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Federal Department of Home Affairs FDHA

Federal Office of Public Health FOPH
Consumer Protection Directorate

Radon Action Plan

2021 – 2030

Contents

1 Summary

Radon is a radioactive gas found in the ground which can accumulate in enclosed spaces. It causes 200–300 lung cancer deaths a year in Switzerland [1]. The risk of lung cancer increases linearly with radon concentration and length of exposure time [2].

The basic principles regarding radon protection in Switzerland are set out in the Radiological Protection Ordinance (RPO) [3]. Since 2012, the Federal Office of Public Health (FOPH) has been implementing the National Radon Action Plan 2012–2020, whose primary aim is to bring Switzerland's strategy in line with international recommendations. In 2018, a new reference level of 300 Becquerel per cubic metre (Bq/m^3) was introduced for the average annual concentration of radon gas in occupied spaces. Over 10% of previously measured buildings in Switzerland exceed this reference level across all Swiss regions.

The evaluation of the National Radon Action Plan 2012–2020 [5] showed that while good progress has been made on the fundamental work, not enough has been achieved regarding widespread implementation of the measures in the Action Plan, particularly with regard to measurement campaigns, remediation, building regulations and cooperation with other programmes. Public awareness is not yet sufficient and the Swiss population is not adequately protected from radon. New buildings are still being planned and built without appropriate preventative radon protection measures, and existing buildings with high levels of radon exposure are not being remediated. This has led to too many people being exposed to a level of radon exposure that is unnecessary and above all dangerous to health, whether in their homes or in the workplace.

The FOPH seeks to provide optimal protection of Switzerland's population from radon by conducting measurements, systematically protecting new buildings against radon, carrying out remediation, and taking specific protective measures for children and people in the workplace.

The challenges faced between 2021 and 2030, which will arise in very different thematic areas, can be summarised in four lines of action:

- Radon protection in building stock must be sustainably improved, in particular by creating synergies with energy-efficiency measures in buildings.
- Public awareness and understanding of the health risk need to be improved, which will result in the issue of radon gaining importance.
- In order to meet the increased demand for planning and implementation of radon protection measures in new buildings and remediation projects, radon expertise among builders, planners, architects and radon specialists must be improved and expanded.
- Radon protection must be guaranteed in the workplace, for employee protection and to prevent occupational diseases.

The four lines of action set out in the Action Plan are substantiated in objectives and measures and accompanied by digital solutions, targeted federal government research projects and information campaigns (see Figure 2).

2 Background

Radon makes up the majority of the Swiss population's average exposure to radiation [6] and also causes between 200 and 300 lung cancer deaths a year in Switzerland [1]. From a geological perspective, Switzerland is a high radon area where measures to protect the public are essential.

According to the World Health Organization (WHO), radon is the second leading cause of lung cancer after smoking [7]. Worldwide, radon is a dominant contributor to human radiation exposure, with the highest exposures occurring in countries with temperate climates (where heating is needed in winter) and with high construction standards (energy-efficient, airtight construction methods).

Various international organisations issue recommendations on the most appropriate radon protection measures. In their basic safety standards, both the International Atomic Energy Agency (IAEA) [8] and the European Union (EURATOM) [9] recommend implementing radon protection measures as part of an action plan. In its Radon Handbook [7], the WHO also recommends developing a national radon programme and introducing a reference level of 100 Bq/m^3 to minimise radon risk. If this reference level cannot be complied with due to the relevant country-specific conditions, a reference level of maximum 300 Bq/m^3 should be set on which there is an international consensus. In the recently-published 'WHO Housing and health guidelines' [10], the WHO also recommends considering radon in the context of overall indoor air quality. Radon is a key parameter in indoor air quality and as such is a crucial indicator of a healthy indoor environment.

The principles concerning radon protection in Switzerland are set out in the RPO [3]; since 2018, new provisions have been applicable in the RPO, which were developed as part of the National Radon Action Plan 2012–2020 [4]. These include a reference level of 300 Bq/m^3 for the average annual concentration of radon gas in occupied spaces. If this reference level is exceeded, the associated individual risk is not permissible and corresponding measures must be taken. Long-term exposure to a radon concentration of 300 Bq/m^3 equates to an increase of around 50% in the relative risk of lung cancer [7]. This results in a considerably higher absolute risk of lung cancer for smokers than non-smokers (approximately 25 times higher).

To date, a radon measurement has been carried out in around 6% of all buildings in Switzerland (which equates to more than 150,000 predominantly existing buildings). These measurements cover the whole of Switzerland, but more have been carried out in geologically hazardous regions. Over 10% of these buildings exceed the new reference level of 300 Bq/m^3 in occupied spaces, compared with approx. 1% based on the previous threshold of 1,000 Bq/m^3. As a result, radon has evolved from a regional to a national issue. The Alps and Jura regions are the worst affected by the issue of radon (see Figure 1). This is due to the soil properties (uranium content, soil permeability, karst areas). The reference level may be exceeded in all regions of Switzerland, however. According to the WHO, most radon-induced lung cancers occur from low and medium dose exposures, as they are predominant among a much greater percentage of the population than high dose exposures [7]. Higher radon concentrations have also been detected in connection with the former use of radium-containing luminous paint in Switzerland's traditional watch making regions.

The RPO [3] sets out new enforcement tasks for the cantons. It provides for special protection for children through the obligation to conduct measurements and carry out remediation in schools and nurseries. In addition, the building permission authorities have been required, since early 2020, to draw the attention of building owners and clients to the issue of radon in the case of new buildings or building alterations. For radon-exposed workplaces, a threshold level of 1,000 Bq/m^3 for the annual average radon gas concentration also applies. If this threshold level is exceeded, the enterprise must determine the annual radon-related effective dose to exposed persons and if the effective dose is above 10 mSv per year, the enterprise must take organisational or technical mitigation measures.

In addition to the Radon Action Plan, the Federal Council passed the Energy Strategy 2050 [11] in 2013. This aims to increase energy efficiency, including in buildings and industry, and to promote measures to expand the use of renewable energies. The building programme [12], for example, which is organised by the cantons, promotes energy efficiency measures in buildings, such as the renovation of building envelopes (excluding windows), and the replacement of fossil fuels with renewable energies. Additional energy efficiency measures are supported through other incentive schemes [13]. It is very important that energy efficiency measures are implemented according to the latest technology as otherwise they can lead to an increase in radon exposure [14] [15]. If these aspects are observed, such renovation projects lead to enhanced energy efficiency and good indoor air quality. The radon action plan is intended to take account of the health aspect of energy-efficiency measures in buildings from this perspective.

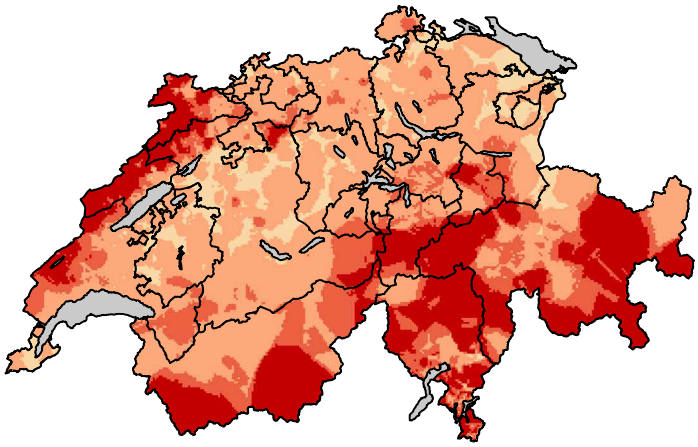

Figure 1:
Radon map of Switzerland
The colours show the likelihood of exceeding the reference level of 300 Bq/m^3 in the respective area.
(Source: FOPH 2018, map can be viewed at map.geo.admin.ch)

3 Vision for radon protection

The vision provides a framework for the national radon strategy. It is designed to demonstrate what the federal government, cantons and their partners intend to do in the years ahead to protect the public from radon exposure.

Vision **The Swiss population is optimally protected from radon.**

This vision will be implemented between now and 2050 by means of the following strategic objectives:

1. Radon concentrations will be measured reliably
2. The lowest possible radon concentrations will be sought for new buildings (100 Bq/m^3) and indoor air quality generally improved
3. The situation in existing buildings will be gradually improved by utilising synergies with renovation work
4. Children will be protected from radon through specific measures in schools and nurseries
5. In the workplace, people should not be permanently exposed to over 1000 Bq/m^3 without mitigation measures

The strategy and the Radon Action Plan 2021–2030 are closely coordinated with the Health2030 strategy, in particular with the topic 'environment and health', as well as with the Federal Council's Energy strategy 2050 [11].

4 Lines of action

The lines of action in the Radon Action Plan 2021–2030 stem from the radon strategy and vision described above, international guidelines, the implementation of radon-related provisions in the RPO and the findings of an external evaluation of the previous action plan for the period 2012–2020 [5].

The challenges of the coming years, which will arise in very different thematic areas, can be summarised in four lines of action.

- Radon protection in building stock must be sustainably improved, in particular by creating synergies with energy-efficiency measures in buildings.
- Public awareness and understanding of the health risk need to be improved, which will result in the issue of radon gaining importance.
- In order to meet the increased demand for planning and implementation of radon protection measures in new buildings and remediation projects, radon expertise among builders, planners, architects and radon experts must be improved and expanded.
- Radon protection must be guaranteed in the workplace, for employee protection and to prevent occupational diseases.

The four lines of action in the Action Plan will each be accompanied by innovative digital solutions. For example, technologies such as the internet of things and smart home apps can intelligently control indoor air quality. Research in the field of intelligent algorithms (artificial intelligence) will help ensure more reliable predictions based on the radon map and improved radon data. In addition, all the lines of action will be supplemented with targeted federal government research projects and information campaigns. The starting position is illustrated in Figure 2.

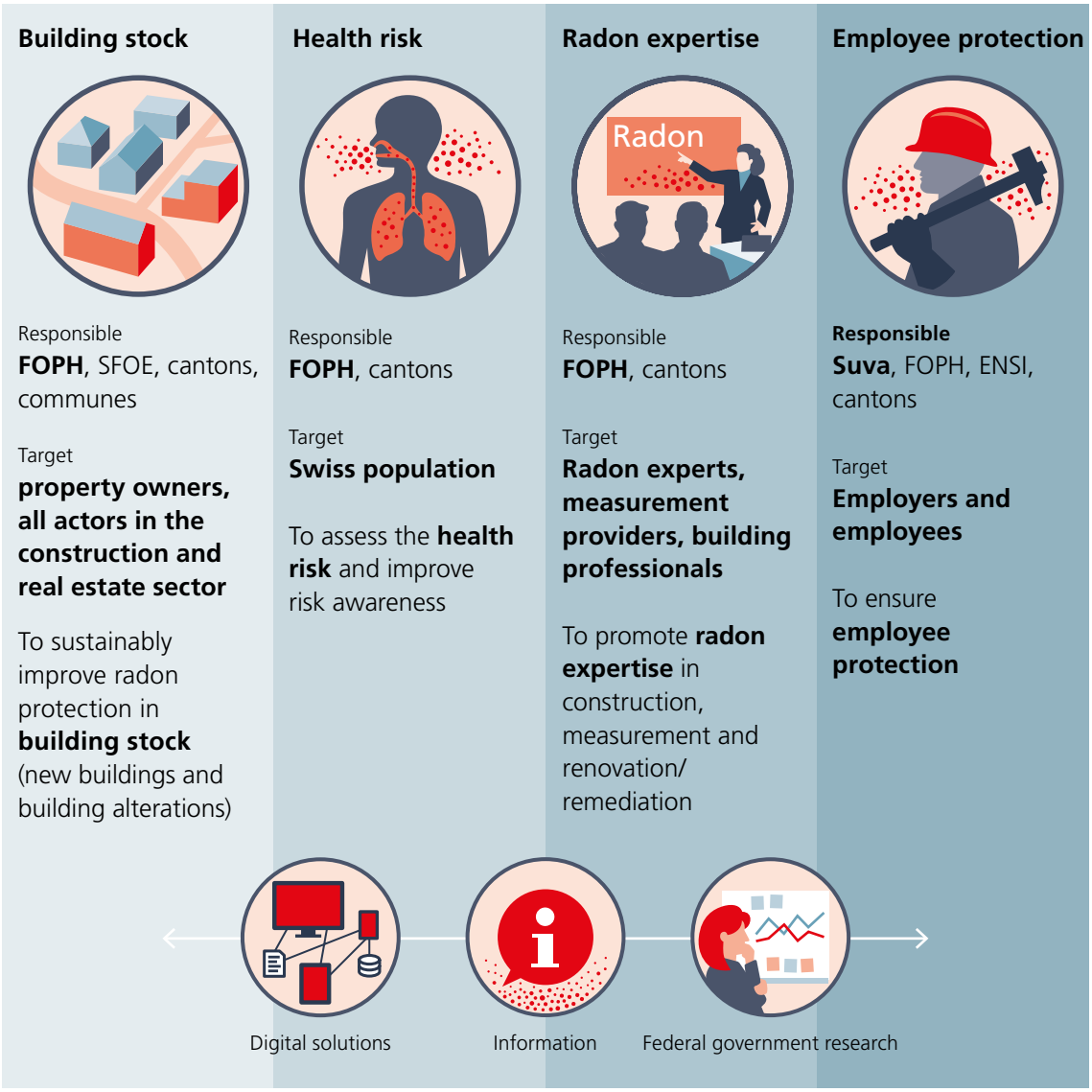

Figure 2: Lines of action of the Radon Action Plan 2021–2030

4.1 Sustainably improve radon protection in building stock

4.1.1 Need for action

In order to achieve the ambitious goals of the Energy Strategy 2050 [11], implementation of energy efficiency measures is set to be stepped up in the next few years. However, under certain circumstances, when renovations are carried out to increase energy efficiency, radon exposure can increase. This is why it is essential that the issue of radon is factored into the planning of energy efficiency measures. As it is extremely useful to be aware of the radon situation beforehand, more radon measurements need to be conducted. This will allow measures to increase energy efficiency and to improve indoor air quality to be optimally combined.

The evaluation of the Action Plan 2012–2020 [5] showed that cooperation with coalition partners – in particular with other federal programmes – needs to be improved. The inclusion of radon protection measures in the standard 180/2014 of the Swiss Society of Engineers and Architects (SIA) means they are now standard technology, but in practice are still not implemented often enough. The evaluation also highlighted gaps in the duty of building permission authorities to provide information which hinder its consistent and systematic implementation. The evaluation also made clear that greater efforts are needed to increase the number of radon measurements conducted. It also noted that radon remediation projects are not always followed up on and that there is insufficient knowledge about completed radon remediation as there is no obligation to provide feedback. As a result, not enough is known about which remediation methods are appropriate and sustainable. To close these gaps, a pilot project has already been launched and will be continued. The radon protection process must also be simplified to appeal to building owners and to ensure continuity in the measurement and remediation process.

It is also important that other dangers are considered when planning radon remediation measures. According to the WHO [10], radon should not be considered in isolation, but in the context of overall indoor air quality.

4.1.2 Implementation goals: Building stock

Goal 1 Sustainably improve radon protection in new and existing buildings

Radon protection measures should be standard technology that is systematically implemented and thus contributes to a general improvement in indoor air quality

Under the SIA standard 180/2014 [17], a ventilation concept must be drawn up when planning building work for new buildings and building alterations that takes into account radon and other pollutants. In addition, building envelopes that are in contact with the soil must be sealed off to prevent radon and humidity entering the building. In new buildings in particular, radon protection measures are much more cost effective than subsequent remediation. It is therefore especially important that new buildings are built to be as radon-free as possible. Suitable building materials also play a key role here. In order to ensure these measures are systematically implemented, specific recommendations for new buildings and building alterations should be developed in collaboration with the SIA, the eco-bau association and other partners, and/or set out in an SIA fact sheet.

Care should be taken to ensure that radon protection measures serve to improve indoor air quality and in no way make it worse. Ventilation in buildings is a crucial element in this process. An assessment should be made as to whether the issues of radon and indoor air quality should be included in the revision of further building regulations.

In the case of radon remediation measures, synergies with other building renovation should be utilised wherever possible (e.g. refurbishments, asbestos or radium remedial measures).

Automated controls using smart home applications can also support efforts to improve air quality in buildings. Such approaches need to be reviewed and developed so that promising solutions can be implemented..

Goal 2 Enhance cooperation with all relevant partners and programmes

Collaboration in the implementation of the Energy Strategy 2050
As many buildings are set to be renovated to be more energy efficient as part of the Energy Strategy 2050 [11], the accompanying change in the air balance and the influence on indoor air quality should also be considered. In light of this, collaboration should be sought with cantons and communes as part of the building programme [12]. In general, it is important to utilise synergies with the Swiss Federal Office of Energy (SFOE) and the Federal Office for the Environment (FOEN) in the sphere of improving energy efficiency. Account should be taken of the building labels, the eco-bau association and other incentive schemes [13].

Cooperation with the enforcement authorities
Building permission authorities are required to inform applicants about radon from 2020. In order to offer more detailed information and more extensive support, recommendations on radon protection measures for new and existing buildings need to be made available. In addition, a coordination platform should be set up with representatives of the cantonal authorities, the communes, Suva (see line of action 4.4), the federal enforcement authorities (e.g. the Federal Department of Defence, Civil Protection and Sport) and the federal programmes concerned, in order to share implementation experience within the scope of regular meetings.

Cooperation with partners concerned in the construction and real estate sector
To systematically implement radon protection measures in new buildings and building alterations, it is important to provide the partners concerned with the right information at the right time. To this end, cooperation with the following partners should be extended, stepped up or initiated: notaries, banks, insurance companies, home owners, tenants associations and potentially consumer protection organisations. The aim is to establish radon protection measures as a criterion in the real estate market. Both tenants and buyers are particularly important target groups. Adding information on the radon concentration (if known) to sale or rental agreements should therefore be encouraged.

Goal 3 Improve the level of knowledge on radon remediation

Recording and documenting completed radon remediation measures
The existing radon database does allow information to be entered on radon remediation. However, as there is no obligation to provide feedback or conduct a follow-up measurement after the remediation measures have been implemented, this has only been done for a very small number of remediated buildings. To improve this situation, feedback on radon remedial measures (including control measurements and documentation) should become an integral part of the radon protection process [18]. To this end, all services need to be offered from a single source (see goal 9) and access to the future radon portal (see goal 4) needs to be expanded. In this way the majority of remediation projects carried out would be documented on the radon portal.

Evaluation of remedial methods in terms of durability and efficiency
As part of the pilot project 'Radon Mitigation Efficiency (RAME)', radon remediation work that has been carried out should be reviewed and documented. This allows the durability of certain radon remediation methods to be analysed. The project is promising and should be pursued and extended to include future radon remediation projects. This will improve our understanding of which remedial methods are most appropriate in specific cases. These insights can in turn be incorporated in the training of radon experts.

Goal 4 Utilise digital platforms as implementation guides

Improve user-friendliness and improve access
The current radon database should be developed into a radon portal with interactive elements (e.g. maps, radon check tool). Access should be made more user friendly, particularly for the cantonal authorities (e.g. through expanded search functions).
The radon portal must be an efficient tool for the cantonal authorities and the approved radon measurement providers. It will reduce and simplify data processing in large-scale measurement campaigns and increase interoperability between the partners involved. The technical and legal implications of providing access to the radon portal to all building permission authorities should be examined, and should be granted if possible.

Data quality and use of data as indicators
Data quality must still be guaranteed, even if the number of users increases. In particular, the data basis for remediation work must be expanded and improved. This will allow the radon portal to provide indicators that can be statistically analysed and also published in an appropriate form.

Review expansion of the radon portal to include other pollutants
To gain a comprehensive overview of a certain building, an assessment should be made to see whether the radon portal can be supplemented with additional data (e.g. radium contamination from the watch making industry or CO_2 measurements). This would allow synergies to be created in the control and reduction of various pollutants. A review should be conducted in collaboration with the cantonal authorities to decide which pollutants to include and whether the legal base needs to be amended.

4.2 Increase risk awareness and assess health risks

4.2.1 Need for action

The FOPH conducted public surveys in 1995 [19], 2008 [20] and 2019 [5]. These surveys revealed that the percentage of people who had never heard of radon is still high, although the level of knowledge is improving (see Figure 3). Of the respondents in the 2019 survey who said they had heard of radon, one in four (26%) yet believed that it does not represent a health risk [5]. This clearly shows that public awareness of radon and its risks needs to be improved.

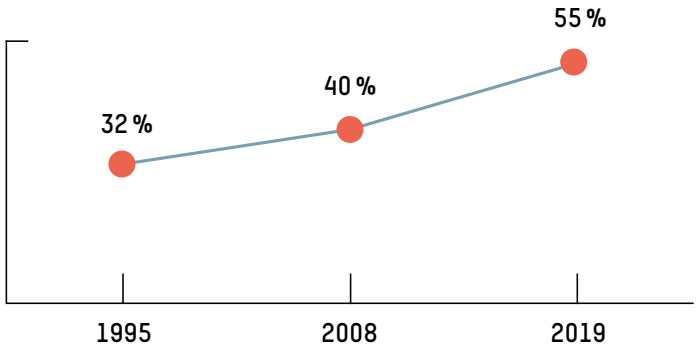

Figure 3:
Development of the level of public knowledge about radon

There are probably various reasons for the low level of public risk awareness in connection with radon. Radon is invisible, odourless and tasteless. As it is undetectable by the human senses, there is no direct indication of a risk. Radon has no immediate health impact, but exposure over long periods of time has a negative effect on health. In addition, radon is a naturally-occurring gas. Natural hazards are generally deemed less dangerous than technical threats. As a result, the risk presented by radon is often not perceived at all, or is considered very low.

With the previous threshold level of 1,000 Bq/m^3, only certain regions of Switzerland (Alps and Jura regions) were really affected by the issue of radon. The dangers of radon are therefore better known and risk awareness is higher in these regions. This threshold level has been significantly reduced to a reference level of 300 Bq/m^3, which means that now the whole of Switzerland is affected by the issue of radon. Accordingly, people need to be informed about radon in the areas that were previously less affected (particularly in the Espace Mittelland) and risk awareness needs to be increased. Radon has evolved from a regional into a national issue. Public knowledge about general radon exposure must therefore be improved.

All these parameters must be considered if risk awareness is to be increased. The radon risk needs to be communicated in a clearer and more immediate fashion. A more direct link needs to be made between radon exposure and cancer, and the danger needs to be highlighted more clearly.

Better public risk awareness requires that everyone – whether property owner or tenant – is able to independently determine their own individual radon risk in a simple manner through shorter, more flexible measurements or in combination with a virtual measurement using an online tool (prediction based on artificial intelligence). This will allow a rapid decision to be made regarding whether structural measures are needed to bring the radon exposure down to an acceptable level.

The reference level of 300 Bq/m³ is the generally acceptable level, but does not mark a boundary between a safe and dangerous level of radon exposure. The optimisation principle would suggest that the lowest possible radon exposure should be sought (100 Bq/m³ [7]). However, situations are conceivable in which radon concentrations that are above the reference level could be acceptable due to proportionality.

4.2.2 Implementation goals: Health risk

Goal 5 Increase risk awareness through enhanced information and efficient radon measurement

Provide clearer communication on the health risk

Up to now, radon risk has only been analysed in epidemiological studies and presented in the corresponding results. Such statistical statements are abstract and do not allow the public to immediately perceive the actual danger. Ways need to be found to link diseases more clearly to radon as a potential cause. Efforts should be made in collaboration with the Swiss Cancer League and Swiss Lung Association, tobacco prevention programmes and doctors in particular, to ensure that radon is considered as a key element of overall indoor air quality.

Implementation of the recommendation by the Federal Commission for Radiological Protection (CPR) on the distribution of radon-related radiation exposure of the Swiss population [21] is also a move in this direction. An application is needed that allows the overall individual radiation exposure to be estimated. Switzerland will advocate harmonisation of the relevant international recommendations.

Measuring and identifying personal risk, in particular in schools and nurseries

The best way to gauge the personal health risk from radon is through a radon measurement. Such measurements must be easy to implement and reliable (see goal 10). Apart from schools and nurseries, measurements do not need to be conducted nationwide, but they are recommended in certain situations (e.g. before or after renovation work in older buildings, conversion of basements or underground spaces, or in buildings with leaky or completely open floors). The existing radon check [22] already allows prioritisation of radon measurement for a particular building on the basis of the radon map and on specific building features. This application should be continually developed and the radon map should be periodically updated to include the new measurements.

Radon measurement should be incorporated in a process that also takes account of what happens next if high radon exposure is detected, bearing in mind the principles of proportionality and optimisation. The question of whether, in certain situations, radon measurements can be combined with measurements of other pollutants should be examined.

Goal 6 More efficient assessment of individual radon exposure

Efficient measurements and smart prediction tools to assess individual radon exposuren
Simple and short assessments of radon concentration should be made more accessible and the process made simpler without reducing the validity of such assessments.
To guarantee a reliable assessment of individual radon exposure, a short-term measurement should be combined with a smart prediction tool. As mentioned under goal 4, the radon database should be developed into a radon portal. With information on nearly 250,000 measurements – a number that is growing all the time – the radon portal offers an excellent basis for the research and development of such instruments, which can be further developed using artificial intelligence and in combination with other data, right up to 'virtual measurements'. This will continue the work already done on the development of prediction methods [23].

The data collected through use of the radon check tool (as per goal 5) can be used to improve predictions with the aid of appropriate algorithms. Other factors that can influence radon exposure in a building (e.g. geology, user behaviour) should also be incorporated in the assessment.

Goal 7 Increase understanding of radon-induced cancer

The FOPH can conduct federal government research, and pursue and participate in international research. The members of the coordination platform (see goal 2) should be regularly informed about the latest studies and findings.

Conduct federal government research on the causes of smoking-related and non-smoking-related lung cancer
From 2020, all lung cancer cases must be reported to the national cancer registry. This will result in a collection of data that together with the radon data will provide a good basis on which to investigate the link between radon exposure and possible illness. These analyses must be initiated and supported, although potential confounding factors (e.g. tobacco use) should be taken into account. Collaboration will also be initiated with NICER (the National Institute for Cancer Epidemiology and Registration) to be able to provide data for international studies. In addition, radon data can be used as part of Swiss Human Biomonitoring (HBM) to consider the corresponding exposure of participants.

The leading cause of lung cancer is smoking. Lung cancer cases where the cause is unknown should be examined more closely for a possible link to radon. International collaboration should be sought for this purpose. Studies in this area should be initiated and supported in collaboration with experts. While the share of non-smoking-related lung cancer cases is quite low, lung cancer case numbers are high, resulting in high absolute figures (see Table 1).

Lung cancer deaths	**3,090**
Of which non-smoking-related	**545**
Stomach cancer	**523**
Cirrhosis of the liver	**505**
Road accidents	**296**

Tabelle 1:
Comparison of non-smoking-related annual lung cancer deaths and other causes of death
(Source: Federal Statistical Office, 2012)

Conduct federal government research on whether radon can also cause other types of cancer
Analyses of other potential health risks caused by radon are important and must be supported. Corresponding studies on leukaemia [24] and skin cancer [25] have already been carried out in Switzerland and should continue to be supported.

4.3 Develop radon expertise

4.3.1 Need for action

In future, radon protection measures should be standard technology that is systematically implemented and thus contributes to a general improvement in indoor air quality (see goal 1). This requires basic and further training for individuals in the construction sector. Building professionals – from bricklayers to building planners and architects – should be aware of, and be able to implement, the preventative radon protection measures for new buildings and building alterations. This means that industry associations and universities should be supported in integrating the topic of radon in their respective syllabuses.

The training of radon experts in Switzerland's three official languages is currently carried out by three regional radon specialist units and other universities (e.g. EPFL, USI). The corresponding radon courses are accredited by the FOPH. The FOPH also maintains a list of around 250 radon experts who can offer support to building owners. This system has proven effective and should be continued by preserving the technical capabilities of the three radon specialist units and developing teaching materials (e.g. e-learning).

The evaluation of the Radon Action Plan 2012–2020 [5] showed that the radon protection process needs to be simplified. The training of radon experts should be modified accordingly, and should also cover the correct way to conduct radon measurements, taking account of innovations in radon measurement technology (see goal 10). The introduction of new measurement processes (e.g. short-term measurements) also requires knowledge and skills to be continuously upgraded. In addition, greater account should be taken of indoor air quality in connection with building energy efficiency measures and other pollutants. The aim is for the owners of affected properties to receive all services from a single provider: from measurement to assessment and remediation.

4.3.2 Implementation goals: Develop radon expertise

Goal 8 The issue of radon should be included in the training plans for all relevant building trades

Knowledge of radon should be a component of training plans for all building trades
Many mistakes can be made with regard to radon in new buildings and building alterations. This is why it is important that all relevant building professionals have an appropriate understanding of radon.

Within the scope of vocational education and training (VET), this must be ensured in cooperation with the relevant professional organisations. The training plans for all vocational training programmes are modified every five years where needed. The State Secretariat for Education, Research and Innovation (SERI) will make sure that the responsible professional organisations take the issue of radon on board. This will guarantee that students on all VET programmes in all learning locations acquire radon expertise at the appropriate level that they can subsequently put into practice. To motivate the professional organisations to include radon in training plans, appropriate teaching materials and training tools need to be offered. The regional radon specialist units should also support the professional organisations as far as possible in teaching students about the issue of radon. Within the scope of professional education and training (PET), the relevant organising institutions will again be made aware of the issue of radon by SERI as part of the development and revision of examination regulations and federal core syllabuses.

The issue of radon should also be included in relevant degree programmes at universities. Architects planning new buildings and building alterations need to be aware of the issue of radon and acquire the knowledge to build in a radon-safe manner. To this end, a dialogue needs to be initiated with higher education institutions to motivate them to include the issue of radon in degree programmes.

Goal 9 Radon services should be simplified and provided from a single source

Radon advice, measurement and remediation to be offered by a single provider
Until now, the approved radon measurement providers have been administratively separate from radon experts. This means that building owners have to contact various providers for measurement, advice and remediation, which results in unnecessary time and expense in tackling a radon problem.

If the whole process is handled by a single provider, this simplifies the process and also makes it easier to take into account other building pollutants. To achieve this goal, the training programmes of radon experts must be adapted so that these new service providers can act as a one-stop shop covering the entire radon process (from measurement to assessment and remediation). This also includes advice on preventative radon protection measures for new buildings and building alterations, and the issue of indoor air quality in connection with energy efficiency measures and other pollutants. As mentioned under goals 1 and 5, synergies should be created where possible, from diagnostics to remediation.

The new service providers must be approved to ensure quality. Until now only radon measurement providers were approved, but not radon experts. It should be established whether the RPO [3] and the Training Ordinance [26] need to be amended accordingly. This will make it easier to track radon remediation measures.

Goal 10 The reliability of radon measurements should be guaranteed in the long term

Appropriate measuring devices and measurement protocols must be available for radon measurement

When new radon measurement devices enter the market, they must be regulated in cooperation with the Federal Institute of Metrology (METAS) in the relevant ordinance [27] so they can be deployed for approved measurements if necessary. As well as the established and commonly-used passive radon dosimeters and radon measuring devices, an increasing number of new types of active radon measurement devices have recently become available, which do not belong to either of these categories as while they measure actively, they do not achieve the accuracy of radon measuring devices. The instrument requirements must be regulated in collaboration with METAS in the next few years. It should be possible to deploy these new, active radon measurement devices for approved short-term measurements in future.

Networked measurement systems – which monitor various properties of ambient air and e.g. control ventilation (such as smart home, internet of things) – should also be considered.

The existing measurement protocols must be periodically reviewed and updated. The measurement protocols for schools and nurseries in particular should be supplemented to include the description of case-by-case assessment. This is set out in the measurement protocol and aims to determine the radon concentration over time, and to clarify whether high radon levels are only observed at off-peak times (at night, at the weekend), and whether radon concentrations are lower when pupils and teachers are present.

Introducing quality management in radon measurements

The most reliable way to determine radon exposure in a building is to conduct an approved radon measurement. In Switzerland, this task is mainly the responsibility of the approved radon measurement providers, which in the longer term are to be replaced by the new service providers (see goal 9). The requirements of these measurement providers have grown, which means greater supervision will be required to maintain quality standards. Efforts must be made to guarantee that these measurement providers are performing their tasks correctly. Besides the monitoring of measurement providers' activities via the radon portal, blind tests or studies by consumer protection organisations should be carried out.

Goal 11 Developing appropriate electronic training materials

The e-learning platform designed to teach the basics on radon will be further developed

The FOPH will work with the regional radon specialist units to ensure a high-quality e-learning platform which will be used to train radon experts.

Developing new training tools and applications

New, electronic training tools should be offered to facilitate attractive and modern radon training. These include a virtual interactive radon house that demonstrates the key aspects of radon protection in buildings, and the extension of the JURADBAT platform – which contains information for various target groups (in particular building professionals and public officials – to cover the whole of Switzerland if possible.

4.4 Ensure employee protection

4.4.1. Need for action

As part of the revision of the RPO [3] and the Dosimetry Ordinance [29], specific radon protection measures for employees were introduced, which take account of international guidelines [28]. All employees – particularly those in radon-exposed workplaces – must be adequately protected from radon health risks to prevent the corresponding occupational diseases. This can be achieved through organisational measures on the one hand, and structural measures on the other.

Enterprises with radon-exposed workplaces must ensure that measurements are conducted. If the threshold level of 1,000 Bq/m^3 is exceeded, the enterprise must reliably determine the annual radon-related effective dose to exposed persons. If the effective dose to a person at the workplace is above 10 mSv per year, the person is considered to be occupationally exposed and will consequently be subject to personal dosimetry. The business therefore requires a mandatory licence.

These new provisions must be implemented in close collaboration with the radiation protection supervisory authorities. This mainly concerns Suva, which is responsible for industrial and commercial enterprises. In the area of supervision of the Swiss Federal Nuclear Safety Inspectorate (ENSI), the new provisions have already been successfully implemented in nuclear power plants. The measurement technology to determine doses and the protective measures for planned exposure situations must be developed and introduced.

4.4.2. Implementation goals: Ensure employee protection

Goal 12 In the workplace, people must be protected from radon and the associated occupational diseases

Identifying radon-exposed workplaces through measurements

In accordance with the RPO, businesses with radon-exposed workplaces must ensure that radon measurements are conducted by an approved radon measurement provider. Workplaces at which the threshold level of 1,000 Bq/m^3 is certainly or presumably exceeded are considered to be radon-exposed. These include workplaces in underground structures, mines, caverns and water supply installations. Sewer systems in localities where radium-containing luminous paint was previously used are also considered potential sources of radon. Enterprises with radon-exposed workplaces must first be identified by the competent supervisory authorities, and subsequently informed about the new measurement requirement. This requires a sufficient number of measurement providers that are approved to conduct measurements at radon-exposed workplaces.

The radon portal needs to be amended in line with the measurement protocol for radon-exposed workplaces so that radon measurement providers can enter their details. If the threshold level of 1,000 Bq/m^3 is exceeded, an estimation of the dose to which the persons are exposed in the workplace must be carried out on the radon portal.

Protective measures at radon-exposed and non-radon-exposed workplaces
In order to reduce radon exposure and to prevent an effective annual dose of over 10 mSv in radon-exposed workplaces, organisational measures (e.g. access restrictions, zoning) and structural measures can be implemented.
This will require recommendations from the supervisory authorities for enterprises concerned, which should develop and implement a protection concept. Workplaces that are not considered to be radon-exposed but which exceed the reference level of 300 Bq/m^3 must reduce their radon concentration. Corresponding recommendations on organisational and technical measures must be developed and communicated.

Establish a process to monitor persons who are occupationally exposed to radon
If it is not possible to ensure an effective annual dose of under 10 mSv for persons in radon-exposed workplaces, the appropriate radon protection measures for the planned exposure situations in workplaces should be defined, and included as a requirement in the licence in accordance with the RPO. These may include training radiation experts, demarcating and designating controlled zones, or the monitoring of radon gas concentration in ambient air. It needs to be clarified whether the results of personal radon dosimetry should be entered in the central dose register or whether a separate dose register for radon should be developed.

Developing a personal radon dosimetry for employees
Radon exposure was not previously included in personal dosimetry at radiation-exposed workplaces. The type of dose assessment must be defined. To facilitate this, a personal dosimetry must be developed and approved for practice.

To be able to correctly assess the situation in workplaces, studies are needed on the equilibrium factor between radon and its decay products. In addition, according to ICRP Publication 137 [30], breathing rates should also be taken into account. Both factors should be incorporated in the dose estimation. Finally, a solution is needed for the dosimetry of occupationally-exposed persons who are exposed both to radon and to artificial radiation.

No radon dosimeters are currently licensed for use in Switzerland for personal dose assessment. Appropriate measuring devices need to be defined and dosimetry providers approved in collaboration with the supervisory authorities and METAS. This will also involve clarifying whether radon measurement providers can also act as radon dosimetry providers.

5 Schedule/implementation planning

The measures will be implemented according to the existing responsibilities of the federal government and cantons. Each goal and the accompanying measures will first be fleshed out with the identified partners and if necessary, submitted to the Federal Council and other decision makers for final sign off.

Table 2 shows how the various measures are to be implemented in stages and coordinated. Interim reports are to be submitted to the Federal Council in 2025 and 2029 to provide an update on how implementation is progressing.

Building stock

	Goal		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1	**Sustainably improve radon protection measures in new and existing buildings**	Radon protection measures should be standard technology that is systematically implemented and thus contributes to a general improvement in indoor air quality	■	■	■	■	■	■	■	■	■	■
2	**Enhanced cooperation with all relevant partners and programmes**	Collaboration in the implementation of the Energy Strategy 2050	■	■	■	■	■	■	■	■	■	■
		Cooperation with the enforcement authorities	■	■	■	■	■	■	■	■	■	■
		Cooperation with relevant partners in the construction and real estate sector			■	■	■	■	■	■	■	■
3	**Improve understanding of radon remediation**	Record and document radon remedial measures implemented						■	■	■	■	■
		Evaluate remedial methods in terms of durability and efficiency	■	■	■	■	■	■	■	■	■	■
4	**Utilise digital platforms to aid implementation**	Improve user-friendliness and expand access	■	■	■	■	■					
		Quality of data and use as indicators			■	■	■	■	■	■	■	■
		Review expansion of the radon portal to include other pollutants			■	■	■	■	■	■	■	■

Health risk

	Goal		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
5	**Increase risk awareness through enhanced information and efficient radon measurements**	Provide clearer communication on health risks			■	■	■	■	■	■	■	■
		Measure and identify individual risk, particularly in schools and nurseries	■	■	■	■	■					
6	**Increase risk awareness through enhanced information and efficient radon measurements**	Efficient measurements and smart prediction tools to assess individual radon exposure			■	■	■	■	■	■	■	■
7	**Increase awareness of radon-induced cancer**	Federal government research on the causes of smoking-related and non-smoking-related lung cancer					■	■	■	■	■	■
		Federal government research on whether radon can also cause other types of cancer	■	■	■	■	■	■				

Radon expertise

	Goal		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
8	**The issue of radon should be integrated in the training plans of all relevant construction jobs**	Knowledge about radon should be an integral part of the training plans for construction jobs	■	■	■	■	■	■	■	■	■	■
9	**The radon process should be simplified and covered by a single provider**	Radon advice, measurement and remediation should be offered from a single source						■	■	■	■	■
10	**The reliability of radon measurements should be guaranteed in the long term**	Appropriate measuring devices and measurement protocols should be available for radon measurements	■	■	■	■	■					
		Introduce quality management in radon measurement						■	■	■	■	■
11	**Developing contemporary electronic training materials**	The e-learning platform designed to teach the basics on radon will be further developed	■	■	■							
		Develop new training tools and applications				■	■	■	■	■	■	■

Employee protection

	Goal		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
12	**People should be protected from radon exposure and the associated occupational diseases in the workplace**	Identify radon-exposed workplaces by conducting measurements	■	■	■	■	■	■	■			
		Protective measures in radon-exposed and non-radon-exposed workplaces	■	■	■	■	■	■	■	■	■	■
		Establish process to monitor persons who are occupationally exposed to radon	■	■	■	■	■					
		Develop personal radon dosimetry for employees	■	■	■	■	■	■	■			

Table 2:
Implementation planning of measures

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