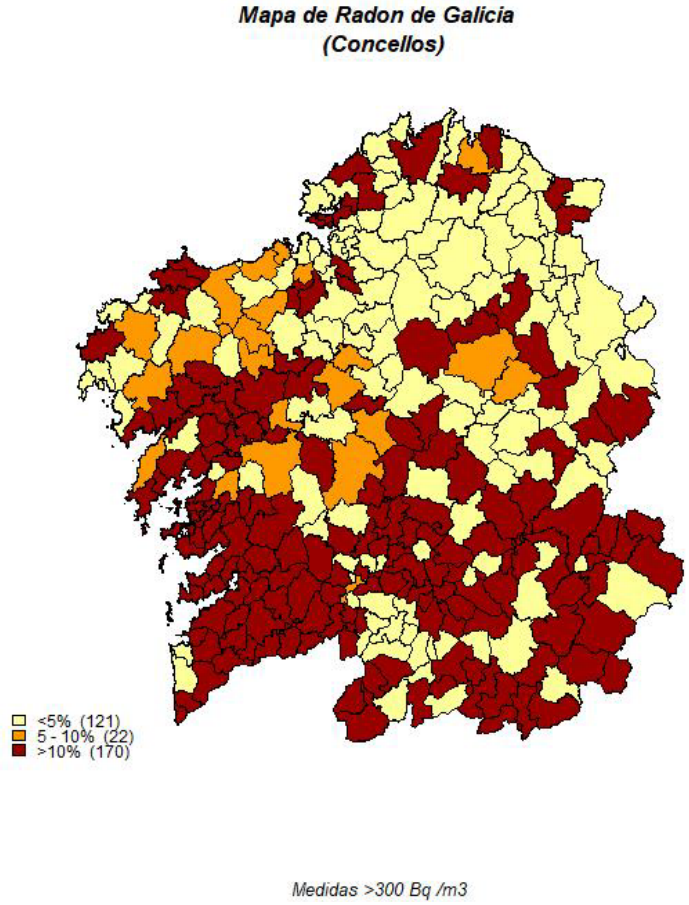
Figure 7. Classification of CTE municipalities according to radon potential.



Source: Ministry of Transport, Mobility and Urban Agenda. Basic concepts on the modification of the CTE, 2020 (87).

On the other hand, in Galicia, the Radon Laboratory of Galicia, which belongs to the USC, has carried out more than 4,300 radon measurements in homes, which has allowed the Galician radon map (Figure 8), which shows radon concentrations in each municipality of the Galician community (88).

Figure 8. Percentage of measurements over 300 Bq/m3 per municipality[2] in Galicia (number of municipalities).



Source: Galician Radon Laboratory (88).

Metrological capacity and infrastructure

A key part of the National Radon Action Plan is to ensure the reliability of both mandatory and voluntary measurements in dwellings and workplaces and to promote an adequate market for services to meet the demand.

In 2010, the CSN published Safety Guide 11.1, which sets out the main requirements to be met by airborne radon measurement laboratories and services. These include general management requirements based on ISO/IEC 17025 and technical requirements specific to radon measurement (89).

[2] Following international guidelines, territorial areas are distributed according to the percentage of houses above the reference level (300 Bq/m^3), the maximum recommended limit is: Low risk if they are below 5%; medium risk if they are between 5 and 10%; and high risk if they exceed 10% of households with more than that level.

The Spanish National Accreditation Body (ENAC) (as per its acronym in Spanish) uses the CSN Guide on the accreditation of measurement laboratories. There are currently accredited laboratories in Spain for the measurement of radon with passive detectors and two laboratories for the use of continuous measurement monitors (https://www.enac.es/entidades-acreditadas/buscador-de-acreditados).

The infrastructures available in Spain include the radon chamber at the University of Cantabria (which has ENAC accreditation) and the one at the Institute of Energy Techniques of the Polytechnic University of Catalonia, where an intercomparison of radon measurements in air under different environmental conditions was carried out in 2021 (90).

Figure 9. Radon chamber.

In addition, the Centre for Energy, Environmental and Technological Research (CIEMAT, as per its acronym in Spanish) is currently in the process of setting up a new radon metrology laboratory to be attached to its Ionising Radiation Metrology Laboratory. This laboratory has been designed on the basis of national metrology laboratories in other related countries and secondary laboratories in Spain. The aim was to optimise existing designs and adapt them to the needs of the state. The laboratory will have a primary national reference standard and a secondary reference standard, the former being unique in Spain. The availability of a primary standard will provide traceability for national laboratories and companies that require it, allow them to participate in key intercomparisons with other equivalent laboratories or to demonstrate their measurement capability.

The Natural Radiation Laboratory (LRN, as per its acronym in Spanish) (Figure 10), was set up in 2010 with the collaboration of ENUSA Advanced Industries at its facilities in Saelices el Chico (Salamanca, Spain), the Spanish Nuclear Safety Council (CSN) and the University of Cantabria (UC). Since 2011, the Laboratory has carried out international intercomparison exercises for radon and external gamma radiation measurements in the greens prepared for this purpose, and training courses for the International Atomic Energy Agency (IAEA) and the CSN.

Figure 10. Natural Radiation Laboratory (LRN).

6. Aims of the National Radon Action Plan

General aim

The main objective of the National Radon Action Plan is **to protect the health of the population and workers from the risks associated with radon exposure**. This aim is supported by Article 77 of Royal Decree 1029/2022 by which the Government shall establish the policy to reduce the risk to the health of the population due to indoor exposure to radon, as well as by Article 103 of Directive 2013/59/Euratom, which aims to establish the basis for reducing, in the medium and long term, the health effects due to indoor exposures to radon (dwellings, public buildings and workplaces).

Strategic and specific aims

In order to achieve the general aim, the document is structured around five strategic axes. It is envisaged that these axes will be built upon, being broken down into the following specific aims:

1. **Understand the magnitude of the problem and identify and address gaps or difficulties in implementing effective controls or solutions.**
    I. Assess the exposure of the population to radon (considering contributions from soil, water and building materials), and estimate its impact on the health of the population.
    II. Ensure the reliability and quality of radon concentration or dose determinations.

2. **Reduce radon concentration in buildings.**
    I. Monitor and promote compliance with applicable legislation and regulations inside buildings.
    II. Promote specific training programmes for the different agents involved in the field of building.
    III. Implement intervention programmes in existing buildings.
    IV. Analyse the impact in terms of architectural typologies, in relation to the existing building.
    V. Design and promote support instruments at regional and municipal level.

3. **Reduce occupational exposures to radon and ensure implementation of the reference level and compliance with the dose limit for exposed workers.**
    I. Monitor and promote compliance with legislation and regulations applicable to workplaces.

4. **Develop action measures to reduce radon exposure in priority action areas.**
    I. Develop a methodology easily applicable in the most affected areas.

II. Incorporate the work carried out by the Autonomous Communities on radon protection.

III. Design and promote support instruments at regional and municipal level.

5. **To raise awareness among the public, professionals and administrations.**

I. Raise public awareness of the health effects of radon, particularly in combination with tobacco.

II. Encourage the commitment of public administrations and the integration of radon into related programmes and plans.

Figure 11. Strategic axes.

7. Axes of the National Radon Action Plan

Knowledge and basic infrastructure

The strategic aim of this axis is to understand the magnitude of the problem and to identify and solve the shortcomings or difficulties for the implementation of effective controls or solutions. In order to achieve this aim, two specific targets have been set: (1) to assess the exposure of the population to radon (considering contributions from soil, water and building materials), and to estimate its impact on the health of the population; and (2) to ensure the reliability and quality of radon concentration or dose determinations. The actions proposed to achieve the first aim are as follows:

- Development of measurement campaigns, in collaboration with Autonomous Communities and local councils.
- Development of radon potential maps on a regional or local scale and production of the national population exposure map.
- Analyse the contribution of drinking water and building materials to radon gas concentration.
- Estimate the number of cancers attributable to radon in the current situation and make projections subject to meeting the targets foreseen in the National Radon Action Plan.

The second of the above-mentioned specific aims is based on the implementation of two specific actions:

- Identification of the metrological and dosimetric technical capacity in terms of existing supply and expected demand.
- Encouraging the development of a metrological infrastructure in line with the needs of the National Radon Action Plan and regulatory requirements, and ensuring homogeneity and traceability of measurements. Support the organisation of intercomparisons.

Building

This axis includes the strategic aim of reducing radon concentration in buildings and compliance with the already established reference level. As in the previous case, the following specific aims and associated actions are set out to achieve them.

Firstly, the specific aim of implementing regulation requires analysing the possibilities for improvement of existing legislation, needs for new regulation, not considered or not available, and the development of these.

The second specific aim focuses on training, and is intended to be achieved through the development of specific actions aimed at training the agents involved in the field of construction, both in the diagnostic and remedial phases.

The third aim is for remedial programmes in existing buildings, for which a cost estimate is required.

The fourth of these aims entails the analysis of the effect according to the architectural typologies related to the existing building. The actions proposed to achieve this are: 1) Identify and assess the applicability and determine the effectiveness in Spain of the different construction solutions against radon in building used internationally; and 2) assess the possible inclusion of radon data into urban information platforms.

Finally, there is the specific aim of designing and promoting support instruments at regional and municipal level. The following actions have been identified as necessary to achieve this aim: 1) providing technical assistance in the field of construction, 2) developing sectoral financial instruments for individuals and SMEs, and 3) integrating radon prevention into urban planning.

Workplaces

The workplace axis has a strategic aim to ensure the implementation of the reference level and compliance with the dose limit for exposed workers in order to reduce occupational exposures to radon and the impact on their health. In order to meet this target, the specific aim of monitoring and promoting compliance with legislation and regulations applicable to workplaces is developed. The actions proposed within the framework of this aim are:

- Establishment of a system of collaboration between the Labour and Social Security Inspectorate (ITSS, as per its acronym in Spanish) and the CSN inspection, for the purposes contemplated in article 82 of Royal Decree 1029/2022, of 20 December. Agreements with other public administrations competent in labour matters may be established at later stages of this National Plan.
- Develop specific campaigns in companies, sectors and priority groups.
- Ensure and promote the competence of entities involved in radon measurement and radon assessment in workplaces (radon measurement laboratories, Radiation Protection Technical Units (RPTU), personal radon dosimetry services).
- Provide radon-specific training for prevention services and promote the integration of gas protection in companies' occupational risk prevention plans.
- Assess the relevance of proposing a specific Health Surveillance Protocol for workers who have been exposed for prolonged periods to annual doses in excess of 20 mSv/year.

Priority action areas

This section consists of a cross-cutting axis that brings together actions from various fields to effectively target the areas most affected by radon levels. Its strategic aim is based on developing action measures to reduce radon exposure in the priority action areas by providing local authorities with action measures to reduce radon exposure. One of the specific aims to achieve the above is to develop a methodology easily applicable in the most affected areas, which includes actions such as: the development of a set of tools to be applied in priority action areas, a guide for the rehabilitation of buildings against radon and a guide of good practices in the field of water. Other specific aims of this axis are the incorporation of the work carried out by the Autonomous Communities on radon protection, as well as the design and promotion of support instruments at regional and municipal level.

Communication and awareness-raising

This axis aims to achieve the main strategic target of raising awareness among the public, professionals and administrations. One of the specific aims identified to achieve the above is

to raise public awareness of the health effects of radon and in particular in combination with tobacco. The actions proposed to carry out this work are as follows:

- Diagnosis of the public perception of radon in Spain.
- Develop information brochures and videos.
- Develop communication systems.
- Organise information days.
- Develop user-focused information and awareness-raising actions in existing buildings.

In the same point, the specific aim is to promote the commitment of public administrations and the inclusion of information on radon into related programmes and plans. To achieve this, the proposed action consists of using grants to enable the integration of the different levels of public administration in the development of radon-related programmes.

8. Coordination, Management and Evaluation

Coordination and management of the National Action Plan

In order to ensure the coordination of the Plan and its actions, the National Radon Action Plan Committee is created based on article 78 of Royal Decree 1029/2022. This committee will be attached to the Ministry of Health and will made up of representatives of the authorities with competence in the matters covered by the National Plan, with the following composition:

Chair: A representative of the Ministry of Health, with the rank of General Director.

Vice-chair: A representative of the Spanish Nuclear Safety Council, with the rank of Technical Director.

Members: members of the Committee:

- Eight people appointed to positions with at least the rank of Head of Area or equivalent, representing each of the following ministerial departments: two representatives from the Ministry of Health; two representatives from the Ministry for Ecological Transition and Demographic Challenge; two representatives from the Ministry of Transport, Mobility and Urban Agenda; two representatives from the Ministry of Labour and Social Economy.
- Two representatives of the Spanish Nuclear Safety Council, with the position of at least Head of Area or similar.
- One representative from each Autonomous Community and City with a Statute of Autonomy interested in participating, with at least rank of Deputy Director General or similar.
- Three representatives from local authorities, appointed by the Spanish Federation of Municipalities and Provinces.

The functions of this Committee are the following:

- Draw up the National Radon Action Plan and submit it to the Ministry of Health for its approval by the Government.
- Update the National Radon Action Plan every five years, in accordance with scientific knowledge and the progress made in the measures included in it, and submit these updates to the Ministry of Health for approval by the Government.
- Promote, evaluate and supervise compliance with the action guidelines set out in the National Plan.
- Act as a liaison body between the ministerial departments and attached bodies and the regional and local administrations, in order to ensure the coordination of the criteria and policies defined by them.

The National Radon Action Plan Committee may set up a working group made up of representatives of the member ministries of the National Radon Action Plan Committee and the Spanish Nuclear Safety Council to discuss and draw up proposals to be submitted to the National Radon Action Plan Committee. This working group may include the participation of such experts as it may convene.

Evaluation of the National Radon Action Plan

The monitoring of the actions and the evaluation of the Plan will make it possible to check the level of compliance, the effectiveness of the actions and, if necessary, the need to re-evaluate the measures adopted. To this end, regular annual monitoring reports will be issued and the National Radon Action Plan will be evaluated on a five-yearly basis, including proposals for revision of the strategic aims.

The evaluation of the National Radon Action Plan should be viewed from a threefold perspective. After the deadline, it should be assessed as to whether the planned actions have been fulfilled. This implies the design of indicators to measure the degree of implementation of the planned measures. In the process and activity-oriented context of the National Radon Action Plan, these would be process indicators intended to measure the degree of compliance with the activities, and would ultimately be answering the question: Are the actions proposed in the radon actions being implemented?

Since process indicators allow measuring the level of execution of the process, how things have been done and what the performance is, we could also refer to efficiency indicators, taking into account that efficiency is determined by the capacity to carry out a task.

On the other hand, and given that the purpose set out in the aims of the National Radon Action Plan is to reduce the risk to the health of the population due to exposure attributable to radon, both in the general population and in the working population, we need to know whether these measures we are carrying out are having an impact on this target. To evaluate this, we need performance indicators.

These indicators allow us to assess the effectiveness of the actions and the extent to which the activity produced the desired effect. Performance indicators are effectiveness indicators, as they answer the question: are the actions we are taking working towards our goals? We could also refer to this type of indicators as impact indicators, as they are intended to measure the effect of a programme or service on the health status of the population. Ultimately, in the context of the National Radon Action Plan, they are used to assess whether the measures proposed to address the problem are actually useful and work.

Finally, a third assessment of structure is proposed, that is whether the structure in terms of material, human and financial resources available to the National Radon Action Plan as a whole is relevant and sufficient for the achievement of the stated aims and purpose.

In this context, the evaluation of the National Radon Action Plan will cover these aspects (process, performance and structural evaluation) and will be carried out from two complementary approaches:

Annual report of compliance

This report will be an annual assessment of the progress of the activities set out in this document. In each activity sheet, various performance indicators are included that will allow us to measure the progress of each measure. In the event that the activity is not completed before the publication of this report, the degree of completion or progress, in percentages, of the activity may be expressed. In turn, this report may additionally contain the different performance indicators that can be obtained in shorter periods of time and provide significant information on the status of the National Radon Action Plan.

National Radon Action Plan five-year report

Five years after the approval of the National Radon Action Plan, a full evaluation of the different parts of the plan will be carried out. In this case, this will include both process indicators, which will be included in the annual reports, as well as performance indicators and analysis of the structure. In this way, it will be possible to observe the degree of final compliance with the activities that will have been carried out and the effectiveness they have had on the targets of the National Radon Action Plan. As with the process indicators, each activity sheet has a performance indicator that will provide information not only on the capacity of the bodies responsible for carrying out the activity, but also on the impact it has actually had on society and public health.

In this case, it is worth noting the incorporation of health data that can be used as performance indicators for the National Radon Action Plan as a whole. It should be recalled that the overall aim is to protect the health of the population and workers from the health risks of radon exposure. Therefore, this final report will be able to measure the effectiveness of the implementation of the National Radon Action Plan by acknowledging the attributable risk before and after its approval, bearing in mind that given the characteristics of the problem the results will only be visible in the long term. In addition, other statistical data can be used to provide a broader view of this indicator, such as lung cancer morbidity and mortality rates by geographical area, as well as information on the level of exposure of the population to radon.

9. Actions

The National Radon Action Plan includes a series of actions aimed at meeting the different specific objectives set out in the plan. Each action establishes its own execution time, so that some of the actions have already been executed and completed (Table 4); and others are in progress or pending execution (Table 5). Both those that have been carried out and those that are in the process of being implemented are listed in order to facilitate their framing within the different axes of the Plan.

Table 4. Actions carried out under the scope of the National Radon Action Plan

Axis	Action	Number
A. Knowledge and basic infrastructure	Lung cancer burden attributable to radon exposure in Spain	A.1
B. Building	Regulations: Development, monitoring and analysis of new section HS 6 in the Basic Document DB HS on Health of the CTE	B.1
	Inclusion of radon field concentration data in the Urban Information System (UIS)	B.3
D. Priority action areas	Monitoring and dissemination of radon remediation guide	D.1

Table 5. Actions in progress or pending under the scope of the National Radon Action Plan

Axis	Action	Number
A. Knowledge and basic infrastructure	Develop and update radon potential map and produce radon maps at regional or local scale	A.2
	Organise periodic intercomparisons of radon air concentration measurements (for integrating measurement systems and continuous monitors)	A.3
	Validate and improve temporal sampling strategies	A.4
	Study the contributions to radon doses from building materials	A.5
	Study the contributions to radon from drinking water	A.6
B. Building	Coordination of building stock remediation for radon exposure	B.2
C. Workplaces	Assess the relevance of proposing a specific Health Surveillance Protocol for workers exposed to radon	C.1
	Facilitate the application of Publication 137 Part 3 of the International Commission on Radiological Protection (ICRP) in workplaces with extreme conditions	C.2
	Establish coordination and collaboration mechanisms between the Labour and Social Security Inspectorate and the Spanish Nuclear Safety Council	C.3
E. Communication and awareness-raising	Raise awareness among the population and/or specific groups	E.1
	Public perception of radon risk in Spain	E.2

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE		A.1
Lung cancer burden attributable to radon exposure in Spain		
Aim	Estimate the number of cancers attributable to radon exposure in Spain	
Description	Characterise and quantify the risk of lung cancer due to radon exposure in relation to areas of elevated radon emission	
Directed by	Ministry of Health	
Collaborators	Spanish Nuclear Safety Council (CSN) and University of Santiago de Compostela (USC)	
Product	Report on the number of cancers attributable to radon exposure in the current situation and statistical model for estimating attributable cancer.	
Timeline of actions	2021	Analysis of related literature. Descriptive analysis of epidemiological data for the estimation of lung cancer cases attributable to radon exposure and other factors.
	2022 and following years	Update and continuation of the analysis, if appropriate. Health surveillance actions.
Budget €	Costs borne by the Ministry of Health	
Performance indicator	Publication of the report	
Results indicator	Lung cancer attributable to radon exposure	
Monitoring	Annual estimate of new lung cancer cases influenced by radon exposure and comparison with previous rates	
Development	The following points shall be covered in the drafting of the report: • Analysis of available related literature. • Descriptive statistics of the Spanish population affected by lung cancer in the study period. • Analysis of the main factors involved in the development of lung cancer and their influence on the incidence rate of the disease in each population associated with risk factors. • Estimation of the incidence of lung cancer in each population and group of people related to the factors shown to be significant. With this population data, it is possible to calculate the relative and attributable risk of lung cancer exposure to radon, as well as the proportion of cases that could be avoided by reducing radon levels for a population. • With zonal radon levels, fitting a statistical model to explain lung cancer cases based on the factors that have been shown to be relevant during the development of lung cancer. • Formulation of the equation for such a statistical model to allow us to predict cancer cases attributable to both exposure to any level of radon and controllable variation in any of the factors included in the statistical model.	

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE		A.2
Develop and update the radon potential map and produce radon maps at regional or local scale		
I. National radon potential map of Spain		
Aim	Update the National radon potential map of Spain (CSN, 2017), incorporating new radon measurements obtained from: (1) the development of regional and municipal maps; and (2) the third phase of the 10 × 10 Radon Project, focusing on karst areas.	
Description	The National radon potential map of Spain, prepared by the CSN, identifies the geographical areas with the highest risk of radon exposure based on: (i) the 12,000 radon measurements available in January 2017; (ii) the MARNA map of exposure to natural gamma radiation (CSN, 2000); and (iii) the IGME lithostratigraphic map. This map, at a scale of 1:200,000, has served as the basis for establishing the zoning of appendix B of section DB-HS6, "Protection against radon", of the Technical Building Code, and will be used to define the municipalities for priority action referred to in the Regulation on health protection against the risks arising from exposure to ionising radiation. The map is a dynamic tool, which must continue to be updated and improved. To this end, the efforts of the CSN will be joined by those of the Autonomous Communities and municipalities that have adopted specific lines of action against radon. The CSN will subsidise the third phase of the 10 × 10 Radon Project, focusing on karst systems, during the period 2023-2027. This type of lithology is a possible radon risk factor, which has not been sufficiently studied. For each new measurement, data on the constructive characteristics of the building shall be incorporated. This information is decisive in determining radon levels in the indoor environment, and its analysis will allow optimisation of protection strategies against the gas, as well as a more accurate assessment of their effectiveness.	
Directed by	Spanish Nuclear Safety Council (CSN)	
Collaborators	University of Cantabria (LARUC), University of Malaga, Polytechnic University of Valencia	
Product	Updated version of the National radon potential map of Spain	
Timeline of actions	2023	Activity 1
	2024	Activities 2 and 3
	2025	Activities 4 and 5
	2026	Activity 6
	2027	Activity 7
Budget €	130,000.00 euros	
Performance indicator	Partial reports of results	
Results indicator	Number of new measurements added to the map; National map update; Definition of new classification units	
Development	The following activities are envisaged to achieve the proposed aim:	

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE	A.2
Develop and update the radon potential map and produce radon maps at regional or local scale	
	Geological and structural characterisation of the karst areas under study (4 karst typologies in Cantabria, Malaga and Castellón). Determine the radon content in water at different points in the supply networks. Carry out radon measurements in dwellings and workplaces (500 measurements), and in areas of interest, selected on the basis of geological-structural characterisation, measure radon concentration in soil gas and gas permeability. Statistical analysis of the data obtained. Apply numerical models to radon behaviour in karst areas and extrapolate these models to the National radon potential map of Spain and report the results. Integrate the results of the map measurements specified in CSN/1-II. • Update Map of radon potential in Spain
II. Regional maps. Radon map of the Canary Islands	
Aims:	1) Preparation of detailed High Level Radon Risk Zoning Maps of the Canary Islands archipelago according to the geology of the territory. 2) Development of a methodology, adapted to the Canary Islands, for the characterisation of the geogenic radon potential of the terrain at plot level. This aim is justified due to the extensive geological heterogeneity of the region and is proposed as a complement to the Risk Maps and as a tool for the design of preventive measures in the project phase of the building.
Description	On the basis of campaigns to measure radon in the indoor air of buildings and the environmental radiological information previously available, an attempt will be made to identify the factors that determine the distribution of areas with higher or lower radon potential in the Canary Islands. Using the concept of "characteristic enclosure", an attempt will be made to homogenise the samples of buildings analysed in order to consider, as far as possible, the influence of factors that are not linked to their geographical location, such as the level of ventilation, the condition of the building or its typology. The territory will be divided into sectors corresponding to the different predominant lithologies on each island that, by means of correlations between interior radon and geology, have been shown to influence the establishment of the different levels of radon risk. In parallel, the necessary research work will be carried out to analyse the possibility of proposing a methodology, adapted to the Canary Islands, for characterising the geogenic radon potential of the terrain at plot level, as a complement to the previous geographical delimitation. The purpose of developing this methodology is to provide a criterion for assessing the risk of radon infiltration for each specific plot on which a building is planned to be constructed, in order to implement appropriate solutions to prevent or reduce its presence. Based on the geographical distribution of the different sectors characterised by different indoor radon concentration levels, sites (plots) close to buildings with certain typologies and radon levels will be selected in order to try to convey the results obtained inside and outside the building.
Directed by	Laboratories and Construction Quality Service of the Department of Public Works, Transport and Housing of the Government of the Canary Islands
Collaborators	University of Las Palmas de Gran Canaria (Environmental Radioactivity Laboratory of the GIRMA research group of the Physics Department)) University of La Laguna (TEMAR research group of the Department of Engineering and Architectural Techniques and Projects))

<table>
<tr><td colspan="3">AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE</td><td>A.2</td></tr>
<tr><td colspan="4">Develop and update the radon potential map and produce radon maps at regional or local scale</td></tr>
<tr><td>Product</td><td colspan="3">Preparation of Radon Exposure Risk Maps for the islands of Gran Canaria and Tenerife and derived technical reports</td></tr>
<tr><td rowspan="3">Timeline of actions</td><td>2023</td><td colspan="2">Campaign to measure radon levels inside homes in the municipalities of Telde and La Laguna. Drafting of municipal geological maps. Implementation of the methodology for measuring the characterisation of geogenic radon.</td></tr>
<tr><td>2024</td><td colspan="2">Extension of the campaign to the municipalities of the islands of Gran Canaria and Tenerife. Drafting of island geological maps. Evaluation of the geogenic radon characterisation measurement methodology.</td></tr>
<tr><td>2025</td><td colspan="2">Extension of the campaign to the municipalities of the islands of El Hierro, La Palma, La Gomera, Fuerteventura and Lanzarote. Drafting of island geological maps. Final validation of the geogenic radon characterisation measurement methodology and correlation with indoor radon.</td></tr>
<tr><td>Budget €</td><td colspan="3">Variable annually</td></tr>
<tr><td>Performance indicator</td><td colspan="3">Partial reports of results</td></tr>
<tr><td>Results indicator</td><td colspan="3">Number of new measurements added to the map. Drafting of the geographic maps of the Canary Islands</td></tr>
<tr><td colspan="4">III. Regional maps. Radon map of Castile and Leon</td></tr>
<tr><td>Aim</td><td colspan="3">Develop the radon map of Castile and Leon with radon measurements obtained in municipalities of Castile and Leon in indoor environments of permanently occupied housing and public buildings with workplaces.</td></tr>
<tr><td>Description</td><td colspan="3">The first phase of the Radon Map of Castile and Leon began in a first phase in March 2021 with a number of sampling points in dwellings and public buildings in the order of 3,300, and in a second phase for the year 2022 the forecast for other sampling points is also around 3,300. The map will therefore contain some 6,700 sampling points for two calendar years, in addition to the approximately 1,800 measurements on the national map.
The sampling method designed facilitates the identification of priority action areas, as 10% of the detectors were placed in public buildings (workplaces), and the criterion is to impact areas of high population. 90% of the detectors were placed in permanently occupied dwellings, and the criteria are: to cover the entire region of Castile and Leon with at least one measurement; to increase the number of measurements according to population and to affect areas identified by the CSN and previous screening studies carried out within this DGSP as having a high radon potential. I. e. surface, population and potential radon criteria, respectively.
The aim is to develop the residential radon map and the radon map in public buildings (workplaces) with a grid of 10 km x 10 km, i. e. to characterise the radon exposure of the population of Castile and Leon and, on the basis of this information, to reduce occupational exposures to radon by keeping the exposures of workers and the general public as low as reasonably achievable, taking into account work organisation, technical, social and economic factors. Therefore, if remedial measures are identified during the study that will reduce exposures at a cost that is affordable for the facility, they should be implemented even if the average radon levels are below the reference level - the optimisation principle.
The Map is being developed within the Public Health Directorate of the Castile and Leon Regional Ministry of Health with the advice and collaboration of the research group of the Environmental Radioactivity Laboratory of the University of Cantabria</td></tr>
</table>

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE		A.2
Develop and update the radon potential map and produce radon maps at regional or local scale		
	(LARUC), and will be constantly updated, which is the intention of this Management Centre. All maps and tables with detailed results of the Map will be published in due course.	
Directed by	Castile and Leon Regional Ministry of Health. Directorate-General for Public Health.	
Collaborators	University of Cantabria	
Product	Radon exposure map of Castile and Leon	
Timeline of actions	2020	Programming and definition of samplings.
	2021	First phase: Determination of radon concentration in dwellings and public buildings
	2022	Second phase: Determination of radon concentration in dwellings and public buildings
	2023	Data processing and creation of maps
	2024	Publication of results
Budget €	Variable	
Performance indicator	3,000-3,300 annual measurements	
Results indicator	Number of new measurements added to the map of Castile and Leon Radon exposure map of Castile and Leon	
IV. Regional maps. Radon map of Galicia		
Aim	Complete the existing radon map of Galicia by incorporating new accredited measurements obtained in Galician municipalities in indoor environments of permanently occupied dwellings and in public buildings with workplaces.	
Description	To date, Radon Map of Galicia (MRG by its acronym in Spanish) has around 6,080 indoor radon measurements taken in as many dwellings in the Autonomous Community. The purpose of this map is to characterise the radon exposure of the Galician population and therefore the criterion is that the municipalities with the largest number of inhabitants have the largest number of measurements. Additional geographical representation targets have been added, which consist of having at least two indoor radon measurements in each of the census sections of a municipality for tracts with less than 1,500 inhabitants, and one additional measurement for every extra 500 inhabitants. Another of the criteria to be followed is to focus on areas identified by the CSN as having a high radon potential. Therefore, population, geographic and potential radon exposure criteria will be followed in the creation of this map. It is intended to continue with the measurement work carried out by the University of Santiago de Compostela, completing the measurements in the coming years in both dwellings. In addition, it is essential to have a viewer containing this data (and allowing other data to be added) to facilitate the visualisation of residential radon exposure in Galician men and women depending on where they live or work. This viewer is also intended to include, albeit separately, measurements taken in certain public buildings in Galicia.	

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE		A.2
Develop and update the radon potential map and produce radon maps at regional or local scale		
	The Galician Radon Map is a dynamic tool, which must continue to be updated and improved through the gradual increase in radon measurements.	
Directed by	Directorate-General for Public Health. Ministry of Health of the Galician Government University of Santiago de Compostela. Galician Radon Laboratory (School of Medicine)	
Collaborators		
Product	Radon exposure map of Galicia	
Timeline of actions	2023	Enlargement of the Map. Determination of radon concentration by census sections in Galician municipalities.
	2024	Creation of an interactive viewer in the Galician Public Health Observatory
	2025	Enlargement of the Map. Determination of radon concentration by census sections in Galician municipalities.
	2026	Extending the mapping and promoting the determination of radon concentration in public buildings.
	2027	To be defined
	Variable annually	
Budget €	200 new measurements per year.	
Performance indicator:	Number of measurements included in the map. Start-up of the radon exposure indicator. Number of measurements included in the indicator. Number of completed municipalities with available information by census section.	

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE		A.3
Organise regular intercomparisons of radon air concentration measurements (for integrating measurement systems and continuous monitors)		
Aim	To ensure the reliability and high quality of radon concentration determinations, by promoting the accreditation of laboratories according to ISO 17025 and the authorisation of Radiation Protection Technical Units in the field of natural radiation by the CSN.	
Description	Exposure to radon in the workplace has been regulated for years in Spain by the Regulation on health protection against the risks arising from exposure to ionising radiation, and by CSN Instruction IS-33. This regulatory framework has been reinforced by Directive 2013/59/EURATOM, which includes additional monitoring requirements for the exposure of workers, as well as the inclusion of radon protection measures in the Technical Building Code (applicable to new buildings and renovations). This will lead to a significant increase in the demand for radon measurement and dose assessment services, making it essential to ensure the quality and reliability of these determinations. To this end, both the accreditation of laboratories according to ISO 17025 and the authorisation of Radiation Protection Technical Units in the field of natural radiation are fundamental tools. The UNE-EN ISO/IEC 17025 standard includes participation in intercomparison programmes as a basic quality assurance requirement, as does CSN Guideline 11.1 on Guidelines on the competence of laboratories and services for measuring radon in air. Intercomparisons lead to improved measurement services by forcing the laboratory or entity, in case of unsatisfactory results, to test its ability to detect the possible source of the error and to correct it. In the field of radon measurement, the response of detectors depends on different environmental conditions, such as temperature, relative humidity or fluctuations in radon concentration, which is particularly relevant in working environments where extreme environmental conditions may be encountered. Therefore, intercomparison exercises should cover, in a controlled manner, a wide range of environmental conditions. The regular organisation of radon measurement intercomparisons also allows to establish a technical dialogue with laboratories and organisations, as well as to verify the adequate response of new measuring devices entering the market.	
Directed by	Spanish Nuclear Safety Council (CSN)	
Collaborators	Polytechnic University of Catalonia (INTE) University of Cantabria (Radon Group) CIEMAT (Laboratory of Metrology of Ionising Radiations)	
Product	Reports on the results of the intercomparison exercises. Technical conferences for the presentation of results. Update of CSN Guide 11.1.	
Timeline of actions	2023	Intercomparison exercise
	2024	
	2025	Intercomparison exercise
	2026	
	2027	Intercomparison exercise
Budget €	180,000.00 euros	

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE	A.3
Organise regular intercomparisons of radon air concentration measurements (for integrating measurement systems and continuous monitors)	
Performance indicator	Publication of results reports
Results indicator	Number of laboratories or entities participating in the intercomparisons and number of participants in the Technical Conferences. Percentage of participants reporting satisfactory results according to the set assessment criteria.
Development	In order to achieve the proposed aim, periodic intercomparison exercises are envisaged, which will be carried out as follows: • Planning of the exercise. Establishment of criteria for prioritisation of participants and criteria for objective evaluation of results. • Carrying out the intercomparison exercise. • Preparation of results reports and individual reports for the participants. • Holding of technical conferences.

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE		A.4
Validate and improve temporal sampling strategies		
Aim	Validate and improve the sampling protocols in CSN Safety Guide 11.4 and Appendix C Basic Document HS 6 "Protection against radon" of the Technical Building Code (CTE)	
Description	Exposure to radon has harmful health effects only in the long term. Therefore, the reference level of 300 Bq/m^3 set in the regulation is expressed in terms of the annual average radon concentration in indoor air. In practice, it may not be feasible or justified to measure over a full year. Based on international experience and information on radon variability available in the scientific literature, the following are considered representative of the annual average: (i) for workplaces, measurements of at least 3 months duration, outside the summer season (except for underground locations where a full year is required to be measured); and (ii) in the scope of the CTE, in order to estimate the need for remedial actions in buildings prior to their retrofitting, measurements of at least two months, at any time of the year, subject to the application of a coverage factor, depending on the climatic zone and the period in which these are carried out. Obtaining time series of radon concentration from continuous measurements taken over a period of two years at a sufficient number of sampling points will allow validation or revision of sampling strategies, quantifying error rates when estimating the annual average, and obtaining coefficients of variation by climatic zone. It will also be possible to assess the possibility of allowing shorter sampling cycles to verify, for example, the effectiveness of remedial measures in a building. For this purpose, a pilot network of 40 radon monitors located on ground or underground floors of workplaces or dwellings, selected on the basis of their radon levels and geographical location, will be established and the time-space series will be analysed.	
Directed by	Spanish Nuclear Safety Council (CSN)	
Collaborators	University of Cantabria (LARUC); University of Las Palmas de Gran Canaria (Radiation Physics Group); Polytechnic University of Valencia (Environmental Radioactivity Laboratory); Ministry of Transport, Mobility and Urban Agenda	
Product	CSN publication (collection of technical reports). Revision of sampling protocols (GS 11.4; DB-HS6)	
Timeline of actions	2023	Activities 1 and 2
	2024	Activities 2 and 3
	2025	Activity 3
	2026	Activity 4
	2027	Activity 5
Budget €	50,000.00 euros	
Performance indicator	Publication of reports with the results and making them available to the public including the data series obtained	
Results indicator	Revision of CSN Guide 11.4. Number of participants in conferences/courses.	
Development	The following activities are envisaged to achieve the aim:	

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE	A.4
Validate and improve temporal sampling strategies	
	• Verification of radon monitors at the Natural Radiation Laboratory at Salices El Chico (Salamanca). Selection of measurement points. Development and commissioning of the pilot network • Collection of data. Statistical analysis of the 1st year series • Collection of data. Analysis of results • Preparation of the final report. Revision of CSN Guide 11.4 • Dissemination activities of the project results and training of the entities involved in the measurement of radon in homes and workplaces.

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE		A.5
Studying radon contributions from building materials		
Aim	Assess the exposure of the population to radon in dwellings due to exhalation from building materials.	
Description	The main source of radon in buildings is generally the ground on which they stand, although under particular conditions, tap water or building materials may also represent important inputs of radon into indoor air. In Spain, Article 75 of Directive 2013/59/Euratom establishes a reference level of 1 mSv/year for exposure to gamma radiation emitted by construction products. This indirectly limits its Ra-226 content and thus the exhalation of radon. However, it is necessary to evaluate the extent to which this regulation is implemented in practice and to assess the extent to which it ensures that the contribution of building materials does not prevent compliance with the reference level set for radon in indoor environments (i. e. 300 Bq/m^3). Based on measurements of radon exhalation from the most commonly used building materials in practice, the impact of this radon source on the effective dose received in dwellings (for the population as a whole and for the most exposed individuals) will be estimated. The knowledge gained will make it possible to determine whether current controls are adequate or whether additional measures are required.	
Directed by	Spanish Nuclear Safety Council (CSN)	
Collaborators	Eduardo Torroja Institute for Construction Sciences (CSIC), University of Cantabria, University of Extremadura (Environmental Radioactivity Laboratory of Badajoz), University of Huelva, Polytechnic University of Valencia, University of Santiago de Compostela (Galician Institute of High Energies).	
Product	Report of results and, if appropriate, proposals for action on the development of new regulations	
Timeline of actions	2023	Activity 1
	2024	Activities 2, 3, 4
	2025	Activity 5,6
Budget €	363,561.00 euros	
Performance indicator	Publication of results reports	
Results indicator	Estimated radon dose contributions from building materials (for the population average and for the most exposed individuals)	
Monitoring	Result report	
Development	The following activities are envisaged to achieve the proposed aim: • Develop a standardised methodology for laboratory evaluation of the exhalation of formed or granulated building materials. • Radiological characterisation (specific activity and radon exhalation) of the most widely used building materials and elements in Spain. • Assess the contribution to radon in the indoor air of a typical room due to exhalation from building materials. • Investigate different remediation/treatment techniques to reduce radon exhalation from a material. • Estimate radon doses due to building materials in dwellings. • Draft results reports.	

AXIS: KNOWLEDGE AND BASIC INFRASTRUCTURE		A.6
Studying radon contributions from drinking water		
Aim	Characterisation of groundwater bodies used for abstraction of water for drinking water production	
Description	One of the sources of radon in the population is through drinking water from groundwater bodies in granitic soils. 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, transposed into Spanish domestic law in Royal Decree 314/2016, of 29 July, amending Royal Decree 140/2003, of 7 February, establishing the health criteria for the quality of water for human consumption and which has been updated in Royal Decree 3/2023, of 10 January, which establishes the technical-sanitary criteria for the quality of drinking water, its control and supply, states in its First Additional Provision that the characterisation of bodies of groundwater used to collect water intended for the production of drinking water due to the presence of radon will be carried out by the health authority under the coordination of the Ministry of Health, with the advice of the Spanish Nuclear Safety Council, where appropriate. This will be based on the information from the initial characterisation carried out before 2019, with the analytical information available from the supply areas and from historical data, supporting studies or other reliable information available, and may be updated when new information becomes available that makes it advisable. It will include the identification of the scale and nature of potential radon exposures in drinking-water arising from the geology and hydrology of the area concerned, the radioactivity of rocks or soil and the type of catchments, so that such information can be used to assess the risks to human health and to guide action in areas with the potential for high exposure.	
Directed by:	Autonomous Communities and Cities	
Collaborators	Spanish Nuclear Safety Council and Ministry of Health	
Product	Report of results in the Annual Technical Report on drinking water quality in Spain and proposals for action	
Timeline of actions	2023	Activity 1
	2024-2025	Activity 2
	2026	Activity 3
Budget €	It is estimated that at least 3 samples per groundwater body (762) would have to be taken, which would cost around 350,000.00 euros	
Performance indicator	No. and % of groundwater bodies characterised.	
Results indicator	Mean and maximum value quantified in Bq/L at each Groundwater Body	
Monitoring	Annual reports	
Development	The following activities are envisaged to achieve the proposed aim: Activity 1: Status of the number of water bodies characterised and quantified values found. Activity 2: Characterisation of groundwater bodies still to be characterised Activity 3. Final report on the radon characterisation of groundwater bodies in Spain	

AXIS: BUILDING			B.1
Regulations: Development, monitoring and analysis of new section HS 6 in the Basic Document DB HS on Health of the CTE			
Aim	Limiting the risk of exposure of people to unacceptable concentrations of radon from the ground inside habitable rooms in buildings.		
Description	In order to meet the aim, a reference level for the annual average radon concentration inside habitable premises is set at 300 Bq/m^3.		
Directed by	Execution: Ministry of Transport, Mobility and Urban Agenda (S.G. Architecture and Building)		
Collaborators	Eduardo Torroja Institute for Construction Sciences (IETcc) of the Spanish National Research Council (CSIC)		
Product	Compulsory regulations: Section HS 6 "Protection against exposure to radon" of the Technical Building Code		
Timeline of actions	2019	Publication of the regulatory document	
	2020	Publication of the support guide for remedial actions	
	2021 and following years	Monitoring and analysis of its implementation	
Budget €	No costs, taken over by ordinary tasks of the S.G. Architecture and Building of the Ministry of Transport, Mobility and Urban Agenda		
Performance indicator	Approval of the regulatory document by Royal Decree 732/2019: https://www.codigotecnico.org/pdf/Documentos/HS/DccHS.pdf and publication of the supporting guide: https://www.codigotecnico.org/Guias/GuiaRadon.html		
Results indicator	No. of licences granted in municipalities included in Appendix B of Section HS 6 of the Basic Health Document of the CTE. Measurements taken on new construction sites where this new regulation has been applied and on interventions on existing buildings before and after the application of this new regulation.		
Monitoring	Through the Ministry of Transport, Mobility and Urban Agenda Survey to be filled in when applying for Building Permits. Through the data provided by the measurement entities.		
Development	The fundamental lines of the new section HS 6 in the Basic Document DB HS on Health, are: *Scope of application* The obligation to implement specific radon protection measures is limited to municipalities where there is a significant likelihood that buildings constructed there without specific radon protection measures have radon concentrations above the reference level. The list of municipalities is provided by the Spanish Nuclear Safety Council and is drawn up on the basis of measurement campaigns carried out by the Council throughout the country. The list classifies the municipalities into two groups, depending on the level of risk, and protection measures are established depending on the group to which the municipality in which the building is located belongs. The new section applies to any building, regardless of its use (residential or commercial). It applies to all new buildings and also to modifications in existing buildings in the following cases: in the case of extensions, to the new part; in the case of change of use, to the whole building in the case of a change of characteristic use or to the affected area, in the case of a change of use affecting only part of a building undergoing alterations, to		

AXIS: BUILDING	B.1
Regulations: Development, monitoring and analysis of new section HS 6 in the Basic Document DB HS on Health of the CTE	
	the affected area, where modifications are made to increase the radon protection or alter the initial protection. *Verification and justification of the requirement.* The radon protection measures to be implemented in the building are established according to the zone to which the municipality where the building is located belongs. Measures to limit indoor radon concentration in buildings are based on two main aspects: • Use protective barriers capable of mitigating the entry of radon gas from the ground into the building. • Use systems capable of redirecting radon gas to the open air to prevent it from entering the interior of buildings, basically by means of ventilation systems in the spaces between the habitable areas of the building and the ground (such as suspended floors or non-habitable ground floors) or systems to depressurise the ground underneath the building. The above measures are adopted in each case according to the risk level of the municipality in which the building is located. *Procedure for measuring radon concentration.* The Basic Document also includes in an appendix a regulated procedure for the experimental determination of the annual average radon concentration in the air in habitable rooms of a building. *Radon rehabilitation guidance.* As a non-regulatory support, the Radon Remediation Guide has been published as a tool to assist in the design of radon protection solutions. It provides the necessary fundamental concepts that support the correct diagnosis of radon entry pathways, illustrates the process of performing radon measurements, as well as presents protective solutions and provides criteria for the choice of the most appropriate solutions in each case. It is intended to be, on the one hand, an essential tool for designers faced with the challenge of designing radon protection solutions and, on the other hand, a source of information for users of affected buildings, so that they can get an approximate idea of the scope of possible solutions, as well as the different ways in which radon can enter the building and the influence that the behaviour of the users themselves can have on the concentration of this gas. It is a guide designed to be updatable and expandable by means of standard solution sheets and sheets with real case studies that can serve as examples.

AXIS: BUILDING			B.2
Coordination of the rehabilitation of the building stock against radon exposure.			
Aim	The purpose is to find out about ongoing remediation programmes aimed at improving radon protection within the building stock in all the Autonomous Communities and Local Authorities, in order to have an observatory and enable the exchange of information.		
Description	Monitoring of aid programmes for building refurbishment in relation to protection against exposure to radon, with special interest in the municipalities included in Appendix B. Classification of municipalities according to radon potential" of Section HS 6 "Protection against exposure to radon" of the Technical Building Code, as these are the areas most affected.		
Directed by	Ministry of Transport, Mobility and Urban Agenda (S.G. Architecture and Building)		
Collaborators	Building Departments of the Autonomous Communities and Local Authorities.		
Product	Building information.		
Timeline of actions	2023 and following years	Data collection and coordination.	
Budget €	No costs, included as part of the ordinary work of the S.G. Architecture and Building of the Ministry of Transport, Mobility and Urban Agenda and the building departments of the Autonomous Communities		
Performance indicator	Number of coordination group meetings		
Results indicator	Data showing the number of actions affected with the aim of reducing radon concentration levels in buildings: Identification of Monitoring Programmes: Number of buildings that have obtained aid.		
Monitoring	Collection of data on the actions concerned through the heads of the Autonomous Communities, once the corresponding action has been carried out. Coordination of data obtained by MITMA.		
Implementation	It will initially be implemented by the Autonomous Communities and Local Authorities, compiling relevant information through their own procedures related to renovation, which will then be supplied to the Ministry of Transport, Mobility and Urban Agenda, which will coordinate this information to ensure that it is homogeneous so that it can be used to determine the scope of these actions within the set of interventions on existing buildings, with a view to future action plans.		

AXIS: BUILDING			B.3
Inclusion of radon field concentration data in the Urban Information System (UIS)			
Aim	Integration of radon concentration data in the field into the UIS urban information platform.		
Description	To integrate protection against radon exposure in urban planning and to be a tool for constructive decision-making for new and existing buildings.		
Directed by	Execution: Ministry of Transport, Mobility and Urban Agenda (S.G. Architecture and Building and S.G. for Land, Information and Evaluation).		
Collaborators	Regional building and town planning departments of the Autonomous Communities. Spanish Nuclear Safety Council (CSN) Local Authorities and institutions and bodies related to territorial information.		
Product	The Urban Information System (UIS) is a general and integrated public information system, included in the First Additional Provision of the RT of the Land and Urban Rehabilitation Law, approved by Legislative Royal Decree 7/2015, and developed by the Ministry of Transport, Mobility and Urban Agenda in collaboration with the Autonomous Communities with the main aim of promoting transparency in land and urban planning in Spain. Link to UIS https://www.mitma.gob.es/portal-del-suelo-y-politicas-urbanas/sistema-de-informacion-urbana/sistema-de-informacion-urbana-siu		
Timeline of actions	2020	Data collection and uploading to the platform	
	2022 and following years	Maintenance and improvement of territorial information data	
Budget €	No costs, included as part of the ordinary work of the S.G. for Land, Information and Evaluation of the Ministry of Transport, Mobility and Urban Agenda		
Performance indicator	Consolidation of the necessary territorial information in the system.		
Results indicator	Use of the territorial information provided		
Monitoring	Maintenance and improvement of territorial information on protection from radon exposure		
Implementation	The UIS contributes to strengthening a system that allows a homogeneous and comparable approach to the urban planning reality, and that guarantees maximum compatibility and coordination, and works in tandem with the rest of the information systems. The main tool for accessing all the graphic and alphanumeric content of the Urban Information System is its map viewer. The UIS Viewer provides free and open access to all the urban planning information of the integrated municipalities. It also provides additional information, including information on natural hazards, which would include information on protection against radon exposure. This information may be relevant when planning future housing projects.		

AXIS: WORKPLACES		C.1
Assess the relevance of proposing a specific Health Surveillance Protocol for workers exposed to radon		
Aim	To be aware of the relevance of proposing a specific Health Surveillance Protocol for workers exposed to radon.	
Description	The effectiveness of lung cancer screening using low-dose radiation computed tomography in reducing lung cancer mortality in people exposed to high doses of radon will be evaluated.	
Directed by	Ministry of Health	
Collaborators	Network of Health Technology Assessment Agencies	
Product	Report on low-dose computed tomography screening for lung cancer	
Timeline of actions	2022	Analysis of related literature. Selection of Health Technology Assessment Agency.
	2023	Start of the evaluation. Drafting and publication of the evaluation report.
Budget €	Costs borne by the Ministry of Health	
Performance indicator	Publication of the report	
Results indicator	Effectiveness of lung cancer screening	
Monitoring	Continuing review of the scientific evidence on the relevance of targeted health surveillance for workers exposed to radon	
Implementation	Work on the management of the pandemic by COVID-19 has delayed the timetable for this line of work. Both the analysis of the related literature and the Health Technology Assessment Agencies' evaluation of lung cancer screening are ongoing. The report is expected to be finalised with the results obtained by the end of 2023.	

<table>
<tr><th colspan="2">AXIS: WORKPLACES</th><th>C.2</th></tr>
<tr><td colspan="3">To facilitate the application of the International Commission on Radiological Protection (ICRP) Publication 137 Part 3 in workplaces with extreme conditions</td></tr>
<tr><td>Aim</td><td colspan="2">To ensure the reliability of the estimates of occupational radon doses and to facilitate the adoption of appropriate operational protective measures in cases where constructive solutions are ineffective or insufficient</td></tr>
<tr><td>Description</td><td colspan="2">The European Directive 2013/59/Euratom requires a dose assessment to be carried out for workers in workplaces with radon concentrations above the reference level. Where these doses may be higher than 6 mSv/year, the exposure of workers must be managed as a planned exposure situation, which entails, among other measures, the implementation of a dosimetric monitoring programme.
In 2018, the ICRP published its new radon dose coefficients (Publication 137, Part 3). According to these, in most workplaces, a radon concentration of 300 Bq/m^3 corresponds to an effective dose of 4 mSv/year. However, under non-standard conditions (e. g. environments with high humidity, with high or very low aerosol concentration or with anomalous particle size distributions) the above ratio may underestimate or, conversely, greatly overestimate the doses received.
Therefore, in certain types of workplaces, it is necessary to carry out research on the parameters that most influence radon dose and, on the basis of the experimental results, to make dose calculations following the methodology proposed by the ICRP.
The information obtained in these investigations will allow the derivation of specific dose coefficients for these workplaces or the design of ad hoc dosimetric monitoring programmes. On the other hand, these investigations will also be relevant for the design of technical mitigation solutions (e. g. forced ventilation) or for the selection of personal protective equipment.</td></tr>
<tr><td>Directed by</td><td colspan="2">Spanish Nuclear Safety Council (CSN)</td></tr>
<tr><td>Collaborators</td><td colspan="2">Polytechnic University of Catalonia (INTE)
Universitat Autònoma de Barcelona (Grupo de Física de las Radiaciones) (Radiation Physics Group)</td></tr>
<tr><td>Product</td><td colspan="2">Report on the validation and methodology for optimal use of the dose conversion coefficients specified in ICRP137.
Revision of CSN Guide 11.4.</td></tr>
<tr><td rowspan="4">Timeline of actions</td><td>2023</td><td>Activities 1, 2 and 3</td></tr>
<tr><td>2024</td><td>Activities 4, 5, 6 7</td></tr>
<tr><td>2025</td><td>Activities 6, 7 and 8</td></tr>
<tr><td>2026</td><td>Activity 9</td></tr>
<tr><td>Budget €</td><td colspan="2">92,580.26 euros</td></tr>
<tr><td>Performance indicator</td><td colspan="2">Publication of the results report.
Revision of CSN Guide 11.4</td></tr>
<tr><td>Results indicator</td><td colspan="2">Specific dose coefficients for typical workplaces, and/or protocols for dose estimation and dosimetric monitoring based on routinely measurable parameters other than radon gas concentration in air.</td></tr>
<tr><td>Implementation</td><td colspan="2">The following activities are envisaged to achieve the proposed aim:
1. Analysis of the system developed in the ICRP137 for dosimetric calculation in the workplace and literature review. Analysis of the application of ICRP 137 for different workplace scenarios where environmental conditions may result in different dose conversion factors.</td></tr>
</table>

AXIS: WORKPLACES	C.2
To facilitate the application of the International Commission on Radiological Protection (ICRP) Publication 137 Part 3 in workplaces with extreme conditions	
	2. Development of the methodology for dose estimates based on the variables measured at the workplace, taking into account the different variables involved in the calculation of the dose, such as, among others, temporal fluctuations, equilibrium factor, free fraction, concentration of particles in the air and their dimensional spectrum. 3. Identification of workplaces to carry out pilot studies of dosimetry estimation according to the methodology developed in section 2. Selection of sites for pilot studies. These sites can be classified into two types: I. Underground workplaces such as caves, mines and caverns, where there are often significant seasonal fluctuations with radon levels higher in summer than in winter (contrary to the case of dwellings, for example) and where the size distribution of aerosols and their density often differ greatly from the values typified in standard atmospheres. II. Workplaces where the main source of radon is groundwater, such as spa resorts and groundwater bottling plants, characterised by extreme and highly variable environmental conditions of temperature and humidity inside the different types of treatment rooms, where very sudden increases can be found. 4. Adaptation of the INTE radon chamber for measurements of the equilibrium factor, the free fraction, the concentration of particles in the air and their dimensional spectrum. 5. An intercomparison was carried out in the INTE-UPC radon chamber with equipment for measuring radon decay, the equilibrium factor, the unbound fraction and the particle concentration. The intercomparison shall be open to different types of equipment available to Spanish measurement groups. 6. Carrying out measurements at selected workplaces. Determination of dose conversion factors and comparison with those specified in ICRP137. Estimation of the dose received by the occupants of the selected enclosures based on the dosimetric model and the recommendations established in ICRP137. 7. Application of the dynamic modelling of radon concentrations and decay in indoor enclosures. The model allowing to simulate the time evolution of both radon concentrations and their total and unattached aerosol particulate progeny will be applied to the results measured in the radon chamber and at the different workplaces. The validation of the model may be useful in improving the determination of dose conversion factors. 8. Analysis of the dose results of points 6 and 7 for the definition of dosimetric calculation procedures in workplaces due to inhalation of radon gas. Dose results will be analysed and procedures for optimal calculations for each type of enclosure studied will be defined. 9. Revision of CSN Guideline 11.4, incorporating a new section on the determination of the dose received due to the inhalation of radon and its progeny in workplaces with extreme conditions.

<table>
<tr><td colspan="2">AXIS: WORKPLACES</td><td>C.3</td></tr>
<tr><td colspan="3">Establish coordination and collaboration mechanisms between the Labour and Social Security Inspectorate and the Spanish Nuclear Safety Council</td></tr>
<tr><td>Aim</td><td colspan="2">Coordinate the actions of the Labour and Social Security Inspectorate (ITSS) and the Spanish Nuclear Safety Council (CSN) and collaborate to improve the performance of their respective inspection functions, with the ultimate aim of ensuring greater protection in workplaces against radon.</td></tr>
<tr><td>Description</td><td colspan="2">The specific regulations and standards on the protection against radon in workplaces are developed in the Regulation on health protection against the risks arising from exposure to ionising radiation (RPSRI) and in CSN Instruction IS-33.
According to this Regulation, employers of certain workplaces - either because of the geographical location or because of the nature of the activity - shall carry out radon measurements in indoor air. In workplaces where the annual average radon concentration exceeds the reference level (RL) of 300 Bq/m^3, employers are obliged to implement actions to reduce exposures and/or carry out mitigation actions. When these fail to ensure concentrations below the RL, employers shall declare this situation to the competent authority of the Autonomous Community.
Without prejudice to the inspection competences of the CSN, the collaboration of the ITSS is essential for the supervision and control of the radiation protection against radon in workplaces.
In this context, a collaboration protocol between the ITSS and the CSN is necessary for better compliance with their respective functions, in accordance with the terms established in the RPSRI.</td></tr>
<tr><td>Directed by</td><td colspan="2">ITSS - CSN</td></tr>
<tr><td>Product</td><td colspan="2">ITSS - CSN collaboration protocol in the field of radon protection in workplaces</td></tr>
<tr><td rowspan="2">Timeline of actions</td><td>2022-2024</td><td>Drawing up and signing of the Collaboration Protocol. Presentation of the Protocol to interested stakeholders</td></tr>
<tr><td>2025-2026</td><td>Implementation of the protocol. Coordination Committee and Monitoring Committee meeting(s)</td></tr>
<tr><td>Budget €</td><td colspan="2">Pertaining to the ITSS and the CSN</td></tr>
<tr><td>Performance indicator</td><td colspan="2">Signing of the Collaboration Protocol.
Minutes of the Coordination Committee and Monitoring Committee meeting</td></tr>
<tr><td>Results indicator</td><td colspan="2">Number of declarations submitted to the regional Registers of Occupational Activities with National Radiation Exposure (CSN).
Number of ITSS communications to the CSN (ITSS).</td></tr>
<tr><td>Implementation</td><td colspan="2">In order to achieve the proposed aim, the signing and establishment of a collaboration protocol between the ITSS and the CSN is foreseen, including the following actions:
1. Training the Labour and Social Security Inspectors and Labour Sub-Inspectors (Occupational Health and Safety scale) to comply with the objectives of the Protocol. The CSN will facilitate this training in coordination with the School of the Labour and Social Security Inspectorate.
2. Arbitrate means of consultation and technical assistance between the Provincial Inspectorates and the CSN in order to resolve any doubts or difficulties that might arise within the framework of their inspection activities.
3. Set up a commission for monitoring the Collaboration Protocol, made up of representatives of the ITSS and the CSN, which will meet every six months.
4. Set up an ITSS-CSN coordination committee that will meet at least once a year to jointly analyse the results of the inspections and actions carried out by both</td></tr>
</table>

AXIS: WORKPLACES	C.3
Establish coordination and collaboration mechanisms between the Labour and Social Security Inspectorate and the Spanish Nuclear Safety Council	
	organisations in relation to radon and to propose actions to improve the efficiency of the inspection function. 5. Carry out information campaigns for workers and companies to provide for information and technical assistance to companies and workers during the exercise of its inspection activity.

AXIS: PRIORITY ACTION AREAS		D.1
Monitoring and dissemination of radon remediation guide		
Aim	The aim of the Radon Remediation Guide is to be a practical tool to assist both the person living in the home and those involved in the technical process of radon protection in interventions in existing buildings. This information given to the person living in the home and others, attempts to cover the whole process starting from the detection or diagnosis of the problem, the interpretation of the results obtained, and the choice of the measures to be adopted to tackle the existing problem.	
Description	The guide has the following features: 1. Practical, with detailed explanations. 2. Simple and easily understood by both layperson and a qualified technician not specialised in the field. 3. Illustrated graphically, with examples of the proposed solutions. 4. Comprehensive, in the sense that it should cover the most common situations, but not necessarily exhaustive. 5. Representative of the circumstances in Spain, taking into account the nature of the way of building in this country.	
Directed by	Execution: Ministry of Transport, Mobility and Urban Agenda (S.G. Architecture and Building)	
Collaborators	Eduardo Torroja Institute for Construction Sciences (IETcc) of the Spanish National Research Council (CSIC) Regional building planning departments of the Autonomous Communities Local authorities	
Product	Bibliographic documentation of an informative nature. Digital format.	
Timeline of actions	2020	Initial publication.
	2021 and following years	Revision and inclusion of new content.
Budget €	Costs associated with the publication (layout...)	
Performance indicator	Digital publication. Degree of dissemination thereof. Number of actions conducted.	
Results indicator	Surveys through professional associations.	
Monitoring	Inclusion of new content and improvement of the initial content according to the needs detected in different areas by the director and the collaborators	
Implementation	Through the Administrative Subcommittee for Quality in Building, a working group has been set up with representatives in the field of building from Autonomous Communities that have requested to form part of it, with the aim of reaching a consensus on the content of the Guide. The Radon Remediation Guide aims to be a practical tool to assist both the resident of the home and those involved in the technical process of radon protection in interventions in existing buildings. The guide is organised into: • a basic text explaining how radon enters the building, how to diagnose the existence of radon, and finally the most common solutions, facilitating the choice of the most appropriate in each case. • An information sheet for each of the solutions with construction details, evaluation of their costs and critical points to be taken into account for their correct execution.	

AXIS: PRIORITY ACTION AREAS	D.1
Monitoring and dissemination of radon remediation guide	
	• Information sheets with specific examples. Dissemination of this document.

AXIS: COMMUNICATION AND RAISING AWARENESS		E.1
Raising awareness among the population and/or specific groups		
Aim	Raise public awareness of the health risks of radon exposure, as well as ways to reduce these risks.	
Description	Promote and disseminate knowledge about the health risks of radon exposure through accurate, reliable and verified information, through a series of activities that will include diagnosis, dissemination, awareness raising and evaluation of what has been achieved, in the population and/or specific groups.	
Directed by	Ministry of Health.	
Collaborators	CSN, Ministry of Transport, Mobility and Urban Agenda, Ministry for Ecological Transition and the Demographic Challenge, Ministry of Labour and Social Economy, Autonomous Communities, local authorities	
Product	Information materials	
Timeline of actions	2024	Development of information material Outreach campaigns
	2025 and following years	Maintenance and updating of content. Outreach campaigns. Development of specific materials according to target groups
Budget €	Own resources	
Process indicator	Social Media Interactions No. of campaigns (with indication of target population): by the Ministry of Health, Autonomous Communities and at local level. Type of media used No. of materials published Total population of the local authorities that make up the Spanish Network of Healthy Cities No. of centres that have collaborated	
Results indicator	Assessment of awareness through analysis and/or surveys	
Monitoring	Maintenance and updating of content	
Implementation	One of the key aspects to be addressed in the National Radon Action Plan is to help ensure that the general public, local decision-makers and working people have reliable and specific information on the health risks of radon exposure, how to reduce these risks, as well as its relationship with tobacco. To this end, different lines of action will be carried out: *Information material* Different information materials such as brochures, posters, spots, etc. will be developed containing information on the health risks of radon exposure and how to reduce them. Outreach materials shall be tailored to each target interest group or, where appropriate, to the general public and shall incorporate simple and understandable information. *Social Networking* In order to achieve greater dissemination and reach among the population and/or specific groups, the radon issue will be included in the social media campaign carried out by the Ministry of Health. This campaign will be conducted through platforms such as Facebook and Twitter. To assess the impact of the campaign, at the end of each year an analysis will be made of the interactions that have been produced by users on this theme. *Synergy between radon and tobacco*	

	Other important information to be presented in the communication campaign is the link between the risk of developing lung cancer and exposure to radon. It is very important to communicate the fact that this risk is multiplied by the synergy between the action of radon and tobacco on the body, so smokers should be considered as a specific risk group. It is important to raise public awareness of the consequences of living in places where people smoke, use heated tobacco products or use electronic cigarettes, especially in priority radon action areas through information/educational activities: -Infographics and brochures -Media and/or social media campaigns *Coordination with other outreach campaigns* Because of the influence of radon on lung cancer and the synergy with the effect of tobacco, joint actions will be carried out with the state campaigns on anti-smoking and cancer prevention. To this end, information on this synergy will be included in the campaigns carried out by the Sub-Directorate General for Health Promotion and Prevention of the Ministry of Health. Similarly, information and documentation will place special emphasis on the increased effect of radon on smokers and national anti-smoking campaigns will be disseminated. Similarly, joint campaigns will be carried out with the Population Cancer Screening Programme of this sub-directorate, focused on training professionals for better cancer prevention in populations exposed to high levels of radon.

AXIS: COMMUNICATION AND RAISING AWARENESS		E.2
Public perception of radon risk in Spain		
Aim	To obtain a pre-communication diagnosis of the public perception of radon in Spain to serve as a baseline for assessing the effectiveness of the National Plan and to generate a scientific basis for approaching radon communication.	
Description	According to the World Health Organization, clear and effective communication with the public should be one of the fundamental aims of a National Radon Action Plan. Communicating any type of risk to the public involves a number of key steps, such as assessing public perception of the risk, using clear and understandable risk messages, and identifying the groups to whom these messages should be addressed. Communicating radon risks and related prevention messages poses a number of difficulties, because the population is not generally familiar with radon and as a natural hazard, it may not be perceived as a health hazard. Radon risk communication campaigns should be designed based on the perceptions and level of knowledge about radon among the target groups. Therefore, a diagnosis will be made of the public perception of radon among politicians, citizens, journalists and scientists in Spain, in general, and in particular in the most affected Autonomous Communities. On the other hand, having a quantitative baseline assessment of the degree of public awareness will provide the baseline level from which to increase the effectiveness and evaluate the efficiency of the communication actions carried out in the National Radon Action Plan	
Directed by	Spanish Nuclear Safety Council (CSN)	
Collaborators	University of Santiago de Compostela	
Product	Indicators are obtained taking into account, in a differentiated manner, the general population and the population residing in areas particularly affected by radon.	
Timeline of actions	2023	Activities 1, 2, 3, 4 and 5
	2024	Activity 6 and 7
	2025	Activity 7
Budget €	72,900.00 euros	
Process indicator	Results report	
Results indicator	Proposal for a Communication Plan to the National Radon Action Plan Committee	
Implementation	The following activities are envisaged to achieve the aim: • Bibliographic Review • Citizen survey • Content analysis of the media agenda • Content analysis of the institutional agenda • In-depth interviews with journalists, communication directors, technicians and politicians linked to the project's subject matter • Design of a proposal for a communication plan for the different actors involved in the coming years • Dissemination, disclosure and sharing of findings	

10. References

1. Real Decreto 1029/2022, de 20 de diciembre, por el que se aprueba el Reglamento sobre protección de la salud contra los Riesgos derivados de la exposición a las radiaciones ionizantes.
2. Ministerio de Sanidad (2021). Plan Estratégico de Salud y Medioambiente 2022-2026. Available at: https://www.sanidad.gob.es/ciudadanos/pesma/docs/241121_PESMA.pdf
3. Ruano-Raviña A et al. (2007). Radón y cáncer de pulmón. Implicaciones para profesionales sanitarios, ciudadanos y administraciones públicas. Med Clin (Barc); 128(4): 545-9
4. IARC (1988). Man-made Mineral Fibres and Radon. IARC Monogr Eval Carcinog Risks Hum, 43:1-300
5. United States Environmental Protection Agency (USEPA). Conducting Human Health risk assessment. Available at: https://www.epa.gov/risk/conducting-human-health-risk-assessment
6. Organización Mundial de la Salud (2021). Nota descriptiva febrero 2021. Available at: https://www.who.int/es/news-room/fact-sheets/detail/radon-and-health
7. Linares Alemparte P. et al. (2020). Guía de Rehabilitación frente al Radón. Available at: https://www.codigotecnico.org/pdf/GuiasyOtros/GuiaRadon/Guia_de_rehabilitacion_frente_al_radon+Fichas.pdf
8. Ministerio de Transportes, Movilidad y Agenda Urbana (2020). Conceptos básicos sobre la modificación del Código Técnico de la Edificación. DB-HS6 Protección frente al Radón. Available at: https://www.codigotecnico.org/pdf/GuiasyOtros/Conceptos_basicos_RD_732_2019_DBHS_6.pdf
9. Ruano-Raviña A et al. (2013). Radón interior. Un carcinógeno laboral olvidado. Arch Prev Riesgos Labor; 16(1):5-6
10. Ruano-Raviña et al. (2014). Radón interior y salud pública en España. Tiempo para la acción. Gac. Sanit.; 28(6):439-441
11. Biological Effects of Ionizing Radiation IV Report (1988). Health risks of radon and other internally deposited Alpha-emitters. BEIR, National Academy Press, Washington D.C.
12. Biological Effects of Ionizing Radiation VI Report (1999). Health effects of exposure to indoor radon. BEIR, National Academy Press, Washington D.C.
13. Darby S et al. (2005). Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. BMJ, 330/7485):223-227
14. Darby S et al. (2006). Residential radon and lung cancer: detailed results of a collaborative analysis of individual data on 7148 subjects with lung cancer and 14208 subjects without lung cancer from 13 epidemiologic studies in Europe. Scand J Work Environ Health, 32 Suppl1: 1-83
15. Krewski D et al. (2005). Residential radon and risk of lung cancer: a combined analysis of 7 North American case-control studies. Epidemiology, 16:137-145

16. Krewski D et al. (2006). A combined analysis of North American case-control studies of residential radon and lung cancer. J Toxicol Environ Health A, 69:533-597

17. Lubin JH et al. (2004). Risk of lung cancer and residential radon in China: pooled results of two studies. Int J Cancer, 109:132-137

18. Quindós L.S. (1985). Radón, un gas radiactivo de origen natural en su casa. Ed. Universidad de Cantabria-CSN

19. European Commission, Joint Research Centre – Cinelli, G., De Cort, M. & Tollefsen, T. (Eds.), European Atlas of Natural Radiation, Publication Office of the European Union, Luxembourg, 2019. Available at: https://remon.jrc.ec.europa.eu/About/Atlas-of-Natural-Radiation/Download-page

20. Frutos Vázquez B et al. (2010). Protección frente a la inmisión de gas radón en edificios. Colección Informes Técnicos 24.2010. Available at: https://www.csn.es/documents/10182/27786/INT-04.20+Protecci%C3%B3n+frente+a+la+inmisi%C3%B3n+de+gas+rad%C3%B3n+en+edificios

21. García-Talavera et al. (2013). Mapping radon-prone areas using gamma radiation dose rate and geological information. Journal of Radiological Protection 33, 605

22. Frutos Vázquez B et al. (2014). Técnica de ventilación como medida de rehabilitación frente a la inmisión de gas radón en edificios y su repercusión en la eficiencia energética. Congreso Latinoamericano REHABEND 2014. Available at: https://repositorio.unican.es/xmlui/bitstream/handle/10902/5748/T%c3%a9cnica%20de%20ventilaci%c3%b3n.pdf?sequence=1&isAllowed=y

23. Quindós L. S. et al. (2016). The Laboratory of Natural Radiation (LNR) – a place to test radon instruments under variable conditions of radon concentration and climatic variables. NUKLEONIKA; 61(3):275–280

24. Piedecausa García B et al. (2011). Radiactividad natural de los materiales de construcción. Aplicación al hormigón. Parte II. Radiación interna: el gas radón. Revista Técnica CEMENTO HORMIGÓN, 946: 34-50. Available at: https://rua.ua.es/dspace/bitstream/10045/27056/1/Radiactividad%20natural%20de%20los%20materiales%20de%20construcci%C3%B3n_Parte%202.pdf

25. Organización Mundial de la Salud (2015). Manual de la OMS sobre el radón en interiores: una perspectiva de salud pública. Available at: http://apps.who.int/iris/bitstream/10665/161913/1/9789243547671_spa.pdf?ua=1

26. Barros-Dios JM et al. (2002). Exposure to residential radon and lung cancer in Spain: a population-based case-control study. Am J Epidemiol; 15; 156(6): 548-55

27. Llorca J et al. (2007). Falta de asociación entre las concentraciones de radón en el domicilio y el cáncer de pulmón en Cantabria. Arch Bronconeumol; 43(12):695-6

28. Barros-Dios JM et al. (2012). Residential radon exposure, histologic types, and lung cancer risk. A case-control study in Galicia, Spain. Cancer Epidemiol Biomarkers Prev; 21(6): 951-8

29. Torres-Durán M et al. (2014). Lung cancer in never-smokers: a case-control study in a radon-prone area (Galicia, Spain). Eur Respir J; 44(4): 994-1001

30. Lorenzo-González M et al. (2019). Lung cancer and residential radon in never-smokers: A pooling study in the Northwest of Spain. Environ Res, May; 172:713-8

31. Lorenzo-González M et al. (2020). Lung cancer risk and residential radon exposure: A pooling of case-control studies in northwestern Spain. Environ Res. 2020 Jul 25; 189:109968

32. Barbosa-Lorenzo R et al. (2017). Residential radon and lung cancer: a cohort study in Galicia, Spain. Cad. Saúde Pública 2017; 33(6):e00189415

33. Barbosa-Lorenzo R et al. (2015). Radón residencial y cáncer de pulmón. Un estudio ecológico en Galicia. Med Clin (Barc). 2015; 144(7):304–308

34. RADPAR: Radon Prevention and Remediation Project. Executive Agency for Health and Consumer (EAHC) of DG SANCO

35. Ruano-Raviña A et al. (2021). Lung cancer mortality attributable to residential radon exposure in Spain and its regions. Environmental Research 199, 111372

36. Pérez-Ríos M et al. (2010). Attributable mortality to radon exposure in Galicia, Spain. Is it necessary to act in the face of this health problem? BMC Public Health; 10: 256

37. Bochicchio F et al. (2012). Quantitative evaluation of the lung cancer deaths attributable to residential radon: A simple method and results for all the 21 Italian Regions. Radiation Measurements; 50: 121-126

38. Catelinois O et al. (2006). Lung cancer attributable to indoor radon exposure in France: impact of the risk models and uncertainty analysis. Environ Health Perspect; 114(9): 1361-66

39. Gray A et al. (2009). Lung cancer deaths from indoor radon and the cost effectiveness and potential of policies to reduce them. BMJ; 338: a3110

40. Menzler S et al. (2008). Population attributable fraction for lung cancer due to residential radon in Switzerland and Germany. Health Phys; 95: 179-189

41. Veloso B et al. (2012). Lung cancer and indoor radon exposure in the north of Portugal – An ecological study. Cancer Epidemiology; 36 (2012): e26-e32

42. Ruano-Raviña et al. (2014). Residential radon exposure and esophageal cancer. An ecological study from an area with high indoor radon concentration (Galicia, Spain). Int J Radiat Biol; 90(4): 299-305

43. Ruano-Raviña et al. (2017). Residential radon exposure and brain cancer: an ecological study in a radon prone area (Galicia, Spain). Scientific Reports; 7: 3595

44. Wheeler BW et al. (2012). Radon and skin cancer in southwest England: an ecologic study. Epidemiol Camb Mass; 23(1):44-52

45. Raaschou-Nielsen O et al. (2008). Domestic radon and childhood cancer in Denmark. Epidemiol Camb Mass; 19(4): 536-43

46. Bräuner EV et al. (2013). Residential radon and brain tumour incidence in a Danish cohort. PloS One; 8(9): e74435

47. Turner Mc et al. (2012). Radon and COPD mortality in the American Cancer Society Cohort. Eur Respir J; 39(5): 1113-9

48. Lanz PM et al. (2013). Radon, Smoking and Lung Cancer: The Need to Refocus Radon Control Policy. American Journal of Public Health, 103:3

49. Directiva 2013/59/Euratom del Consejo 5 de diciembre de 2013 por la que se establecen normas de seguridad básica para la protección contra los peligros derivados de la exposición a radiaciones ionizantes

50. WHO. The global health observatory. (2021). National radon action plans and regulations. Available at: https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/gho-phe-radon-database

51. European Commission, Joint Research Centre (JRC), Directorate G – Nuclear Safety & Security. REM project. (2020). European Indoor Radon Map, December 2020. Available at: https://remon.jrc.ec.europa.eu/About/Atlas-of-Natural-Radiation/Digital-Atlas/Indoor-radon-AM/Indoor-radon-concentration

52. Ministero della Sallute (2002). Piano Nazionale Radon. Available at: https://www.salute.gov.it/portale/documentazione/p6_2_2_1.jsp?lingua=italiano&id=2436

53. Ministero della Salute (2004). Progetto Avvio del Piano Nazionale Radon per la riduzione del rischlo di tumore polmonare in Italia. Available at: https://www.ccm-network.it/documenti_Ccm/prg_area6/prg_6_Radon.pdf

54. Istituto Superiore di Sanità (2022). Pretezione dalle radiazioni. Available at: https://www.iss.it/protezione-dal-radon/-/asset_publisher/L6pCAKa9c9V6/content/radon-e-piano-nazionale-radon-italian-national-radon-program-

55. Autorité de sûreté nucléaire (2011). Plan nacional d´actions 2011-2015 pour la gestion du risque lié au radon. Available at: https://www.asn.fr/l-asn-informe/dossiers-pedagogiques/le-radon-et-les-professionnels/plans-nationaux-d-action/plan-national-d-action-2011-2015-pour-la-gestion-du-risque-lie-au-radon

56. Autorité de sûreté nucléaire (2015). Plan nacional d´action 2016-2019 pour la gestion du risque lié au radon. Available at: https://www.asn.fr/l-asn-informe/dossiers-pedagogiques/le-radon-et-les-professionnels/plans-nationaux-d-action/plan-national-d-action-2016-2019-pour-la-gestion-du-risque-lie-au-radon

57. Autorité de sûreté nucléaire (2021). Plan national d'action 2020-2024 pour la gestion du risque lié au radon. Available at: https://www.asn.fr/l-asn-informe/dossiers-pedagogiques/le-radon-et-les-professionnels/plans-nationaux-d-action/plan-national-d-action-2020-2024-pour-la-gestion-du-risque-lie-au-radon-national-action-plan-2020-2024-for-management-of-the-radon-risk

58. National Radon Control Strategy Coordination Group, Ireland (2019). Final Report on the National Radon Control Strategy – Phase 1 April 2014 to 2018. Available at: https://www.epa.ie/publications/monitoring--assessment/radon/national-radon-control-strategy---phase-1-2014-2018.php

59. National Radon Control Strategy Coordination Group, Ireland (2019). National Radon Control Strategy Phase 2 2019-2024. Available at: https://www.epa.ie/publications/monitoring--assessment/radon/nrcs-phase-2.php

60. Environmental Protection Agency (2014). National Radon Control Strategy for Ireland. Available at: https://www.epa.ie/our-services/monitoring--assessment/radiation/national-radon-control-strategy/

61. State Office for Nuclear Safety (2019). National Action Plan for control of public exposure to Radon. Available at: https://www.sujb.cz/fileadmin/sujb/docs/radiacni-ochrana/PZIZ/Radon/RANAP_ENG.pdf

62. Public Health England (2018). UK National Radon Action Plan. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/719911/UK_National_Radon_Action_Plan.pdf

63. Strålsäkerhetsmyndigheten, Swwdish Radiation Safety Authority (2018). Nationell handlingsplan för radon. Available at: https://www.stralsakerhetsmyndigheten.se/globalassets/radon/nationell-handlingsplan-for-radon.pdf

64. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany (2019). Radon action plan for the sustainable reduction of radon exposure. Available at: https://www.bmuv.de/fileadmin/Daten_BMU/Pools/Broschueren/radonmassnahmenplan_en_bf.pdf

65. Ministry of the Environment, Republic of Estonia (2019). National Radon Action Plan. Available at: https://envir.ee/en/media/2038/download

66. Federal Agency for Nuclear Control, Belgium (2021). Plan national belge d'action radon 2020-2025. Available at: https://afcn.fgov.be/fr/system/files/2021-09-22-belgian-national-radon-action-plan-2020-2025-fr-v2.pdf#:~:text=Le%20plan%20int%C3%A8gre%20les%20activit%C3%A9s,et%20des%20travailleurs%20au%20radon

67. Federal Office of Public Health FOPH Swiss Confederation (2020). Radon Action Plan 2021-2030. Available at: https://www.bag.admin.ch/dam/bag/en/dokumente/str/srr/broschueren-radon/paradon2130.pdf.download.pdf/255.018.052%20Radon-Aktionsplan%202021-2030_DE%20RZ.pdf

68. Federal Office of Public Health FOPH Swiss Confederation (2011). National Action Plan concerning Radon 2012-2020. Available at: https://www.bag.admin.ch/dam/bag/en/dokumente/str/srr/radonaktionsplan-2012-2020.pdf.download.pdf/radon-action-plan-2012-2020.pdf

69. Ministry of Social Affairs and Health, Helsinki (2021). National Radon Action Plan. Disponible en: https://julkaisut.valtioneuvosto.fi/handle/10024/163672

70. Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovaion und Technologie (2021). Nationaler Radon-Maßnahmenplan. Available at: https://www.radon.gv.at/fileadmin/daten-radon/Radon_Massnahmenplan_genehm-20210713.pdf

71. Diário da República, 1.ªsérie. Nº 250 de 29 de dezmbro de 2022. Resolução do Conselho de Ministros nº 150-A/2022. Aprova o Plano Nacional para o Radão. Available at: https://files.dre.pt/1s/2022/12/25001/0001400091.pdf

72. Godet JL, Strand P, Dechaux E, Mrdakovic Popic J. French Nuclear Safety Authority (ASN), Norwegian Radiation Protection Authority (NRPA). (2015). Radon National Action Plan. Report of an International Workshop. Norwegian Radiation Protection Authority

73. Heads of the European Radiological protection Competent Authorities (HERCA). (2014). HERCA Action Plan in relation to the transposition and implementation of Directive 2013/59/Euratom (Euratom BSS). Available at: https://herca.org/docstats/Action%20Plan%20BSS.pdf

74. Bochicchio, F. et al. (2022). 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. Available at: https://doi.org/10.3390/ijerph19074114

75. Suárez Mahou E et al. (2000). Proyecto MARNA. Mapa de radiación gamma natural. Colección Informes Técnicos 5. 2000. Available at: https://www.csn.es/documents/10182/27786/INT-04-02+Proyecto+Marna.+Mapa+de+radiaci%C3%B3n+gamma+natural

76. García-Talavera, M. et al. (2013). El mapa predictivo de exposición al radón en España. Colección Informes Técnicos 38.2013. Available at: https://www.csn.es/documents/10182/27786/INT-04-31%20El%20mapa%20predictivo%20de%20exposici%C3%B3n%20al%20rad%C3%B3n%20en%20Espa%C3%B1a

77. Consejo de Seguridad Nuclear (2017). Mapa del potencial de radón en España. Available at: https://www.csn.es/ca/mapa-del-potencial-de-radon-en-espana

78. Consejo de Seguridad Nacional (2011). Reglamento sobre protección sanitaria contra las radiaciones ionizantes (RPSRI). Available at: http://piramidenormativa.sne.es/Repositorio/CSN/RD_783-2001%20Reglamento%20proteccion%20sanitaria%20sobre%20rad%20ion.pdf

79. Instrucción IS-33 del CSN, de 21 de diciembre de 2011, del Consejo de Seguridad Nuclear, sobre criterios radiológicos para la protección frente a la exposición a la radiación natural

80. García-Talavera, M et al. (2013). Avances reguladores en el control de la exposición al radón en España. Radioprotección (Madrid), 75(XX), 32-35

81. Consejo de seguridad Nacional (2012). Guía de seguridad 11.2 para el control de la exposición a fuentes naturales de radiación. Available at: https://www.csn.es/guias-de-seguridad/-/asset_publisher/0IH2ca8a9jhH/document/id/899064

82. Consejo de seguridad Nacional (2012). Guía de Seguridad 11.4. Metodología para la evaluación de la exposición al radón en los lugares de trabajo. Available at: http://piramidenormativa.sne.es/Repositorio/CSN/GSG-11.04%20Evaluacion%20de%20exposicion%20al%20radon%20en%20trabajo.pdf

83. Quindós L.S. et al. (1989). Radón, principal fuente de radiación natural. Revista española de física; vol 3, nº2, 22-27

84. García-Talavera M. et al. (2019). Cartografía del potencial de radón de España. Colección Informes Técnicos (INT-04.41) Available at: https://www.csn.es/documents/10182/27786/INT-04.41+Cartograf%C3%ADa+del+potencial+de+rad%C3%B3n+de+Espa%C3%B1a

85. del Pozo Gómez, M. (Coord) (2009): Mapa Litoestratigráfico, de Permeabilidad e Hidrogeológico de España continuo digital a escala 1:200.000. Convenio de colaboración entre el Ministerio de Medio Ambiente y el Instituto Geológico y Minero de España para la realización de trabajos técnicos en relación con la aplicación de la Directiva Marco del Agua en materia de agua subterránea. IGME. Madrid. Available at: http://info.igme.es/cartografiadigital/geologica/mapa.aspx?parent=../tematica/tematicossingulares.aspx&Id=15

86. Fernández A. et al. (2020). A New Methodology for Defining Radon Priority Areas in Spain. Environmental Research and Public Health (Int. J. Environ. Res. Public Health 2021, 18, 1352) Public Health, 17, 1780

87. Código Técnico de la Edificación (CTE) (2019). Documento Básico HS 6 Protección frente a la exposición al radón. Available at: https://www.codigotecnico.org/pdf/Documentos/HS/DBHS.pdf

88. Laboratorio de Radón de Galicia. Mapas de mediciones. Available at: http://radon.gal/radon-en-galicia/mapa-mediciones/?lang=es

89. Consejo de seguridad Nacional (2010). Guía de Seguridad 11.1. Directrices sobre la competencia de los laboratorios y servicios de medida de radón en aire. Available at: http://piramidenormativa.sne.es/Repositorio/CSN/gs-11.01.pdf

90. Grossi C et al. (2022). Intercomparación 2020 de medidas de la concentración de radón en aire bajo diferentes condiciones ambientales. Equipos de medida en continuo y detectores integrados. Colección Informes Técnicos 55.2022. Available at: https://www.csn.es/documents/10182/27786/INT-04.45+Intercomparaci%C3%B3n+2020+de+medidas+de+la+concentraci%C3%B3n+de+rad%C3%B3n+en+aire+bajo+diferentes+condiciones+ambientales.+Equipos+de+medida+en+continuo+y+detectores+integra/0b042258-39ec-1f00-50cf-2a725befaad4

11. Annex

Actions associated with each aim and axis of the National Radon Action Plan and responsible body

Axis	Strategic aim	Specific aim	Action	Responsible body
1. Knowledge and basic infrastructure	Understand the magnitude of the problem, and identify and address gaps or difficulties in implementing effective controls or solutions	Assess the exposure of the population to radon (considering contributions from soil, water and building materials), and estimate its impact on population health	Development of measurement campaigns, in collaboration with Autonomous Communities and local councils.	Spanish Nuclear Safety Council (CSN)
			Develop radon potential maps on a regional or local scale and produce the national population exposure map.	Spanish Nuclear Safety Council (CSN)
			Study the contributions to radon doses from building materials.	Spanish Nuclear Safety Council (CSN)/Ministry of Health
			Study radon contributions from drinking water.	Autonomous Communities and Cities
			Estimate the number of cancers attributable to radon in the current situation and make projections subject to meeting the targets foreseen in the National Radon Action Plan.	Ministry of Health.
		Ensure the reliability and quality of radon concentration or dose determinations	Identify the metrological and dosimetric technical capacity in terms of existing supply and expected demand.	Spanish Nuclear Safety Council (CSN)
			Promote the development of a metrological infrastructure in line with the needs of the National Radon Action Plan and regulatory requirements, and which ensures homogeneity and traceability of measurements. Support the organisation of intercomparisons.	Spanish Nuclear Safety Council (CSN)

Axis	Strategic aim	Specific aim	Action	Responsible body
2. Building	Reducing radon concentration in buildings	Develop and update regulations	Analyse needs for new regulation, which has not been previously contemplated or is not available, and the development of these needs.	Ministry of Mobility, Transport and Urban Agenda.
		Promote specific training programmes for the different agents involved in the field of building.	Develop specific actions aimed at training the agents involved in the field of construction, both in the diagnostic and remedial phases.	Ministry of Mobility, Transport and Urban Agenda.
		Implement intervention programmes in existing buildings.	Estimate of costs.	Ministry of Mobility, Transport and Urban Agenda.
		Analyse the impact in terms of architectural typologies	- Develop specific actions aimed at training the agents involved in the field of construction, both in the diagnostic and remedial phases. -Assess the possible integration of radon data into urban data platforms.	Ministry of Mobility, Transport and Urban Agenda.
		Design and promote instruments of support at the regional and municipal level	- Provide technical assistance in the field of construction. -Develop sector-specific financial instruments for individuals and SMEs - Integrate radon prevention into urban planning.	Autonomous Communities
3. Workplaces	Reduce occupational exposures to radon and ensure implementation of the reference level and	Monitor and promote compliance with legislation and regulations applicable to workplaces	Establish a coordination agreement between the Labour and Social Security inspectorate and the CSN inspectorate.	
			Develop specific campaigns in companies, sectors and priority groups.	

Axis	Strategic aim	Specific aim	Action	Responsible body
	compliance with the dose limit for exposed workers		Ensure and promote the competence of entities involved in radon measurement and radon assessment in the workplace (Rn measurement laboratories, RPTU, personal radon dosimetry services).	
			Provide radon-specific training for prevention services and promote the integration of gas protection in companies' occupational risk prevention plans.	
			Assess the relevance of proposing a specific Health Surveillance Protocol for workers exposed to radon	Ministry of Health.
4. Priority action areas	Develop action measures to reduce radon exposure in priority action areas	Develop a methodology easily applicable in the most affected areas	- Development of a toolkit to be applied in priority action areas - Guidance on radon retrofitting of buildings. - Good practice guidelines on water issues.	Transversal
		Incorporate the work carried out by the Autonomous Communities on radon protection		
		Design and promote instruments of support at the regional and municipal level		

Axis	Strategic aim	Specific aim	Action	Responsible body
5. Communication and awareness-raising	Raise awareness among the public, professionals and administrations	Raise public awareness of the health effects of radon, particularly in combination with tobacco	- Diagnosis of the public perception of radon in Spain - Production of information brochures and videos. - Development of communication systems (website, social networks). - Organisation of information days - Develop user-focused information and awareness-raising actions in existing buildings.	Transversal
		Encourage the commitment of public administrations and the integration of radon in related programmes and plans	- Facilitate with support the integration of the different levels of public administration in the development of radon-related programmes.	Transversal