LIFE16 ENV/IT/000553

RESPIRE

Radon real time
monitoring system

LIFE RESPIRE PROJECT

Radon rEal time monitoring System and Proactive Indoor Remediation Layman Report

Participants to the LIFE RESPIRE KICK OFF Meeting

Life RESPIRE Project improves the quality of indoor air, keeping it free from radon of deep underground and buildings materials origin. RESPIRE demonstrated in 4 significant areas, in Italy and Belgium, a cost-effective and eco-friendly solution for radon real-time measurement and remediation.

R3S is the intelligent, versatile and adaptable remediation system implemented by the RESPIRE Project, able to reduce the average indoor radon level.

RESPIRE provided local authorities with the Radon Hazard Guidelines and WebGis radon maps for land use planning and health risk assessment.

WHAT IS LIFE RESPIRE?

View of historical part of Caprarola Town, including palazzo Farnese, one of the sites of the project.

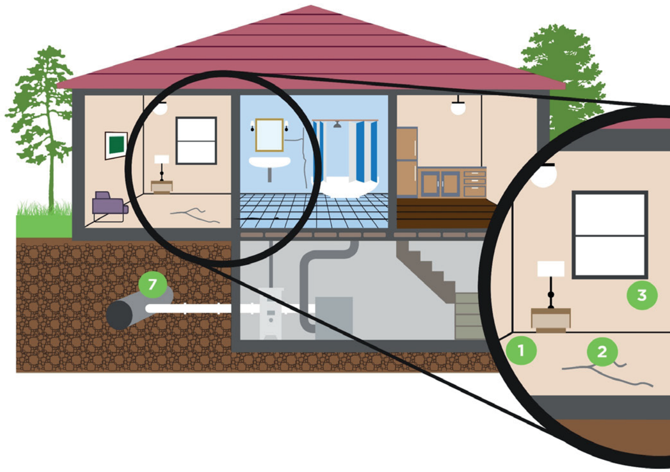
RESPIRE is a research project funded by the European Union's LIFE Programme, which is the EU's funding instrument for the environment and climate action.

LIFE RESPIRE Project ran from 2017 to 2022 and involved five partners (CERI-Sapienza, INGV, CNR-IGAG, FANC and ELICA) This partnership included four research institutes (three in Italy and one in Belgium) and one Italian industrial partner.

Work within the project was focussed on indoor radon, a very important topic given that the European Union had recently published the 2013/59/EURATOM Directive. This Directive lays down basic safety standards for protection against the dangers arising from exposure to ionising radiation, including radon, and is the framework on which European nations were to codify their national laws. Initial research was concentrated in three municipalities in central Italy (Ciampino, Caprarola, and Celleno) as well as the Belgium region of Ardennes. The Italian sites were chosen because they represent a wide range of different radon risk levels due to the local geological units, while Ardennes was chosen because of the known radon problem in that area. Interest in the project led to the work being performed in the Italian communities of Pomezia, Nettuno, Rocca di Papa, and Bassano Romano.

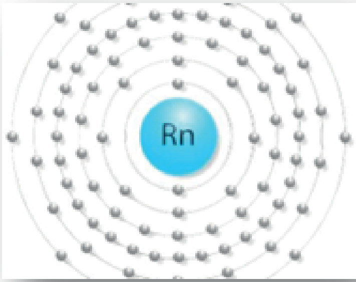
About radon

INFORMATION ON RADON, THE LIFE RESPIRE MAIN ITEMS



What is radon and why is it important?

Radon is a colourless, odourless, naturally occurring gas. It is formed by radioactive decay and also itself decays to other elements by the same process. The period that the radon atom is stable is defined by its “half-life”, which is the amount of time it takes for half of the atoms present to decay. Of the many isotopes of radon, Rn-222 is the most important because it has the longest half-life, which is about 3,8 days. Rn-222 gas is formed by the decay of radium (Ra-226) and then it decays into polonium (Po-218). Radon is measured by counting how many decays occur in time. This activity concentration is reported in most of the world as the number of Becquerels in a cubic meter of air, where one Becquerel is equal to one disintegration per second; this is abbreviated as Bq/m3. When radon decays to polonium it also releases an alpha particle, which is identical to the nucleus of a helium atom (to be precise, the helium-4 isotope, which consists of 2 protons and 2 neutrons). If we breath in radon gas molecules, a portion of them will decay and the released, high-energy alpha particle can cause cellular damage. In addition, subsequent decay products, like Po-218, get deposited on the lung tissues as solids and continue to release alpha particles as they too decay. Over time, and if concentrations are high enough, this can potentially lead to lung cancer.
Radon is the second largest cause of lung cancer after smoking, and the risk is even higher when these two causes are combined (in other words, a smoker who is exposed to high radon concentrations).



300 Bq/m^3

Because the health impact of radon is caused by individual atoms decaying, its effect is cumulative. This means that safe radon levels are defined in terms of average value over an entire year.
In Europe the framework for addressing exposure to all forms of ionizing radiation, including indoor radon, was laid out in the Council Directive 2013/59/EURATOM and then codified into national laws. As an example, in Italy the maximum reference levels are 300 Bq/m3 for existing homes, 200 Bq/m3 for houses that will be built after 31 December 2024, and 300 Bq/m3 for places of work, even if it is recommended to reduce levels as low as possible.

How does radon get into a building?

There are three main ways that radon can accumulate indoors. The most common is from the rock and soil surrounding the foundation, with cracks, pipes or sumps providing a way in. The radon is often drawn inside by a small gradient in pressure, linked to wind or rising warm air when the building is heated. Tap water is another way, although this entry route is usually only associated with private wells and not a municipal supply.
Finally, the material that was used to construct the building can be another source, one that is often closely linked with nearby geology. This is because this radon usually comes from building stone, which is often sourced locally (like volcanic tuff in Italy).

Where is radon found?

Radon is formed wherever there is radium. This is mainly in certain types of rocks or soil but can also be in groundwater enriched in dissolved radium. The highest radon values are typically measured in the soil air in areas that have granite, light coloured volcanics like tuff, some clays, or other specific units. Values can sometimes be as high as 400,000 Bq/m3.
Radon in the soil slowly moves into the atmosphere, but here it is rapidly diluted and typically only has values of around 10 Bq/m3. Of most interest, however, are the levels in our buildings, as we spend a large amount of time indoors breathing this air. Although often less than 300 Bq/m3, if large amounts of radon enter a building the indoor values can range from 500 to 5000 Bq/m3. These values can vary, however, on a daily and seasonal basis, depending on environmental conditions and occupant habits like opening windows or turning on heating.

A section of soil near the surface, which can be rich in minerals that produce radon.

what can we do?

MEASURE AND REMEDIATE

How can I measure radon?

Radon measurement techniques can be broadly divided into two general approaches: passive cumulative sensors and active electronic monitors. To obtain an accurate estimate of the average annual radon level in a building it is usually necessary to install one of these sensors for a prolonged period of time to take into account daily and seasonal variability.

Passive sensors are small objects that are deployed for a period that can range from a few days up to a year (depending on the type and model) and then recovered and sent to a laboratory for analysis. The result is the total amount of radon that occurred in that room during the entire exposure period. These sensors, which include alpha track, activated charcoal, or electret detectors, are inexpensive and easy to use.

Active sensors are electronic devices that continuously measure radon levels, often displaying the value on a screen in real-time and/or saving it so that daily and seasonal trends can be plotted on a graph. These units are more expensive, however they give immediate, more-detailed results and can be moved between rooms to assess different conditions.

Passive sensor to measure indoor radon.

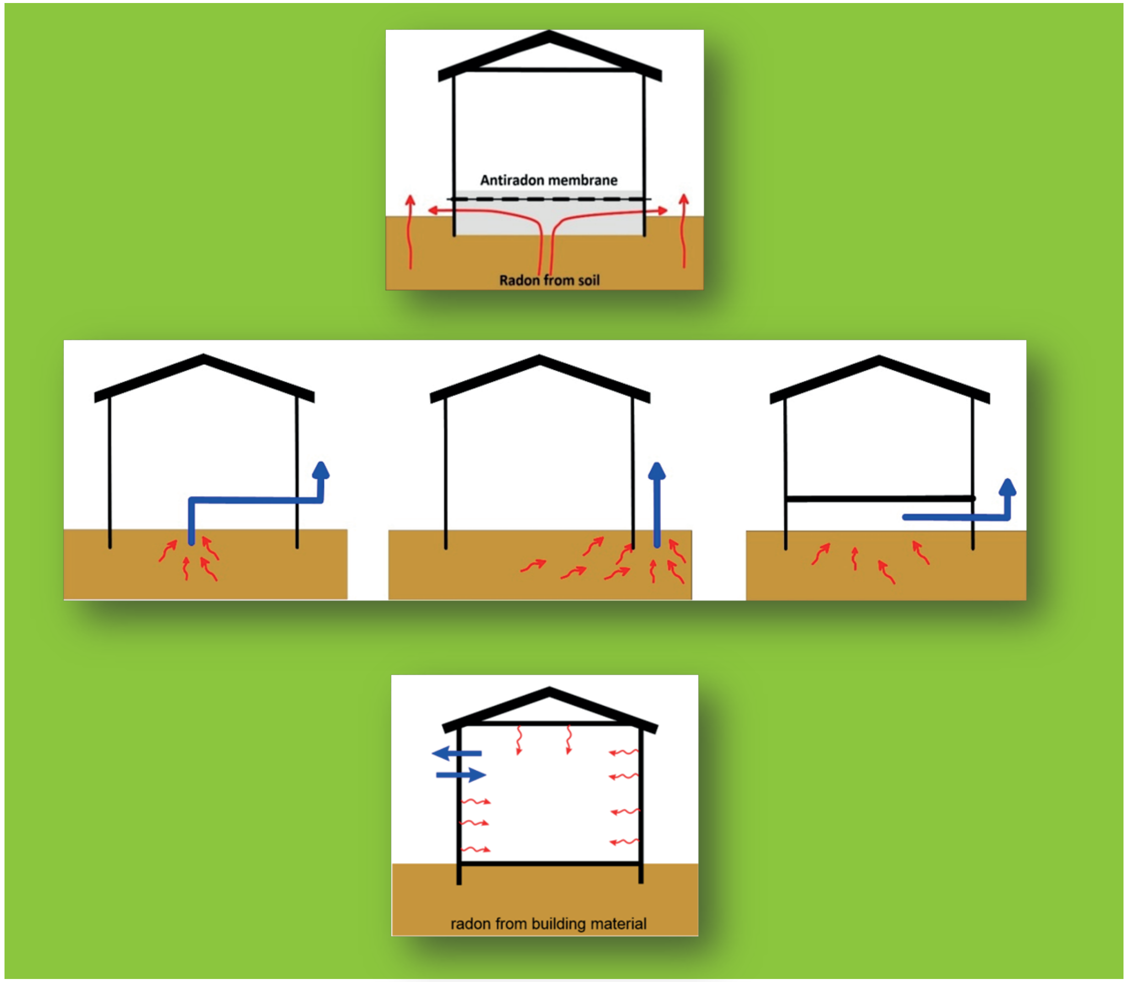
How can indoor radon be reduced ?

There are numerous approaches that can reduce indoor radon, with the eventual choice depending on whether the building is being constructed or already exists, what is feasible based on site conditions and building characteristics, and the origin of the radon.

For a new construction where radon originates in the soil, the easiest, cheapest, and most effective method is to install an impermeable membrane at the base of the building to block radon entry.

If the building has already been constructed and, once again, the radon is coming from the soil, it is preferable to prevent radon entry by modifying air movement within or just above the soil. Although passive systems are possible in some cases, active depressurization (or pressurization) of the sub-slab soil or a crawlspace is more commonly used to deviate radon away from the building and towards the atmosphere.

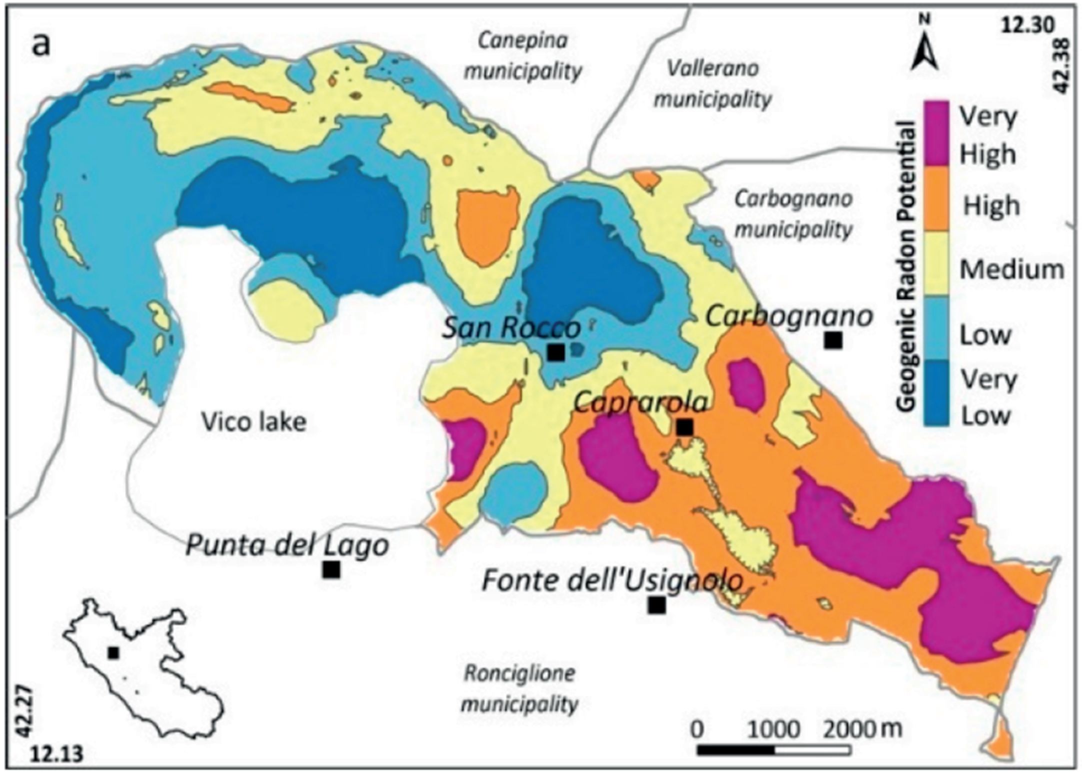
Another approach is ventilation of the indoor living areas, which involves substituting radon-rich indoor air with radon-free outside air. This option is less efficient than depressurization but is one of the few alternatives when the radon comes from building materials. Passive ventilation can be done with open windows or vents, however this may not be practical in colder climates. Instead, active ventilation using heat exchange or heat recovery units are very energy efficient, however they have to be sized properly (as a function of total indoor volume and radon accumulation rate) to be effective.



PROJECT IN NUMBERS

FIELD ACTIVITIES

LIFE-RESPIRE created Geogenic Radon Potential Maps for the three Italian Municipalities. This document required the construction of datasets filled with geological and geochemical parameters linked to radon production in the soil. The maps highlighted the strong difference in radon risk potential coming from the local geology of the Italian sites, with Caprarola having the highest due to the type of volcanic rocks present in the area, Celleno having intermediate levels, and Ciampino the lowest.



The geogenic radon potential areas of Caprarola one of the Municipalities of the project

400

Measurement in soil

The database included 200 mesurements of soil gas and gas flux at the surface, 40 mesurements of radon dissolved in spring water, U-238, Th-232 and Ra-226 content in 19 soil and rock samples, and 82 measurements of gamma ground spectrometry in the soil, for a total of more than 400 mesurements.

149

Short term monitoring

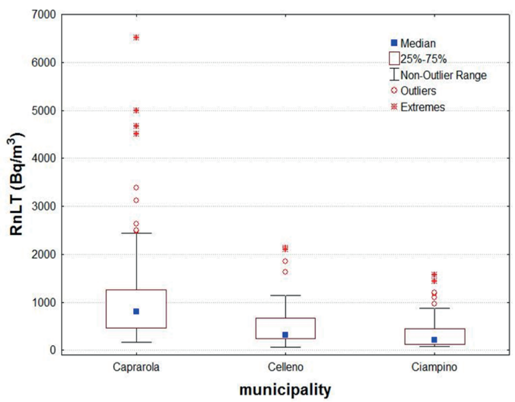
The short-term monitoring activities were completed for the three Italian sites (Caprarola, Ciampino and Celleno), in 60 buildings using 149 Active Charcoal Collectors (ACC), that is a low cost, passive method, left for 48 hours in the building and then analysed in Laboratory.

353

Long term monitoring

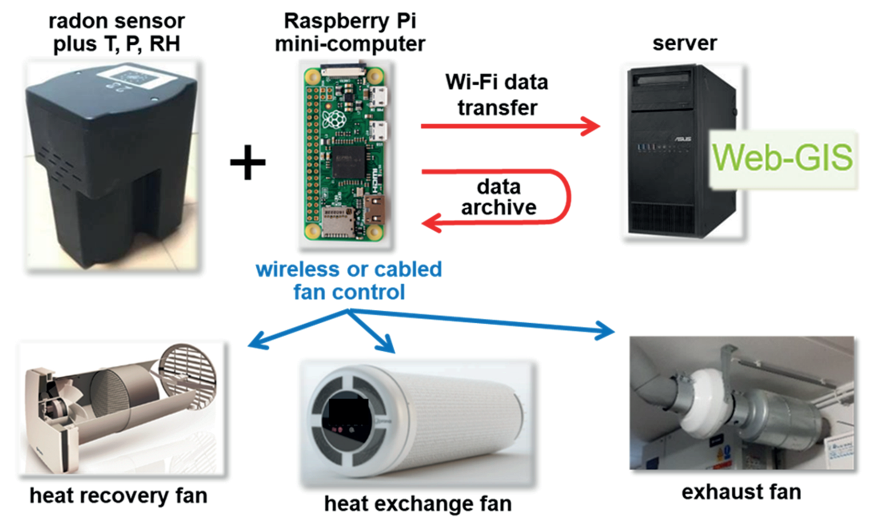
The long-term monitoring (3 months, repeated twice and analysed in the Laboratory) involves the use of 353 track-etch detectors that were installed in 186 buildings of Caprarola, Ciampino and Celleno, in the homes of all the citizens that requested them, as well as in several public buildings.

INDOOR RADON SURVEY



Similar to the geological results, Caprarola buildings had the highest indoor radon values measured during the winter survey (801 Bq/m3 average and 91% of buildings above the reference level), Celleno has the intermediate values (386 Bq/m3 and 51%) and Ciampino has the lowest values (259 Bq/m3 and 47%). Indoor gamma tests showed a strong link both with the local geology and local building stone. These results and the contacts made during the campaigns were used to select, and ask permission for, building sites to install and subsequently test the Respire Radon Remediation System (R3S) described below.

RESPIRE RADON REMEDIATION SYSTEM



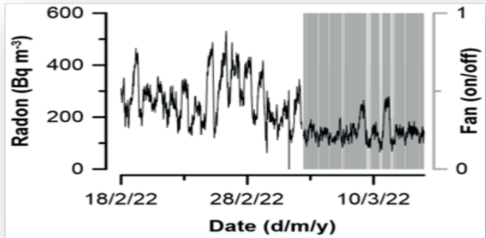
The RESPIRE Radon Remediation System, or R3S for short, is a dependable, low-cost, and energy efficient system that is capable of autonomously controlling an installed ventilation system to reduce indoor radon levels. The R3S control unit consists of a commercial radon sensor (FTLab RD200M) integrated with a pressure/temperature/relative humidity sensor (Bosch BME280) and a mini-computer (Raspberry Pi model Zero W) equipped with Wi-Fi, Bluetooth, and data logger capabilities. The software interrogates the sensors, saves the data, and transmits it via Wi-Fi to a central server that manages the database and makes it available on the web. Based on measured indoor radon values, the Raspberry Pi activates / deactivates a remediation ventilation system.

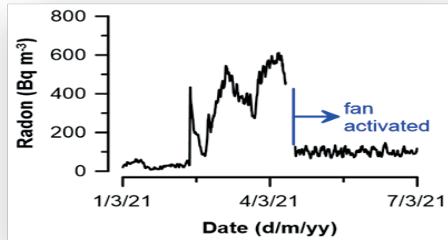
The R3S can turn on or off any type of ventilation system with which it has been associated, either via a direct cable link or by using a Bluetooth signal, based on a pre-set radon concentration threshold (typically 100 - 300 Bq/m3). Three types of fans were tested during the project, including in-wall heat recovery and heat exchange fans for living area ventilation as well as in-line exhaust fans for sub-slab, crawlspace or basement depressurization. The living area ventilation approach was used primarily in the Italian sites because the indoor radon usually originates from the building materials. Instead, in Belgium, the combination of soil-originating radon and the common occurrence of crawl spaces beneath the buildings meant that the more efficient depressurization approach could be used at these sites.

The project installed 25 R3S units in Italy and 10 R3S units in Belgium

Other experimental sites, besides these 25 R3S, were located in Bassano Romano, Pomezia, Nettuno and Rocca di Papa.

A total of 25 R3S units were installed in Italy. Among the 18 units still operating, 15 pilot in-wall heat recovery fans, 1 pilots an in-wall heat exchange fan, and 2 pilot sub-slab extraction fans. Instead, 10 R3S units were installed and are still operating in Belgium. Six of these units pilot an exhaust fan that depressurizes a crawlspace or similar while the remaining four pilot sub-slab sumps to depressurize the soil beneath the building. One example from each country is given below.



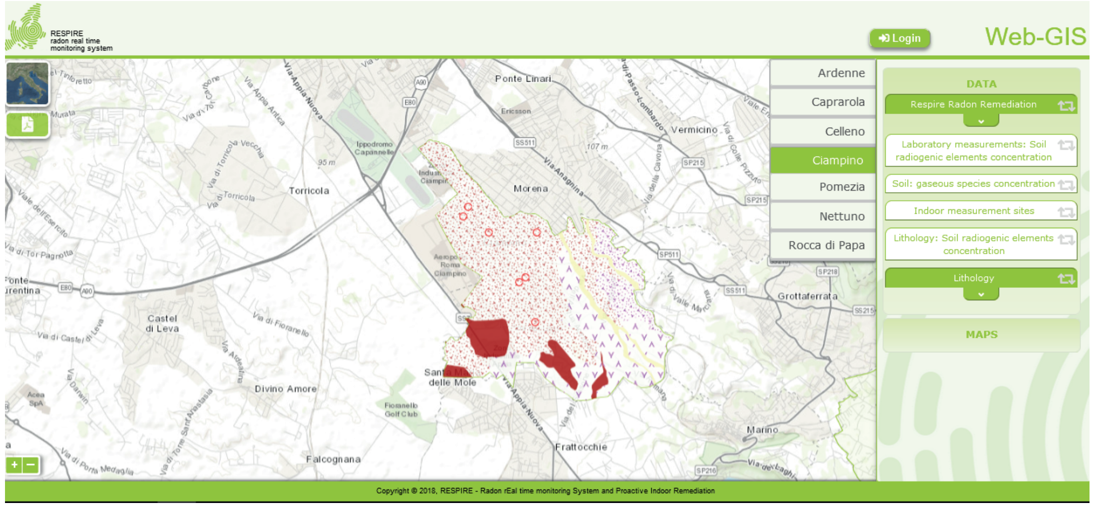


Two heat recovery fans were installed in a 75 m3 office in Pomezia, Italy, where radon typically ranged from 200 to 500 Bq/m3 (left graph above). Two fans were used to avoid any depressurization that may draw radon-rich air into the room and to ensure that fresh outdoor air is always introduced. This is accomplished by synchronizing the alternating flow directions so that one fan injects outdoor air while the other exhausts indoor air. Results at this site were very promising, with fan activity reducing average indoor radon levels to around 150 Bq/m3. It must be highlighted, however, that because the ventilation approach is essentially one of dilution, the fan flow rate must be scaled properly to the indoor volume to be remediated, the radon accumulation rate at the site, and the desired target radon level. In addition, because indoor radon entry rates can vary with environmental conditions, values may vary in time even with fan activity.

This site is a private home located in Spa, Belgium (right graph above). The house is a single family dwelling with a cellar and crawlspace underneath. Prior to remediation, radon values in the living room could exceed 800 Bq/m3. An extraction fan installed in the crawl space is piloted by an R3S unit in the ground floor living room via a cable. Initial tests conducted shortly after the unit was installed show how the R3S and associated extraction fan is capable of reducing indoor radon values from around 600 Bq/m3 to around 100 Bq/m3. This remediation approach can be very effective, given the proper site conditions, because it prevents the radon from entering the building. The R3S helps save power and money by turning the fan on only when it is needed, an important consideration as radon entry rates will vary on a daily, and especially, a seasonal basis.

WebGis

THE GEOGRAPHIC INFORMATION SYSTEM OF LIFE RESPIRE PROJECT



An internet-based Geographic Information System (known as a "WebGIS") was created to present all data collected from the various study areas during the project lifetime. This WebGIS can be accessed at http://www.liferespire.it/webgis/

Information for the initial four sites of Ciampino, Celleno, Caprarola and Ardenne includes layers that present public domain data (like geological units) and maps of geochemical data produced using project results (like radon in the soil air and gamma spectrometry measurements). These maps are accessible to all users who access the site. Instead, the WebGIS is also a repository, data management, and data visualization tool for all results produced by the installed R3S remediation units, including indoor radon concentrations, temperature, atmospheric pressure, and relative humidity. This data can be downloaded or can be graphed directly on the web page. For privacy reasons, results from each R3S unit are only accessible to the associated home owner (for private buildings) or administrator (for public buildings) via a unique username and password.

100%

All the geological and geochemical data collected by the project are now available and reachable by the citizens as required by the EU - LIFE programme.

100%

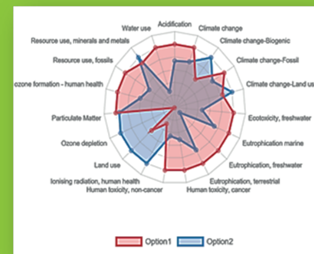
All data from the installed RESPIRE monitoring systems are available by local Authorities in the case of public buildings or by the owner in the case of private buildings.

100%

All the data will remain available for three years after the end of the project.

Impact evaluation by LCA and socio-economic analysis

An important requirement of all funded EU-LIFE projects is that practical, feasible solutions are found for real-world problems. This means that end results should be transferable to other sites in Europe and/or should yield a tool or approach that can be applied at large scale, including through commercialization.



Considering that one of the principal goals of LIFE-RESPIRE was to create an innovative technology capable of autonomously remediating indoor radon levels, work was performed to examine its market potential. This included questionnaires given to the general public, a study into replicability, and the creation of a first-stage business plan. In addition, a detailed Environmental Impact - Life Cycle Assessment was conducted on two versions of the developed prototype, taking into consideration all materials, production techniques and transport involved. Results show that the main impact is the use of fossil fuels, primarily due to transport plus some plastic production, while silicon carbide production for heat recovery fans was also found to have a significant impact. Overall, impacts were not very large and are comparable to other similar consumer products.

10%

environmental impact

R3S construction required about 6 kg of CO_2 equivalent, which is about one order of magnitude less than the CO_2 required for a TV or a pair of shoes.

Socio-economic aspects

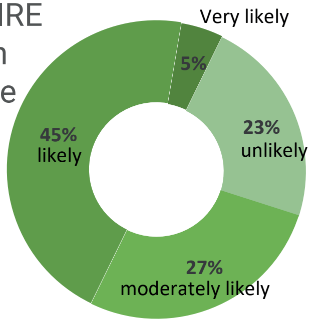
RESPIRE INCREASED INDOOR RADON AWARNESS AND INTEREST IN REMEDIATION SYSTEMS

The RESPIRE project evaluated and increased the interest regarding the risks connected to the exposure of high values of indoor radon, and increased the knowledge of relevant remediation systems.

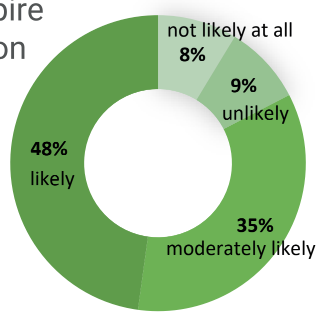
The analysis included dissemination and informative actions, during events and meetings, and was evaluated through questionnaires dedicated to the evaluation of awarness and potential market.

POTENTIAL MARKET

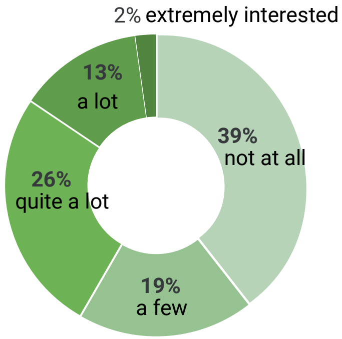
If the RESPIRE remediation system were available would you choose it for your house?



If the Respire remediation system were available, would you suggest it to other people?

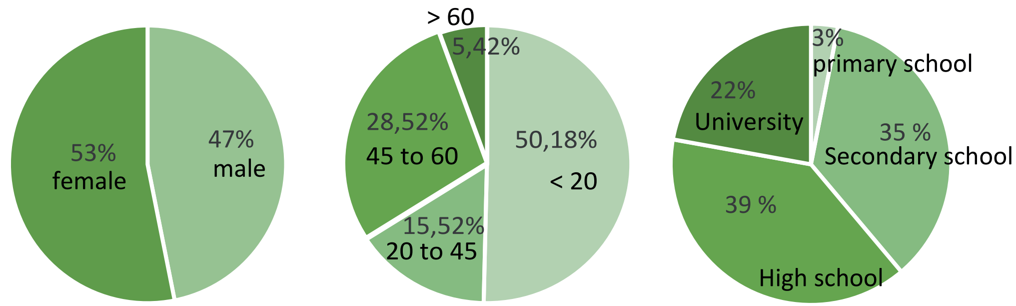


Are you interested to the result of the R3S ?



Ten questions were dedicated to explore potentiality of the market potential (sample over 20 years old, 200 persons); the more significant are reported here. In general, although very few of people were informed about potential remediation systems (about 3%), people showed interest both in monitoring of radon indoor and RESPIRE remediation system, but mainly if the costs remain limited (lower than 1000 euro).

Sample composition of the interviewed people from the RESPIRE project municipalities



GENDER

Gender distribution of the sample is very well balanced

AGE

The sample included a higher number of students, due to the activity in the schools

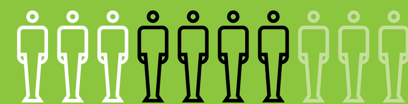
EDUCATIONAL LEVEL

Considering the age, all the educational levels are represented.

Risk perception survey results showed that information is crucial to deal with radon risk awareness and mitigation measure acceptance. Information campaigns of the RESPIRE project showed an increase of about 30 % in positive answers about respondent's knowledge of radon risk (knowledge of natural radioactivity, prolonged radon inhalation damage, and radon exposure as a risk and a relevant cause for cancer), which highlights the impact of information on radon risk mitigation action.

Are you aware of the existence of risk due to exposure to radon?

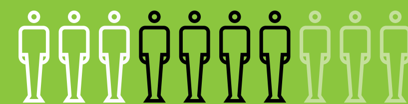
+27,9%



the awarness increased from 37,4 % to 64,9 %

Are you aware of the damage radon could cause if inhaled for prolonged periods?

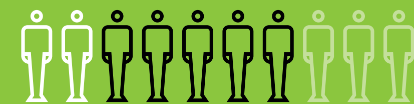
+35,3%



the awarness increased from 31,4 % to 66,7 %

Are you aware of the fact that your region is one of the Italian areas where concentration of radon in the soil is higher?

+44,5%



the awarness increased from 22, 2 % to 66,7 %

The graph indicates the percent increase of public avareness based on the answers before (white) and after (black) the informative campaign of the RESPIRE project

Involvement of the public, information dissemination and networking www.liferespire.it

Life RESPIRE has created numerous communication products (such as brochures, articles and newsletters) to inform stakeholders about the problem of radon and the work of the project. It also organized many seminars, webinars and events to raise awareness of the population on the problem of indoor radon. Among the final products, the Radon Hazard Guideline has been produced to describe radon risks and possible mitigation actions (http://www.liferespire.it/download). Information and dissemination materials were produced by the integration of the field data and the results of the experimentation, distributed to inform local authorities on the prevention and monitoring measures of the indoor radon. On the project website, in addition to the WebGis portal where data maps (http://www.liferespire.it/webgis/) are available, news and progress, initiatives and events organized by the project are constantly published. The publications, presentations and webinars made by the project team are also downloadable.

Final Event at Sala Zuccari

The results of the "Life Respire" project and the proposal of the National Action Plan were presented

The LIFE RESPIRE team participated in many international and national meetings with the aim to promote the project, exchanging information and good practices and to interact with stakeholders such as local authorities, citizens, professionals who work in the field of environmental remediation of indoor radon, as well as researchers who deal with the geological-geochemical aspects of the radon (http://www.liferespire.it/networking). The project consolidated collaboration and exchange of results with other European projects (EU-RAP, Metraradon, Asset) that deal with the same topic, and established a continuous and profitable collaboration with the University of Roma Tre, in the development of specific analysis on construction materials and radon production, as well as with the scientific group that works on the National plan for Radon, following the transposition of the European Directive 2013/59 / Euratom in 2020.

On 10th May, 2022 at Sala Zuccari, the results of the "Life Respire" project and the proposal of the National Action Plan for Radon, edited by the Ministries of Ecological Transition (MITE) and Health Ministry as part of the conference "Radon from geology to indoor risk management". The event was the opportunity to discuss the relationship between geological setting and radon indoor occurrence, the importance of geology in territorial management and plan, in perspective of the future definition of the National Action Plan for Radon, presented by the working group of MITE, ISIN, ISS, and ISPRA. The study day ended with a video message from the Undersecretary for MITE Vannia Gava.

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LIFE RESPIRE

Radon Real Time
Monitoring System

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