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The Harmonization of Radon Exposure Mitigation for the Sustainability of Buildings: Assessing the Impact of the EURATOM Directive on European Legislation

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Abstract: Radon exposure is a major health concern associated with an increased risk of lung cancer, particularly in smokers, highlighting the need for effective mitigation measures in enclosed spaces by improving indoor air quality (IAQ), thus ensuring more sustainable buildings. The Euratom Directive, a key piece of EU legislation, sets standards for the protection of workers and the general public from ionizing radiation throughout Europe. It requires member states to implement safety measures, set exposure limits, monitor radon levels, and develop emergency plans and mitigation strategies for nuclear accidents and radiation incidents. The directive also sets reference and action levels for indoor radon. The aim of this article is to analyze the legislation on indoor radon exposure in European countries and to evaluate the impact of the directive on the standardization of the action and intervention levels. By conducting a comprehensive legislative review, this study will compare the action levels, assess the directive's ability to harmonize the regulations, and identify legislative trends and developments. In addition, it will examine the factors contributing to the discrepancies between countries and highlight areas for improvement to ensure adequate protection against the risks of radon exposure and thereby increase the sustainability of buildings.



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1. Introduction

Radon exposure is a matter of great concern due to its association with an increased risk of lung cancer, particularly among smokers, as the harmful chemicals in tobacco exacerbate the lung damage caused by radon exposure [1]. The inhalation of radon can lead to the deposition of alpha particles in the lungs, potentially leading to cancer development [2]. The World Health Organization (WHO) recognizes radon as the second leading cause of lung cancer after tobacco smoking [3]. Therefore, it is essential to take measures to reduce the radon exposure in indoor environments, thereby improving indoor air quality (IAQ) and contributing to the sustainability of buildings, by measuring radon levels and implementing strategies to reduce indoor exposure [4]. The 2013/59/Euratom Directive (<https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32013L0059>, accessed on 7 February 2025) is a legislative act of the European Union that establishes the standards for protection against ionizing radiation throughout Europe, encompassing the safeguarding of workers and the public [5]. It mandates that member states establish

fundamental safety requirements in all activities involving ionizing radiation, set exposure limits, and monitor exposure [6]. Additionally, the directive requires national authorities to formulate contingency plans and mitigation measures in the event of nuclear accidents or other radiation incidents, address the management of radioactive waste, and establish decontamination programs for outdated nuclear facilities [7]. The directive is periodically updated to ensure that safety standards align with the latest scientific and technological advancements [8]. The directive sets the reference and action levels for radon in indoor environments [9]. The reference levels indicate whether exposure to a particular source of radiation poses health risks, while the action levels guide the appropriate responses to the measured levels of radiation [10]. If the measured radiation levels exceed the action level, mitigation measures must be taken to reduce exposure to radiation [4]. The reference levels for the radon exposure in workplaces and residences are set at $300 \text{ Bq}\cdot\text{m}^{-3}$, and the action levels are established at $400 \text{ Bq}\cdot\text{m}^{-3}$ for occupational exposure and $1000 \text{ Bq}\cdot\text{m}^{-3}$ for exposure in public buildings [11].

EU member states must implement the guidelines outlined in the 2013/59/Euratom Directive, which establishes fundamental safety standards for protection against the hazards arising from exposure to ionizing radiation, including radon [12]. Each country is responsible for transposing the directive into its national legislation, involving an internal legislative process, including the creation of new laws or amending existing laws, establishing regulatory bodies, and implementing monitoring and control systems [13]. The directive aligns with the international norms and recommendations established by the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP) and is perceived as a blueprint for the best practices regarding protection against ionizing radiation globally [14]. EU legislation frequently influences the policies and regulations of other European countries, and certain countries that have an association or free trade agreements with the EU also adopt and enforce the guidelines and standards outlined by the Euratom Directive within their legislative frameworks [15].

This article seeks to identify and analyze the current legislation regarding radon exposure in indoor environments across European countries, including both European Union (EU) member states subject to the Euratom Directive and non-member countries that are not directly bound by the directive. The primary objective is to assess the directive's influence on the standardization of the action and intervention levels for mitigating the effects of radon exposure in indoor spaces. The analysis will involve a comprehensive review of the legislation from all European countries, focusing on the action levels established for residential and workplace settings. It will compare the action levels adopted by EU member states, which are required to comply with the Euratom Directive, with those implemented by non-member countries, which typically follow guidelines and recommendations issued by international organizations such as the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Additionally, this study will explore the directive's effectiveness in harmonizing the radiological protection measures among member states, highlighting the similarities and differences in national legislations. Particular attention will be given to the monitoring and mitigation practices for radon exposure, as well as protocols and procedures for assessing and reducing the associated risks in indoor environments. The analysis will also examine the legislative trends and developments across Europe, identifying the factors—such as political, economic, and cultural considerations—that may contribute to variations between countries. The aim of this evaluation is to provide a deeper insight into the role of the directive in standardizing the levels of action and intervention across Europe and to identify areas where further improvements are needed to ensure comprehensive

protection against the risks of radon exposure, thereby contributing to the sustainability of buildings through improved IAQ.

2. Materials and Methods

2.1. Study Design

This study employed a comparative review of the legislation concerning radon exposure in indoor environments across European countries. The methodology consisted of three main stages. First, the data sources were identified and selected, including official databases and regulatory documents. Subsequently, the relevant data were collected and categorized, with a focus on extracting legislative information, action levels, and mitigation measures. Finally, a comparative analysis was conducted to examine the differences between EU member states, which are required to comply with the Euratom Directive, and non-signatory countries that follow international guidelines.

2.2. Data Sources

National and international databases were used to ensure a comprehensive collection of radon-related regulations. Table 1 presents the data sources, including Eur-Lex, the WHO, the ICRP, the IAEA, and UNSCEAR, along with the national legislative databases listed in Tables 2 and 3.

Table 1. List of digital databases used in the collection of general information, monitoring parameters, technical procedures, and action levels.

Database	Description
Eurolex	Eur-Lex is a database maintained by the European Union that provides access to legal documents, including treaties, legislation, case law, and preparatory acts, from all EU member states. It is available in all official EU languages and can be accessed at https://eur-lex.europa.eu/ .
WHO	The World Health Organization (WHO) is a specialized agency of the United Nations dedicated to international public health. It plays a central role in coordinating and directing global health initiatives, including efforts to control and prevent infectious diseases, improve maternal and child health, and promote healthy lifestyle practices. The organization's headquarters are located in Geneva, Switzerland (https://www.who.int/).
ICRP	The International Commission on Radiological Protection (ICRP) is an independent international organization that provides recommendations and guidance on radiation protection. Its mission is to safeguard people and the environment from the harmful effects of ionizing radiation (https://icrp.org/).
IAEA	The International Atomic Energy Agency (IAEA) is an international organization dedicated to promoting the peaceful use of nuclear energy and preventing the proliferation of nuclear weapons. Established in 1957, the IAEA is headquartered in Vienna, Austria (https://www.iaea.org/).
UNSCEAR	The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established in 1955 to provide scientific advice to the United Nations and its member states on the effects of ionizing radiation on human health and the environment (https://www.unscear.org/).

Table 2. Digital legislation databases in EU member states.

Country	Description
Austria	The official database for online legal information in Austria is the “Rechtsinformationssystem des Bundes” (RIS). It can be accessed at https://www.ris.bka.gv.at , accessed on 7 February 2025.
Belgium	The official database for online legislation in Belgium is the “Moniteur Belge/Belgisch Staatsblad”, accessible at https://www.ejustice.just.fgov.be/cgi/welcome.pl , accessed on 7 February 2025. It contains all laws, decrees, orders, and other regulations published in the Belgian Official Journal, including consolidated and updated versions. Additionally, private databases such as LegalWorld, Lex.be, Juridat, and Jurisquare also provide free or paid access to legal information in Belgium.

Table 2. Cont.

Database	Description
Bulgaria	The official database for online consultation of legislation in Bulgaria is the Bulgarian Legislative Information System (LEX), maintained by the Council of Ministers. It provides free access to all laws, regulations, and decisions published in the Official Gazette of Bulgaria since 1990. The database can be accessed at http://www.lex.bg , accessed on 7 February 2025.
Cyprus	The online database for legislation in Cyprus is called “CYLAW”, maintained by the Press and Information Office of the Government of Cyprus. It provides access to legal information and can be accessed at https://www.cylaw.org/ .
Croatia	The official database for online legislation consultation in Croatia is called “Narodne novine”, meaning “National Newspapers”. This digital platform, maintained by the Croatian government, provides access to all laws, regulations, and other official acts published in the Official Gazette of the Republic of Croatia. The site is available in both Croatian and English and can be accessed at https://narodne-novine.nn.hr/ , accessed on 7 February 2025.
Czech Republic	The official database for online legislation consultation in the Czech Republic is the “Sbírka zákonů” (Collection of Laws). It is maintained by the Chamber of Deputies of the Czech Republic and can be accessed at https://www.nssoud.cz/ , accessed on 7 February 2025.
Denmark	The official database for online legislation consultation in Denmark is “Retsinformation”. It provides access to laws, decrees, executive orders, and other legal acts of the Danish government. The service is free and open to the public and can be accessed at https://www.retsinformation.dk/ , accessed on 7 February 2025.
Estonia	The official database for online legislation consultation in Estonia is the “Riigi Teataja”. It provides access to laws, decrees, regulations, directives, and other legal documents issued in Estonia. The database can be accessed at https://www.riigiteataja.ee/en , accessed on 7 February 2025.
Finland	The official legislation database for online consultation in Finland is “Finlex”, accessible at https://www.finlex.fi/en/ , accessed on 7 February 2025.
France	The official database for online legislation consultation in France is “Legifrance”, accessible at https://www.legifrance.gouv.fr/en/ , accessed on 7 February 2025.
Germany	The official database for online legislation consultation in Germany is called “Bundesrecht”. It is available on the official website of the German federal government at https://www.gesetze-im-internet.de/ , accessed on 7 February 2025.
Greece	The official database for online consultation of Greek legislation is the “National Printing House”, accessible at http://www.et.gr/ , accessed on 7 February 2025.
Hungary	The official database for online legislation consultation in Hungary is the “Magyar Közlöny Lap- és Adattár” (Official Journal and Database). It provides access to all laws, regulations, and other official publications of the Hungarian government and can be accessed at https://www.mhk.hu/ , accessed on 7 February 2025.
Ireland	The official database for online legislation consultation in Ireland is the “Irish Statute Book”, accessible at https://www.irishstatutebook.ie/ , accessed on 7 February 2025. Additionally, the Office of the Attorney General in Ireland maintains an updated list of legislative acts, which is available at https://www.attorneygeneral.ie/en/for-the-public/the-law/ , accessed on 7 February 2025.
Italy	The official database for online legislation consultation in Italy is the “Gazzetta Ufficiale”, maintained by the Italian government. It provides access to Italian laws, public announcements, and judicial decisions. The database can be accessed at https://www.gazzettaufficiale.it/ , accessed on 7 February 2025.
Latvia	The official database for online legislation consultation in Latvia is “Latvijas Vēstnesis”, accessible at https://www.vestnesis.lv/ , accessed on 7 February 2025.
Lithuania	The official database for online legislation consultation in Lithuania is the “Register of Legal Acts” (Registruotų teisės aktų registras). It is accessible at https://www.e-tar.lt/portal/en/legalActs.aspx , accessed on 7 February 2025.
Luxembourg	The official database for online legislation consultation in Luxembourg is “Legilux”. It serves as the official electronic publishing platform of the Luxembourgish state, offering free access to all laws, decrees, and regulations published in the Journal Officiel (Official Journal) of Luxembourg since 1972. The website can be accessed at https://legilux.public.lu , accessed on 7 February 2025.

Table 2. Cont.

Database	Description
Malta	The official database for online legislation consultation in Malta is the Maltese government's official website, "Laws of Malta", accessible at https://legislation.mt/ , accessed on 7 February 2025. It provides access to all of the current legislation in force in Malta, allowing users to search and access laws, regulations, and other legal provisions of the country.
Netherlands	The official legislation database for online consultation in the Netherlands is the "Wettenbank", accessible at https://wetten.overheid.nl/ , accessed on 7 February 2025.
Poland	The official database for online legislation consultation in Poland is the "Internetowy System Aktów Prawnych" (ISAP), or the Online System of Legal Acts. This portal provides free access to updated Polish legislation, including the laws, regulations, and decisions of the Constitutional Tribunal. It is available in Polish and can be accessed at https://isap.sejm.gov.pl/ , accessed on 7 February 2025.
Portugal	The official database for online legislation consultation in Portugal is the Electronic Official Gazette (<i>Diário da República Eletrónico</i> , or DRE). It serves as the official source for laws, decrees, regulations, and other acts published by the Portuguese government. The DRE can be accessed at https://dre.pt/home/-/dre/117407729/details/maximized , accessed on 7 February 2025.
Romania	The official database for online legislation consultation in Romania is the "Monitorul Oficial al României" (Official Gazette of Romania). It allows users to search for regulatory acts and laws and view the latest editions of the official gazette. The database can be accessed at https://www.monitoruloficial.ro/ , accessed on 7 February 2025.
Slovakia	The official database for online legislation consultation in Slovakia is Slov-Lex, maintained by the Ministry of Justice of Slovakia. It provides free access to updated legislation and other legal information. The database can be accessed at https://www.slov-lex.sk/legislativne-procesy/LexKons/ , accessed on 7 February 2025.
Slovenia	The official database for online legislation in Slovenia is the "Slovenski zakonodajni informacijski sistem" (Slovenian Legislative Information System), also known as "SloLIS". It can be accessed at https://www.uradni-list.si/1/seznam-zakonov , accessed on 7 February 2025.
Spain	The official database for online legislation consultation in Spain is the "BOE" (Boletín Oficial del Estado), accessible at https://www.boe.es/ , accessed on 7 February 2025.
Sweden	The official database for online legislation consultation in Sweden is the "Swedish Code of Statutes" (SFS), accessible at https://www.riksdagen.se/sv/dokument-lagar/bocker/svensk-forfattningssamling/ , accessed on 7 February 2025. While the Riksdagen website also provides access to laws and regulations, the SFS serves as the official database.

Table 3. Digital legislation databases in non-signatory European countries.

Country	Description
Albania	The online legislation database for Albania is the Albanian Legal Information System (ALIS), accessible at http://alis.cdb.gov.al/ , accessed on 7 February 2025.
Andorra	Andorra is a principality situated between France and Spain, with a legal system based on civil and canon law, as well as international agreements signed by the country. However, there is no official online legislation database available through the Andorran government's website. Legislation may be accessible in physical format at libraries or public agencies within the country.
Armenia	The official online database for legislation consultation in Armenia is the "Unified Information System of Legal Acts", accessible at http://www.arlis.am/DocumentView.aspx?docID=12230 , accessed on 7 February 2025. Additionally, the website of the National Assembly of Armenia provides a "Legislation" section with access to national laws and regulations at http://www.parliament.am/legislation.php , accessed on 7 February 2025.
Azerbaijan	The online database for legal acts in Azerbaijan is the "Legal Acts Database", available on the "National Legal Internet Portal of Azerbaijan" at http://www.e-qanun.az/ .
Belarus	The National Legal Internet Portal of the Republic of Belarus is the official database for online legislation consultation in Belarus. It can be accessed at https://www.pravo.by/ , accessed on 7 February 2025.

Table 3. Cont.

Country	Description
Bosnia and Herzegovina	The online database for legislation consultation in Bosnia and Herzegovina is the “Official Gazette of Bosnia and Herzegovina”, accessible at https://www.sluzbenilist.ba/ , accessed on 7 February 2025. Additionally, the Parliament of Bosnia and Herzegovina provides a legislative database, which can be accessed at http://www.parlament.ba/ , accessed on 7 February 2025.
Georgia	The official database for online legislation consultation in Georgia is the “Legislative Herald of Georgia”, accessible at http://matsne.gov.ge/en/ , accessed on 7 February 2025.
Iceland	The online legal database for Iceland is the “Legal Gazette”, accessible through the official website of the Icelandic government at https://www.althingi.is/lagasafn/ , accessed on 7 February 2025.
Kosovo	The official website of the Kosovan government is https://kryeministri-ks.net/en/ , accessed on 7 February 2025. The legislation section is accessible at https://kryeministri-ks.net/en/category/documents/legislation/ , accessed on 7 February 2025.
Liechtenstein	The legislation of Liechtenstein is available on the official website https://www.gesetze.li/ , accessed on 7 February 2025.
Moldova	The online database for legislation in Moldova is the Legislative Information System (SIL), accessible at https://lex.justice.md/index.php/home/index/en , accessed on 7 February 2025.
Monaco	The official legislation database of Monaco is the <i>Journal de Monaco</i> , where the laws, regulations, and government decisions of the principality are published. It is available online through the official website of the Government of Monaco. Additionally, French legislation is applicable in Monaco due to the cooperation agreement between the two countries. French legislation can be consulted on the official website of the French government.
Montenegro	The official database for online legislation consultation in Montenegro is the “Official Gazette of Montenegro”, accessible at https://www.sluzbenilist.me/ , accessed on 7 February 2025.
North Macedonia	The official database for online legislation consultation in North Macedonia is the “Official Gazette of the Republic of North Macedonia”, accessible at https://www.slvesnik.com.mk/Home/Index , accessed on 7 February 2025. The website provides free access to legislation in both Macedonian and English.
Norway	The official legislation database for online consultation in Norway is “Lovdata”. This online platform provides access to all Norwegian legislation, including laws, regulations, agreements, and other legal provisions. The site is regularly updated and features advanced search options to help locate specific information. While basic access is free, some advanced features require a subscription. The database can be accessed at https://lovdata.no/ , accessed on 7 February 2025.
United Kingdom	The website for online legislation consultation in the United Kingdom is https://www.legislation.gov.uk/ , accessed on 7 February 2025.
Russia	The official database for online legislation consultation in Russia is the “Legal Information Consultation System”, accessible at https://www.consultant.ru/ , accessed on 7 February 2025. It contains a comprehensive collection of the federal laws, government decrees, and other legal regulations of Russia. An English version of the portal, which includes a selection of laws and legal regulations translated into English, is available at https://www.consultant.ru/en/ , accessed on 7 February 2025. Additionally, other platforms such as “Garant” (https://www.garant.ru/ , accessed on 7 February 2025) provide access to federal and regional legislation, jurisprudence, and other legal information sources.
San Marino	San Marino provides access to its legislation online through the government’s official website at https://www.sanmarino.sm/ , accessed on 7 February 2025.
Serbia	The official legislation database for online consultation in Serbia is the Službeni glasnik Republike Srbije (Official Gazette of the Republic of Serbia). It can be accessed at https://www.sluzbenikupac.rs/ , accessed on 7 February 2025.
Switzerland	The official database for online legal information and legislation in Switzerland is the Legal Information System (SIS), accessible through the Swiss government’s website at https://www.admin.ch/gov/en/start/documentation/laws/official-compilation-of-federal-law.html , accessed on 7 February 2025. SIS serves as the official legal information system of the Swiss federal government and includes federal laws, orders, provisions, and decisions, as well as the opinions of the federal courts.

Table 3. Cont.

Country	Description
Turkey	The official database for online legislation consultation in Turkey is the “Electronic Official Gazette (e-Gazette)”, accessible at https://www.resmigazete.gov.tr/ , accessed on 7 February 2025.
Ukraine	The official online database for accessing legislation in Ukraine is “Legal Space”, available at https://zakon.rada.gov.ua/ , www.vatican.va . The platform provides access to all Ukrainian legislation, including laws, decrees, regulations, and other legal provisions. It also offers advanced search tools to facilitate finding specific information. Access to the platform is free and regularly updated.
Vatican	The Vatican, as an independent state, has its own legal system and legislation database. The Vatican’s legislation can be accessed through the official website of the Vatican, which includes the “Lexicon recentis Latinitatis” section containing updated laws in Latin and Italian: www.vatican.va .

2.3. The Selection Criteria

Documents were selected based on specific inclusion and exclusion criteria. Included materials comprised official legislation on radon exposure, technical standards, official reports from radiation organizations, and national policies applicable to indoor environments, including both residential and workplace settings. Excluded materials encompassed academic studies unrelated to legislation, opinion articles, and unofficial technical documents.

2.4. The Data Collection Procedures

Data were manually collected through a structured search of official databases. Each document was systematically reviewed to extract information on the action and intervention levels (in Bq/m³), monitoring and mitigation requirements, enforcement and compliance mechanisms, and differences between EU member states and non-signatory countries. The collected data were subsequently organized into a spreadsheet for further analysis.

2.5. Analytical Methods

The analysis was conducted in two main phases. In the qualitative analysis, regulations were examined in terms of their implementation of the Euratom Directive and their alignment with recommendations from the ICRP and UNSCEAR. In the comparative analysis, the data were structured into a comparative matrix to assess the discrepancies between EU member states, which are required to comply with the Euratom Directive, and non-signatory countries, which follow international guidelines.

3. Transposition of the Euratom Directive in the Countries of the European Union

3.1. Framework

The Euratom Directive is signed by the member states of the European Union, which currently consists of 27 nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. It is important to note that not all EU member states have transposed the Euratom Directive into their national legislation within the deadline established by the European Union. However, the transposition of the directive is mandatory for all member states, and failure to comply may result in legal consequences being imposed by the EU.

3.2. European Union Countries

3.2.1. Austria

The Allgemeine Strahlenschutzverordnung (ASV)—2018 General Radiation Protection Regulation—is Austrian legislation that establishes guidelines and requirements for protection against ionizing and non-ionizing radiation, including radon exposure in indoor environments. In accordance with the ASV, Austria has adopted a reference level for the radon concentration in enclosed spaces, as recommended by the Euratom 2013/59 Directive of the European Commission. The reference level for radon exposure in workplaces and residences in Austria is set at 300 Bq/m³.

3.2.2. Belgium

The Arrêté Royal relatif à la protection de la population et de l'environnement contre les dangers résultant des rayonnements ionisants (Royal Decree on the protection of the population and the environment against hazards arising from ionizing radiation) is a piece of legislation in Belgium that establishes guidelines and requirements for protection against ionizing radiation, including radon exposure in indoor environments. In accordance with the Euratom Directive, Belgium has set a reference level for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences in Belgium is 400 Bq/m³.

3.2.3. Bulgaria

Regulation No. 8 of 28 July 2004, on the Basic Standards of Radiation Safety, is Bulgarian legislation that establishes guidelines and requirements for protection against ionizing radiation, including radon exposure in indoor environments. In accordance with the recommendations of the Euratom Directive, Bulgaria has set a reference level for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences in Bulgaria is 300 Bq/m³.

3.2.4. Cyprus

The Regulations for Protection against Ionizing Radiation of 2002 (K.D.P. 112/2002) are a set of laws in Cyprus that establish guidelines and requirements for protection against ionizing radiation, including radon exposure in indoor environments. In compliance with the Euratom Directive, Cyprus has set a reference level for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences in Cyprus is 200 Bq/m³.

3.2.5. Croatia

The Radiological and Nuclear Safety Act of 2018 is Croatian legislation that establishes guidelines and requirements for protection against ionizing radiation, including radon exposure in indoor environments. In compliance with the Euratom Directive, Croatia has set a reference level for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences in Croatia is 300 Bq/m³.

3.2.6. The Czech Republic

In the Czech Republic, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by Vyhláška č. 499/2000 Sb., o radiační ochraně (Regulation No. 499/2000 Coll., on Radiation Protection). This legislation was established in alignment with the Euratom Directive. According to Czech regulations, the reference level for the radon concentration in enclosed spaces has been set at 300 Bq/m³ for workplaces and residences.

3.2.7. Denmark

The Bekendtgørelse om ioniserende stråling og strålebeskyttelse (Instruction on Ionizing Radiation and Radiation Protection) of 2018 is Danish legislation that establishes guidelines and requirements for protection against ionizing radiation, including radon exposure in indoor environments. In accordance with this regulation and as recommended by the Euratom Directive, Denmark has set reference levels for the radon concentration in enclosed spaces. The reference level for radon exposure is 200 Bq/m³ in workplaces and 100 Bq/m³ in residences.

3.2.8. Estonia

The Radiation Act of 2004 is Estonian legislation that establishes guidelines and requirements for protection against ionizing radiation, including radon exposure in indoor environments. This act was updated in 2018 to incorporate the recommendations of the Euratom Directive and introduce new provisions aiming to protect the population and the environment from the dangers of ionizing radiation. Additionally, the Radiation Work Requirements of 2019 provide specific regulations for activities involving ionizing radiation, including the proper handling of radon. Under the updated Radiation Act and Radiation Work Requirements, Estonia has set reference levels for the radon concentration in enclosed spaces. The reference level is 300 Bq/m³ for workplaces and 200 Bq/m³ for residences.

3.2.9. Finland

Finland's Radiation Act No. 859/2018 and Radiation Decree No. 861/2018 establish guidelines and requirements for protection against ionizing radiation, including radon exposure in indoor environments. In accordance with these regulations and the recommendations of the Euratom Directive, Finland has set reference levels for the radon concentration in enclosed spaces. The reference level is 400 Bq/m³ for workplaces and 300 Bq/m³ for residences.

3.2.10. France

In France, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by the Code de la Santé Publique (Public Health Code) and related regulations, such as the Euratom Directive. The French Public Health Code, together with other regulations, establishes a reference level for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences in France is 300 Bq/m³.

3.2.11. Germany

The Strahlenschutzgesetz (Radiation Protection Act) and the Strahlenschutzverordnung (Radiation Protection Regulation) are key pieces of legislation in Germany that establish guidelines and requirements for protection against ionizing and non-ionizing radiation. These regulations address various aspects of radiation protection, including occupational, medical, and environmental exposure, as well as radon exposure in indoor environments. In alignment with the recommendations of the Euratom Directive, German legislation sets the reference level for radon exposure in workplaces and new residential buildings at 300 Bq/m³. For existing buildings, the reference level is applied flexibly, taking into account specific circumstances such as the technical feasibility and cost-effectiveness of mitigation measures. Additionally, property owners are encouraged to voluntarily reduce the radon levels if they exceed 100 Bq/m³.

3.2.12. Greece

In Greece, protection against ionizing radiation, including radon exposure in indoor environments, is governed by Ministerial Decision Υ1γ/Γ.Π/οικ. 26008 (Υ1g/G.P/oik. 26008) of 2020. This decision updated and complemented the existing legislation in alignment with the Euratom Directive. Under Ministerial Decision Υ1γ/Γ.Π/οικ. 26008, Greece has established a reference level for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences is 300 Bq/m³.

3.2.13. Hungary

In Hungary, protection against ionizing radiation, including radon exposure in indoor environments, is governed by Regulation No. 16/2000 (8 June) EüM on Protection against Ionizing Radiation and Related Procedures. In alignment with the Euratom Directive, this regulation establishes the reference levels for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces is 400 Bq/m³, while in residences, it is 300 Bq/m³.

3.2.14. Ireland

In Ireland, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by the Ionising Radiation Regulations 2019 (S.I. No. 30 of 2019). These regulations were established in alignment with the Euratom Directive. According to the Ionising Radiation Regulations 2019, Ireland has set a reference level for the radon concentration in enclosed rooms. The reference level for radon exposure in workplaces and residences is 200 Bq/m³.

3.2.15. Italy

In Italy, protection against ionizing radiation, including radon exposure in indoor environments, is governed by Legislative Decree No. 101 of 31 July 2020. This decree implements the Euratom Directive, replacing earlier legislation on the subject. According to Legislative Decree No. 101/2020, Italy has established a reference level for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences is set at 300 Bq/m³.

3.2.16. Latvia

In Latvia, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by the Radiācijas drošības un radioaktīvo atkritumu pārvaldības likums (Law on Radiation Safety and Radioactive Waste Management) of 2018 and the Grozījumi Ministru kabineta noteikumos par ionizējošo starojumu aizsardzību (Amendments to the Cabinet of Ministers Regulations on Protection against Ionizing Radiation) of 2019. These laws and regulations were established in accordance with the Euratom Directive. Under Latvian legislation, a reference level for the radon concentration in enclosed spaces has been set. The reference level for radon exposure in workplaces and residences is 300 Bq/m³.

3.2.17. Lithuania

In Lithuania, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by the Lietuvos Respublikos Radiacinės saugos įstatymas (Law of the Republic of Lithuania on Radiological Safety) of 2018 and the Vyriausybės nutarimas dėl Ionizuojančiosios spinduliuotės šaltinių naudojimo ir Radiacinių nuotekų valdymo (Government Decision on the Use of Ionizing Radiation Sources and Management of Radioactive Waste) of 2019. These laws and regulations were established in alignment with the Euratom Directive. Lithuanian legislation sets a reference level for the radon

concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences is 200 Bq/m³.

3.2.18. Luxembourg

In Luxembourg, the regulation on protection against ionizing radiation, including radon exposure in indoor environments, is governed by the Law of 25 March 2020 on the Protection of Public Health Against the Dangers Arising from Ionizing Radiation. This law transposes the Euratom Directive and establishes general requirements for radiation protection. While specific details regarding the action levels of radon are not explicitly mentioned in these laws, it is likely that the reference level for radon exposure in workplaces and residences aligns with the directive's recommendation of 300 Bq/m³.

3.2.19. Malta

In Malta, protection against ionizing radiation, including radon exposure in indoor environments, is governed by the Protection from Ionising Radiation Regulations (SL. 424.29). These regulations were established in alignment with the Euratom Directive. According to Maltese regulations, the reference level for the radon concentration in enclosed spaces is set at 300 Bq/m³ for both workplaces and residences.

3.2.20. Poland

In Poland, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by the Rozporządzenie Ministra Zdrowia w sprawie ochrony przed promieniowaniem jonizującym (Regulation of the Minister of Health on Protection Against Ionizing Radiation) of 2018. This legislation was established in accordance with the Euratom Directive. Under Polish regulations, the reference level for the radon concentration in enclosed spaces has been set at 300 Bq/m³ for both workplaces and residences.

3.2.21. Portugal

In Portugal, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by Decree-Law No. 108/2018, of 3 December. This legislation was established in compliance with the Euratom Directive. According to Portuguese regulations, the reference level for the radon concentration in enclosed spaces is set at 300 Bq/m³ for both workplaces and residences.

3.2.22. Romania

In Romania, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by Legea nr. 111/1996 privind desfășurarea în siguranță a activităților nucleare (Law No. 111/1996 on the Safe Conduct of Nuclear Activities) and its associated regulations. This legislation was established in alignment with the Euratom Directive. Although the main legislation does not explicitly specify the reference levels for the radon concentration in enclosed spaces, Romania likely adheres to the recommendations of the European Commission, which sets a reference level of 300 Bq/m³ for radon exposure in workplaces and residences.

3.2.23. Slovakia

Regulation No. 345/2006 Coll., Concerning the Specifics of Protection Against Ionizing Radiation, serves as the legislative framework in Slovakia outlining the guidelines and requirements for safeguarding against ionizing radiation, including radon exposure in indoor environments. In accordance with the Euratom Directive, this regulation establishes a reference level for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences in Slovakia is set at 300 Bq/m³.

3.2.24. Slovenia

The Regulation on Ionizing Radiation of 2017 is the current legislation in Slovenia that establishes the guidelines and requirements for protection against ionizing radiation, including radon exposure in indoor environments. In alignment with the Euratom Directive, this regulation sets reference levels for the radon concentration in enclosed spaces. The reference level for radon exposure is 300 Bq/m³ for workplaces and 200 Bq/m³ for residences.

3.2.25. Spain

Royal Decree 783/2001 serves as the legal framework in Spain for protection against ionizing radiation, including radon exposure in indoor environments. This decree was updated by Royal Decree 1439/2010, which introduced new provisions to enhance the protection of the population and the environment from the hazards of ionizing radiation. In accordance with Royal Decree 783/2001, as updated by Royal Decree 1439/2010, Spain has established a reference level for the radon concentration in enclosed spaces, as recommended by the Euratom Directive. The reference level for radon exposure in workplaces and residences is set at 300 Bq/m³.

3.2.26. Sweden

In Sweden, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by the Strålskyddslag (2018:396) (Radiation Protection Act of 2018) and the Strålskyddsförordning (2018:506) (Radiation Protection Regulation of 2018). In alignment with the Euratom Directive, the Swedish legislation establishes a reference level for the radon concentration in enclosed spaces. The reference level for radon exposure in workplaces and residences is set at 200 Bq/m³.

3.2.27. The Netherlands

In The Netherlands, protection against ionizing radiation, including radon exposure in indoor environments, is regulated by the Besluit basisveiligheidsnormen stralingsbescherming (Decision on Basic Safety Standards for Protection Against Radiation) of 2017. This legislation was established in compliance with the Euratom Directive. Under Dutch regulations, reference levels for the radon concentration in enclosed spaces have been set. The reference level is 100 Bq/m³ for new constructions and 200 Bq/m³ for existing buildings.

4. Other Legal Norms and Regulations

4.1. Framework

Not all European countries adhere to the Euratom Directive. If a country chooses not to follow Euratom, it may establish its own laws and regulations to ensure protection against ionizing radiation and radon. Additionally, such countries may align with other international standards and directives, such as those formulated by the International Atomic Energy Agency (IAEA), which promotes global collaboration on nuclear-related matters, including protection against ionizing radiation and radon. European countries that do not adhere to Euratom can also reference the guidelines and standards issued by international organizations such as the World Health Organization (WHO) and the International Commission on Radiological Protection (ICRP).

4.2. Legislation in Countries Outside the European Union

4.2.1. Albania

Regarding the radon legislation in Albania, no specific information is available. However, as Albania is a member of both the International Atomic Energy Agency (IAEA) and the European Union (EU), it is likely that this country follows international guidelines and recommendations for protection against ionizing radiation, including radon exposure. Generally, countries adhering to the IAEA and EU guidelines implement measures to safeguard public health from the hazards of ionizing radiation, including the establishment of reference levels for radon exposure.

4.2.2. Andorra

Specific information on the legislation related to ionizing radiation in Andorra is not readily available. However, it is likely that Andorra adheres to the international and European regulations to ensure the safety and protection of its citizens.

4.2.3. Armenia

Although specific information about the radon legislation in Armenia is not available, it is noteworthy that Armenia is a member of the International Atomic Energy Agency (IAEA) and adheres to international guidelines and recommendations related to ionizing radiation protection, including radon exposure. In 1999, Armenia adopted the Armenian Law on Nuclear Energy and Radiological Safety, which outlines fundamental principles for radiological safety and the protection of the public and the environment from ionizing radiation hazards. This law also established a regulatory framework and designated authorities responsible for monitoring and enforcing radiological protection measures. While specific action levels for radon exposure were not identified, Armenia likely follows the international guidelines and recommendations set by the IAEA and other related organizations.

4.2.4. Azerbaijan

Specific information on the radon legislation in Azerbaijan is not readily available. However, as a member of the International Atomic Energy Agency (IAEA), Azerbaijan is likely to adhere to the international guidelines and recommendations for protection against ionizing radiation, including radon exposure. In 1998, Azerbaijan adopted the Law on Radiological Safety, which established the fundamental principles for radiological safety and the protection of the population and the environment from the hazards of ionizing radiation. This law also outlined the regulatory framework and designated authorities responsible for supervising and enforcing radiological protection measures. While specific details about the action levels for radon exposure are not known, Azerbaijan likely follows the international guidelines and recommendations issued by the IAEA and other related organizations.

4.2.5. Belarus

Radon legislation in Belarus is governed by the Law of the Republic of Belarus on Radiological Safety of the Population, enacted on 8 January 1998. This law established the fundamental principles for radiological safety and the protection of the population and the environment from the hazards of ionizing radiation, including radon exposure. As a member of the International Atomic Energy Agency (IAEA), Belarus likely adheres to international guidelines and recommendations for protection against ionizing radiation. However, specific details about the action levels for radon exposure in Belarus are not currently available.

4.2.6. Bosnia and Herzegovina

Specific information on the radon legislation in Bosnia and Herzegovina is not available. However, as a member of the International Atomic Energy Agency (IAEA), Bosnia and Herzegovina is likely to adhere to the international guidelines and recommendations for protection against ionizing radiation, including radon exposure.

4.2.7. Georgia

In Georgia, the legislation related to radon and protection against ionizing radiation is based on the Law on Occupational Hygiene and Radiological Safety of Georgia. This law outlines the requirements and responsibilities for protecting workers and the general public from the risks associated with exposure to ionizing radiation, including radon. However, specific information regarding the action levels for radon and other details in the Georgian legislation is limited and may be subject to change over time.

4.2.8. Iceland

In Iceland, protection against ionizing radiation, including radon exposure, is governed by the Lög um geislavörn (Radiation Protection Act) No. 44/2015. This act establishes the general requirements for radiation protection and defines the responsibilities of regulatory bodies and stakeholders. In alignment with the Euratom Directive, Icelandic legislation sets a reference level for the radon concentration in indoor environments at 300 Bq/m³ for both workplaces and residences.

4.2.9. Kosovo

In Kosovo, the legislation related to protection against ionizing radiation, including radon, is based on the Law on Protection Against Radiation No. 05/L-109, adopted in 2016. This law established the general requirements for radiation protection and defined the responsibilities of regulatory bodies and stakeholders. While Kosovo aligns with the recommendations of the Euratom Directive concerning radon exposure, detailed information on the specific reference levels for radon in Kosovo is not readily available.

4.2.10. Liechtenstein

In Liechtenstein, the legislation regarding protection against ionizing radiation, including radon, is based on the Strahlenschutzgesetz (Radiation Protection Act) and the Strahlenschutzverordnung (Radiation Protection Regulation). These laws and regulations cover the general aspects of radiation protection and define the responsibilities of regulatory authorities and stakeholders. Liechtenstein aligns with the recommendations of the Euratom Directive concerning the action levels for radon. However, detailed information on the specific reference levels for radon in Liechtenstein may not be readily available.

4.2.11. Moldova

In Moldova, the legislation regarding radon is governed by Law No. 121 of 14 June 2012 on Protection Against Ionizing Radiation. This law establishes a legal framework for radiological protection in Moldova and incorporates EU guidelines on protection against ionizing radiation. However, specific information on the action levels for radon exposure in Moldovan legislation is not available.

4.2.12. Monaco

No specific legislation on radon has been identified in Monaco to date. However, as an “associated country” for the EU, Monaco maintains close relations with the EU through special cooperation and partnership agreements. Consequently, the guidelines and standards established by the Euratom Directive are applicable within the Monegasque territory.

4.2.13. Montenegro

Montenegro currently lacks specific and comprehensive legislation related to radon. However, this country may adhere to the guidelines established by the Euratom Directive, which recommends a reference level of 300 Bq/m³ for the radon concentration in indoor environments. Additionally, the International Atomic Energy Agency (IAEA) has published a guide titled “Protection of the Public Against Radon: A Guide to the Implementation of the European Radon Action Plan”, which provides recommendations for developing radon mitigation measures.

4.2.14. North Macedonia

In North Macedonia, there is currently no specific legislation addressing radon in indoor environments. However, this country adopts the reference values recommended by the European Commission for the radon concentration in indoor environments, set at 300 Bq/m³. North Macedonia also aligns with the Euratom Directive, which establishes basic safety requirements for protection against the hazards of ionizing radiation.

4.2.15. Norway

Radon legislation in Norway is governed by the Regulation on Protection Against Radon (Radonbeskyttelsesforskriften) of 2013. This regulation provides guidelines for measuring and evaluating the radon concentration in indoor environments and specifies action levels to protect against radon exposure. These action levels are based on the annual average concentration of radon in a given area, and mitigation measures may be required if these levels are exceeded. In areas with low potential, the action level is set at 100 Bq/m³. For areas with moderate potential, the action level is 200 Bq/m³, while in areas with high potential, it is 400 Bq/m³. These classifications are determined using geological maps and radon measurement data. Additionally, this regulation establishes guidelines for assessing and reducing radon exposure in workplaces.

4.2.16. The United Kingdom

In the United Kingdom, radon legislation is governed by the Ionising Radiations Regulations (IRR) of 2017, which include specific provisions for radon. The IRR 2017 set the reference level for the radon concentration at 300 Bq/m³ for workplaces and 200 Bq/m³ for dwellings, in line with the EU's recommendations. These regulations also mandate mitigation measures in buildings where the radon levels exceed the established reference levels.

4.2.17. Russia

In Russia, radon legislation is governed by the federal regulation SanPiN 2.6.1.2523-09: Sanitary and Epidemiological Rules and Regulations for Protection of the Population from Exposure to Ionizing Radiation. This regulation establishes reference levels for the radon concentration in indoor environments and provides guidelines for mitigating radon exposure. According to the regulation, the reference level for the radon concentration in indoor environments is set at 200 Bq/m³ as an annual average, with a maximum allowable concentration of 400 Bq/m³ for up to 10% of the measurement period. Additionally, this regulation includes guidelines for mitigating radon exposure in both new constructions and existing buildings. Mitigation measures may be required by Russian authorities if radon levels exceed the established reference limits.

4.2.18. San Marino

San Marino does not have specific legislation on radon. However, the Technical Commission for Radiological and Nuclear Protection, associated with the Public Health Service,

plays a key role in promoting radiological protection and nuclear safety in this country. This commission can be consulted for guidance and recommendations on the subject.

4.2.19. Serbia

In Serbia, the legislation regarding radon is governed by the Ionizing Radiation and Nuclear Safety Act (Zakon o jonizujućem zračenju i nuklearnoj sigurnosti) of 2015, along with technical norms for protection against radon. These include the Radiological Protection Norm against Radon (Radon radiološka zaštita) and the Radiological Protection Norm in Buildings (Radiološka zaštita u građevinarstvu). The Ionizing Radiation and Nuclear Safety Act establishes reference levels for the radon concentration in public and private buildings, as well as requirements for radon measurement and evaluation. It also includes provisions for the radiological protection of workers exposed to radon, covering exposure monitoring and risk assessment. However, specific action levels for radon in Serbia are not readily available.

4.2.20. Switzerland

The Swiss legislation concerning radon includes the Federal Law on Protection Against Radiation (RS 814.501) and the Regulation on Protection Against Radiation (RS 814.501.1). These regulations outline the requirements and guidelines for protection against ionizing radiation across all sectors, including radon exposure. Switzerland has established a reference level of 300 Bq/m³ for the radon concentration in indoor environments, consistent with the values adopted by many other European countries. The recommended annual average exposure to radon is 100 Bq/m³. For workplaces, the regulations mandate mitigation measures if the radon concentration exceeds 1000 Bq/m³. In residences, authorities may require mitigation measures if radon levels exceed 300 Bq/m³.

4.2.21. Turkey

In Turkey, radon legislation is governed by the Regulation on Radiation Control in Buildings (Binalarda Radyasyon Kontrolü Yönetmeliği), adopted in 2015. This regulation establishes the concentration limits for radon in buildings, setting an action level of 400 Bq/m³ for workplaces and 300 Bq/m³ for residences. Additionally, it mandates mitigation measures when the radon levels exceed these action limits.

4.2.22. Ukraine

In Ukraine, several laws and regulations address protection against ionizing radiation, although there is no specific legislation exclusively dedicated to radon. Radon protection is integrated into general measures for protection against ionizing radiation in buildings and workplaces. Key laws and regulations include the Ukrainian Law on Protection of Population Against Ionizing Radiation (2017), the Resolution of the Government of Ukraine on Approval of Rules for Protection of Population Against Ionizing Radiation (2012), the Rules of Radiological Safety of Ukraine (approved by the Ministry of Health in 2012), the Typical Norms of Radiological Safety (2012), and the Norms of Radiological Safety of Ukraine (2012). Ukrainian legislation sets the reference level for the radon concentration in indoor environments at 200 Bq/m³. Additionally, it establishes an action level of 400 Bq/m³. When radon levels exceed this action level, mitigation measures are recommended to reduce exposure.

4.2.23. Vatican

No specific information is available regarding legislation related to radon in the Vatican. As an independent state, the Vatican may choose to follow European Union guidelines or implement its own regulations on the matter.

5. Discussion

The Euratom Directive serves as a legislative framework for establishing stringent radiological protection standards across EU member states [16,17]. Applicable to activities involving ionizing radiation sources, such as nuclear medicine, radiotherapy, and industrial radiography, the directive primarily addresses enhanced safety standards for radiation exposure [18]. It prescribes the radiation dose limits for workers and the public, mandates rigorous monitoring protocols, and necessitates the formation of national radiological protection authorities in each member state [19]. While the action levels adopted under the Euratom agreement depend on individual countries' legislation, they generally adhere to the international recommendations, including those issued by the ICRP and UNSCEAR [20]. The directive sets common dose limits for ionizing radiation exposure across EU member states, although the action levels may differ between countries [21]. The process for determining action levels is intricate, taking into account various factors, including the types of radiation sources and exposure activities [22]. Countries may adopt action levels divergent from those in the international recommendations, reflecting political, economic, and cultural considerations [23]. The recommendations of international organizations are summarized in Table 4, and the action levels for countries that are signatories of the Euratom Directive are summarized in Table 5.

Table 4. Recommendations from the international organizations.

Organization	Workplaces (Bq·m ^{−3})	Public Buildings and Dwellings (Bq·m ^{−3})
EURATOM ¹	300	300
ICRP ²	100–300 (optimized range)	100–300 (optimized range)
IAEA ³	Not specified	Not specified
UNSCEAR ⁴	Not specified	Not specified
WHO ⁵	Not specified	100 (but it should not exceed 300)

¹ For radon exposure, the Euratom Directive (2013/59/Euratom) establishes the following action levels: Workplaces—A radon concentration action level of 300 Bq·m^{−3}. If the radon levels measured in workplaces exceed this value, employers are required to take measures to mitigate the radon exposure for the safety of their employees. Residences and public buildings—While there is no specific action level mentioned in the directive for residences and public buildings, it encourages member states to develop their own national action plans for managing indoor radon concentrations. In practice, many countries adopt a reference level of 100–300 Bq·m^{−3} for residential buildings, based on the World Health Organization's recommendations. ² In ICRP Publication 126, the ICRP recommends an optimized range of the radon concentrations for dwellings, public buildings, and workplaces. The optimized range provided is 100–300 Bq·m^{−3} for dwellings and public buildings, and the same range is suggested for workplaces. It is emphasized that the objective is to keep the radon levels as low as reasonably achievable (the ALARA principle) within this range, considering social and economic factors. ³ In the IAEA Safety Standards Series No. GSG-1, "Classification of Radioactive Waste", the IAEA addresses radon exposure by emphasizing the importance of the ALARA (as low as reasonably achievable) principle and the optimization of protection in controlling radon levels. ⁴ UNSCEAR primarily focuses on evaluating the sources, doses, and risks associated with ionizing radiation, including radon exposure. Their findings are used by other organizations and member states to develop and implement radiation protection policies, regulations, and recommendations. ⁵ In "the WHO Handbook on Indoor Radon: A Public Health Perspective", this organization recommends a reference level for the radon concentration in indoor environments. The WHO suggests a reference level of 100 Bq·m^{−3} for the radon concentration in dwellings. However, if this level cannot be achieved under national circumstances, the reference level should not exceed 300 Bq·m^{−3}. This guidance aims to minimize the health risks associated with indoor radon exposure, particularly lung cancer.

Non-Euratom European countries typically follow the ICRP and UNSCEAR recommendations, establishing national radiological protection authorities to oversee the implementation of radiological protection measures [24]. Most European countries, including non-Euratom members, adhere to the international standards on indoor radon concentrations [24]. The IAEA facilitates technical assistance and cooperation, emphasizing global collaboration and expertise-sharing to improve radiological protection measures [25]. Table 6 summarizes the action levels and legislation status of the non-Euratom members.

Table 5. Action levels in Euratom Directive signatory countries.

Country	Workplaces (Bq·m ^{−3})	Public Buildings and Dwellings (Bq·m ^{−3})
Austria	300	300
Belgium	400	400
Bulgaria	300	300
Cyprus	200	200
Croatia	300	300
The Czech Republic	300	300
Denmark	200	100
Estonia	300	200
Finland	400	300
France	300	300
Germany	300	300 (for new residential buildings and recommended voluntary measures to reduce to 100)
Greece	300	300
Hungary	400	300
Ireland	200	200
Italy	300	200 for new public buildings after 31 December 2024
Latvia	300	300
Lithuania	200	200
Luxembourg	Probably 300	Probably 300
Malta	300	300
Poland	300	300
Portugal	300	300
Romania	300	300
Slovakia	300	300
Slovenia	300	300
Spain	300	300
Sweden	200	200
The Netherlands	100	200

Comparing the Euratom Directive to the international norms reveals its rigor in establishing stricter safety standards for ionizing radiation exposure [26]. For instance, the directive prescribes an annual limit of 20 mSv for occupational exposure and 1 mSv for general public exposure, with radon concentration limits similar to those in other countries, such as Canada and the US [27]. The Euratom Directive necessitates specific requirements for occupational radon exposure, including assessment, monitoring, and concentration reduction measures [28]. Although the directive does not set a specific action level for occupational radon exposure, EU member states have enacted varying national regulations and guidelines [12]. The action levels for occupational exposure vary depending on the circumstances and risks involved.

The majority of European countries, including non-Euratom members, have legislation addressing radon exposure, highlighting this issue's significance and governmental concern [24]. Radon is a natural radioactive gas that poses health risks, primarily of lung cancer, particularly among smokers [29,30]. Implementing measures to monitor and reduce the radon exposure in indoor environments is vital, as reflected in the legislation of various

European countries, regardless of their Euratom membership. This legislation encompasses reference and action levels for indoor radon concentrations and procedures for evaluating and monitoring occupational radon exposure, promoting the protection of populations.

Table 6. Action levels and legislation status of the non-Euratom members.

Country	Active Legislation? ¹	Workplaces (Bq·m ^{−3})	Public Buildings and Dwellings (Bq·m ^{−3})
Albania	n	No information available	No information available
Andorra	n	No information available	No information available
Armenia	y	No information available	No information available
Azerbaijan	y	No information available	No information available
Belarus	y	No information available	No information available
Bosnia and Herzegovina	n	No information available	No information available
Georgia	y	No information available	No information available
Iceland	y	300	300
Kosovo	y	No information available	No information available
Liechtenstein	y	No information available	No information available
Moldova	y	No information available	No information available
Monaco	n	Probably 300	Probably 300
Montenegro	n	Probably 300	Probably 300
North Macedonia	n	Probably 300	Probably 300
Norway	y	Depending on the regional potential (low, moderate, or high), it can be, respectively, 100, 200, or 400	Depending on the regional potential (low, moderate, or high), it can be, respectively, 100, 200, or 400
The United Kingdom	y	300	200
Russia	y	Annual average of 200 (with maximum peaks of 400 in 10% of the measurement time)	Annual average of 200 (with maximum peaks of 400 in 10% of the measurement time)
San Marino	n	No information available	No information available
Serbia	y	No information available	No information available
Switzerland	y	300	300
Turkey	y	400	300
Ukraine	y	400	400
Vatican	n	No information available	No information available

¹ y—with active legislation; n—without active legislation or information not found.

6. Conclusions

The Euratom Directive represents a robust and comprehensive legislative framework that establishes high-level standards for radiological protection across the European Union. It addresses all areas involving the use of ionizing radiation, including nuclear medicine, radioactive waste management, and nuclear safety. The directive mandates dose limits for both workers and the general public, requires the monitoring of radiation exposure in workplaces, and calls for the establishment of national radiological protection authorities to ensure effective implementation of its provisions in each member state. The presence of specific radon legislation in nearly all European countries, including non-Euratom member states, highlights the significance of this issue and the deep concern of governments regarding radon exposure. As a naturally occurring radioactive gas, radon can accumulate in indoor environments, posing risks to public health. Consequently, governments are tasked with adopting measures to monitor and mitigate the radon exposure in both residential and workplace settings. The Euratom Directive is widely regarded as a cornerstone of radiological protection in the European Union, ensuring the implementation of stringent safety

standards across all member countries. It facilitates the deployment of effective radiological protection measures in all activities involving ionizing radiation. The widespread adoption of radon-specific legislation by European countries, irrespective of their Euratom membership, underscores the recognition of radon's risks and the commitment of governments to safeguarding public health. The ultimate goal of indoor radon mitigation is to improve the air quality in buildings and thus contribute to their sustainability, as the health of buildings is highly dependent on the quality of indoor air.

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