RESPIRE

Radon real time monitoring system

8th July 2021
Villa Aurelia
Via Leone XIII, 459
Rome, Italy

# LIFE RESPIRE
# Final Conference

**Sabina Bigi**
Project Coordinator

RESPIRE
Radon real time monitoring system

# Budget

| Total Budget | 2.239.158 Euro |
| --- | --- |
| Budget eligble | 2.188.758 Euro |
| EU Contribution | about 1.313.254 Euro |

LIFE RESPIRE Project
September 2017
August 2020 – August 2021

# Life topics:
# Environment and Health

Projects improving the use of **chemical monitoring data** (e.g. environmental monitoring, human bio- monitoring, product monitoring, indoor air monitoring) in the **protection** of human health and the environment, by making the chemical **monitoring** data available, accessible, comparable and interoperable, and allowing for linking them with monitoring of human and environmental health and for assessment of exposures from chemical mixtures via various routes of exposure.

RESPIRE

Radon real time monitoring system

# Partnership

Centro di Ricerca, Previsione, Prevenzione e Controllo dei Rischi Geologici

Sapienza Università di Roma

STVDIVM VRBIS

INGV

Istituto Nazionale di Geofisica e Vulcanologia

Consiglio Nazionale delle Ricerche

IGAG

elica

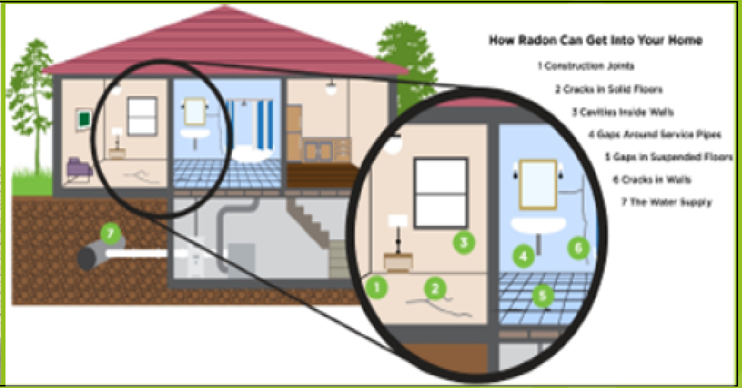
FANC

federaal agentschap voor nucleaire controle

# RESPIRE

Radon real time
monitoring system

LIFE RESPIRE LIFE16 ENV/IT/000553




100%

### SAFETY

RESPIRE will be able to completely match the European Directive 2013/59/EURATOM, reducing thus abating the average indoor radon concentration at demonstration sites from 500 Bq/m3 to less than 100 Bq/m3, reducing the average indoor radon concentration level of more than 400 Bq/m3.

91%

### PERFORMANCE

The RESPIRE system can complete the air change process in a room in 60 minutes two times a day, using 0,014 kWh instead of 0,168 kWh per day (saving 91% of energy), for a total per year of 60KWh (for one house of about 100mq).

100%

### MONITORING

RESPIRE aims to completely innovate the current Radon monitoring system, introducing a real-time system which provides measurements every 10 minutes of
indoor Radon concentrations, making them available to public institutions and research institutes via an online (webGis) platform.

# LIFE RESPIRE

RESPIRE is a Life project. Its main objective is to improve the quality of indoor air, keeping it free from radon of deep underground origin.
RESPIRE demonstrates in 4 significant areas, in Italy and Belgium, a cost-effective and eco-friendly solution for radon real-time measurement and remediation to keep indoor radon levels below 100 Bq/m3 level (as indicated in the European Directive 2013/59/EURATOM).

## 1

Implement an intelligent, adaptable and versatile hybrid radon remediation system composed by sensors, an Air Quality Balancer (SNAP) and an external additional fan-system (eolian and/or electric) working on positive pressure method.

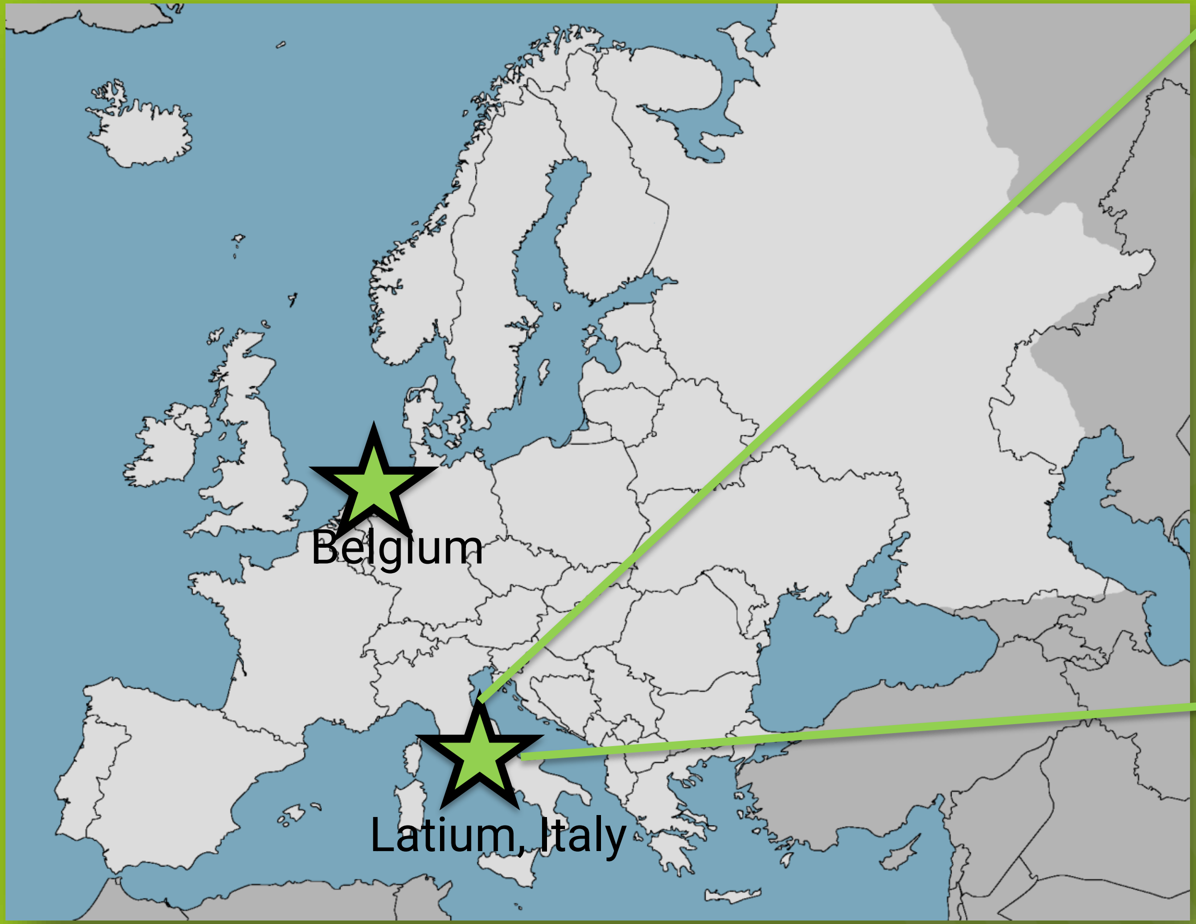
## 2

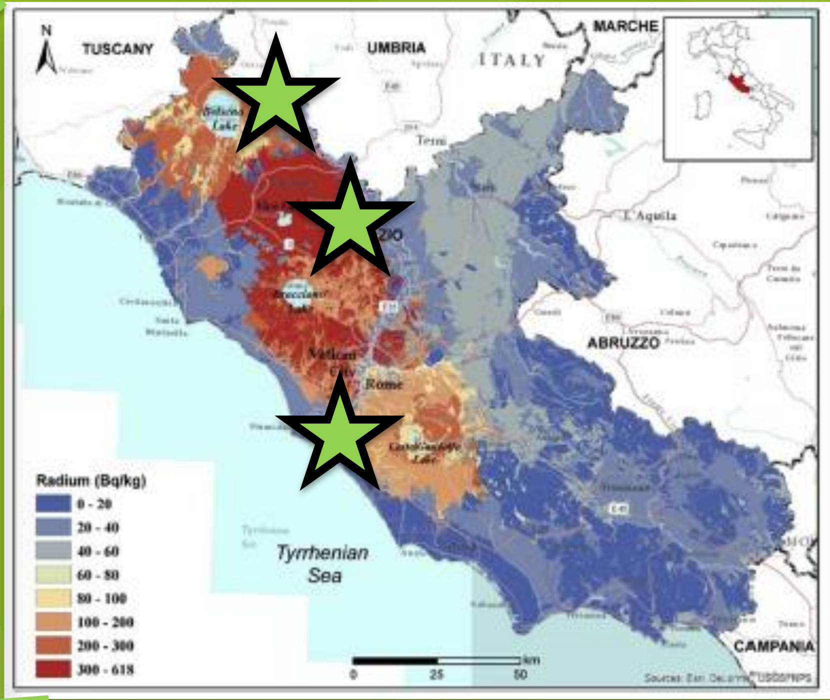
Construct a real time LIFE-RESPIRE geodatabase of continuous radon measurements, coupled with other geological, geochemical and building characteristics data, within the framework of the European Atlas of Natural Radiation (promoted by EU).

## 3

Provide local authorities with radon hazard guidelines and real-time WebGis radon maps for land use planning and health risk assessment, helping to prepare relevant national action plans (Articles 54, 74 and 103 in 2013/59/EURATOM).

# RESPIRE sites




Ciotoli et al, 2016

Caprarola, Celleno, Ciampino
Municipalities in Italy
Ardenne in Belgium

## Preparatory actions

- A1 Caprarola Site Characterization
- A2 Permissions for Demonstration cases implementation

## Implementation actions

- B1 Prototype assembly and tests
- B2 Implementation of demonstration cases including remediation measures
- B3 Monitoring and WebGis
- B4 Replicability potential evaluation and demonstrative case in Belgium

## Monitoring of the impact of the project actions

- C1 Monitoring of project impact indicators and LCA
- C2 Socio-economic impact assessment

## Public awareness and dissemination of results

- D1 Dissemination planning and execution
- D2 Networking

E Management

RESPIRE

Radon real time monitoring system

# Site characterization (Actions A)

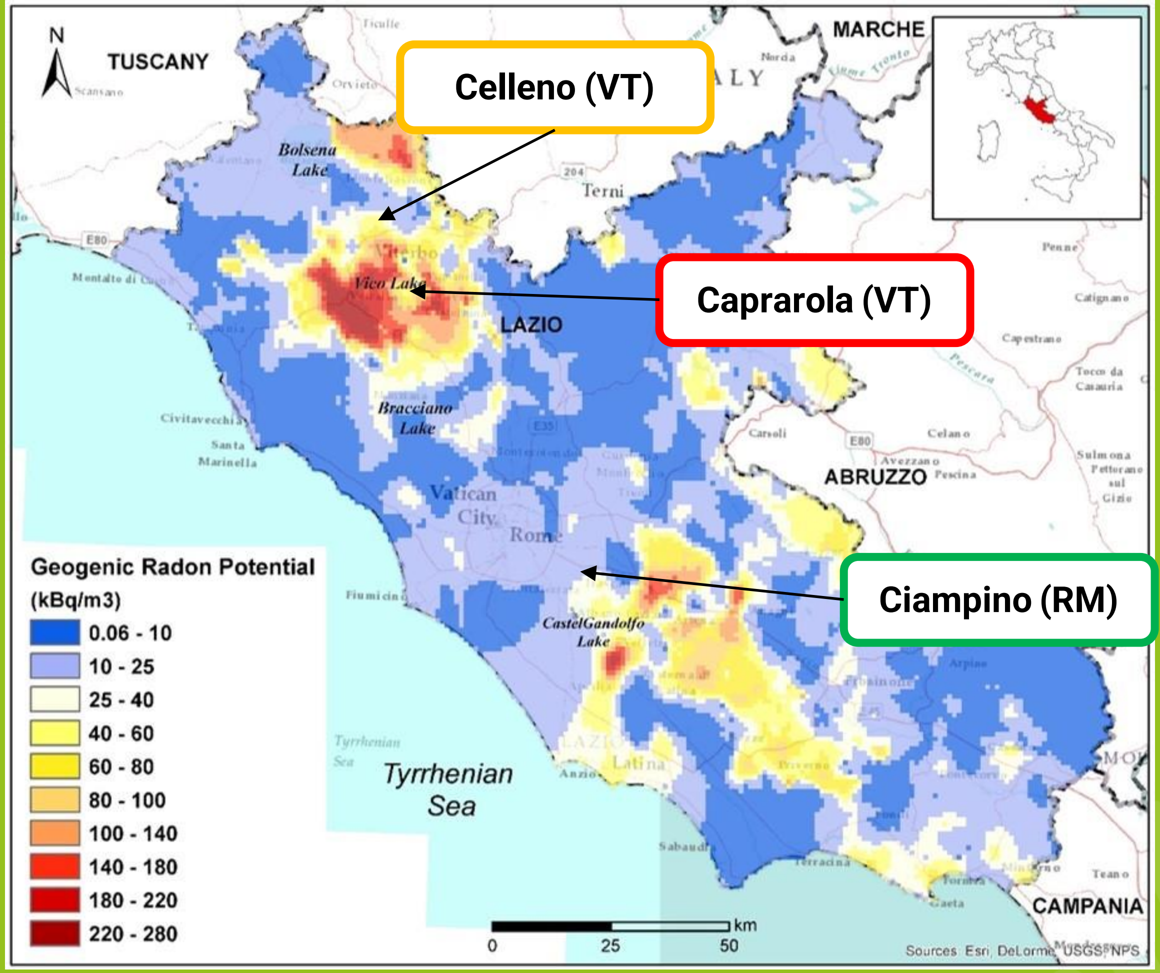
# LIFE-RESPIRE project objectives

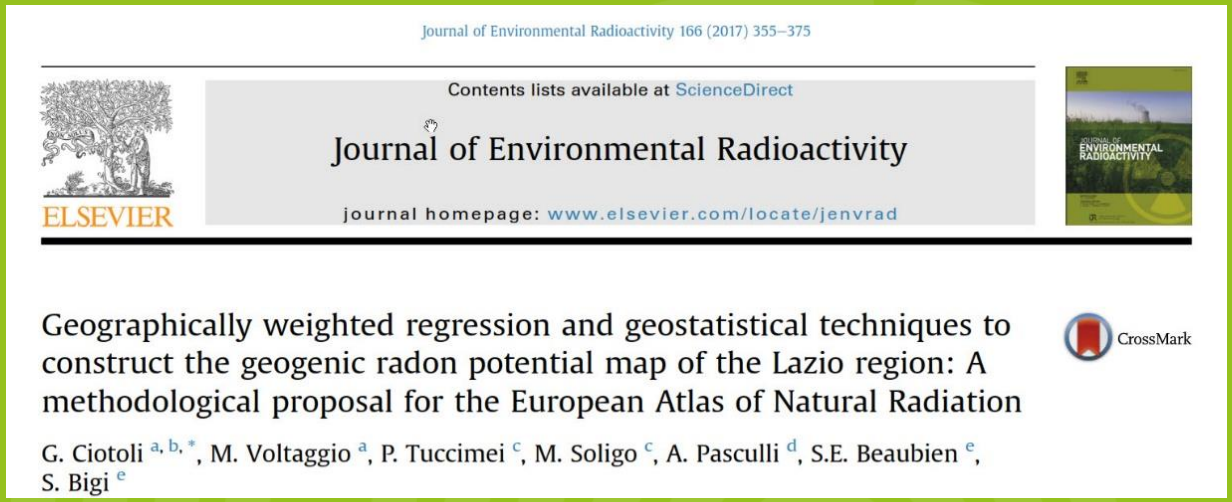
Site characterization represents the first result of the project.
New data on the territory of Caprarola were integrated to the already available data of Ciampino and Celleno for a complete geochemical characterization of the three sites.
All the collected map are now available on the webGis on the LIFE RESPIRE Project website.

- The characterization allowed to map the Geogenic Radon Potential (GRP) and Radon Prone Areas (RPAs) in the 4 sites, in Italy and Belgium and provided an innovative tool for local Authorities for land use planning.

# The Geogenic Radon potential map of the Lazio region

RESPIRE
Radon real time monitoring system





Journal of Environmental Radioactivity 166 (2017) 355–375

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

ELSEVIER

Geographically weighted regression and geostatistical techniques to construct the geogenic radon potential map of the Lazio region: A methodological proposal for the European Atlas of Natural Radiation

CrossMark

G. Ciotoli [a, b, *], M. Voltaggio [a], P. Tuccimei [c], M. Soligo [c], A. Pasculli [d], S.E. Beaubien [e], S. Bigi [e]

**High Rn potential**

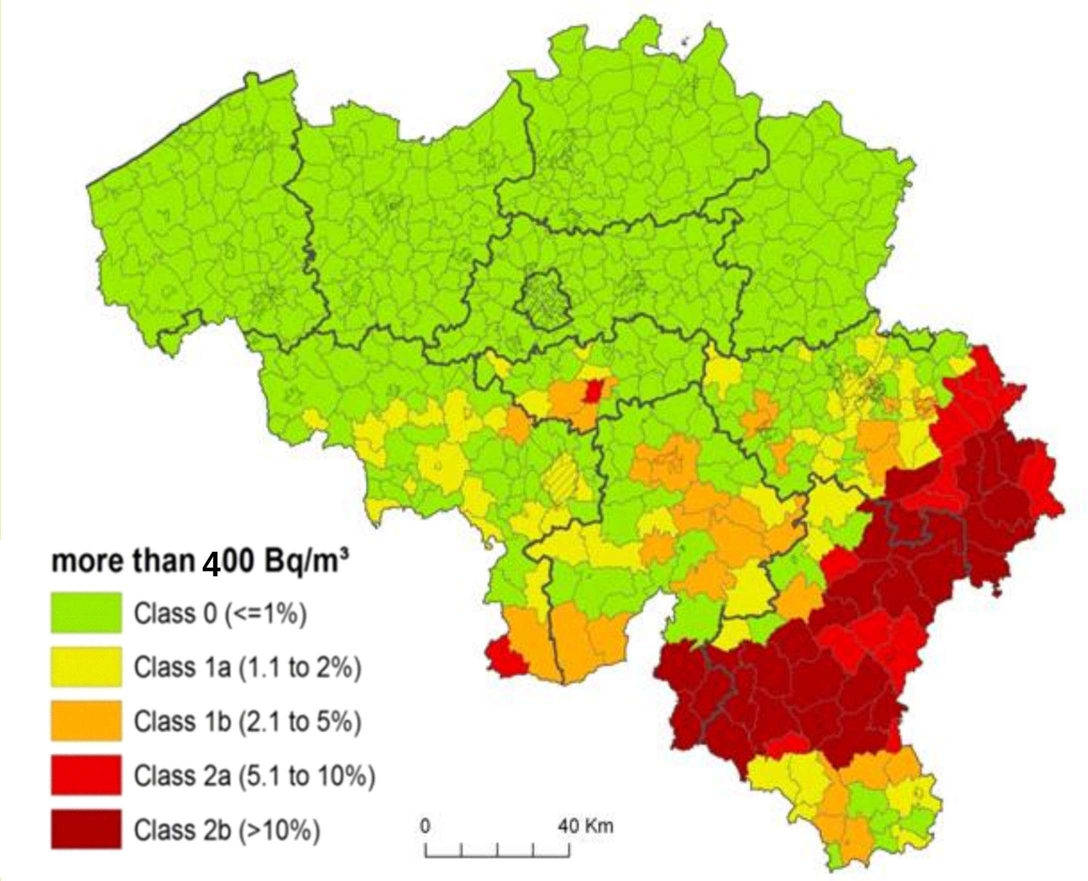
**Medium Rn Potential**

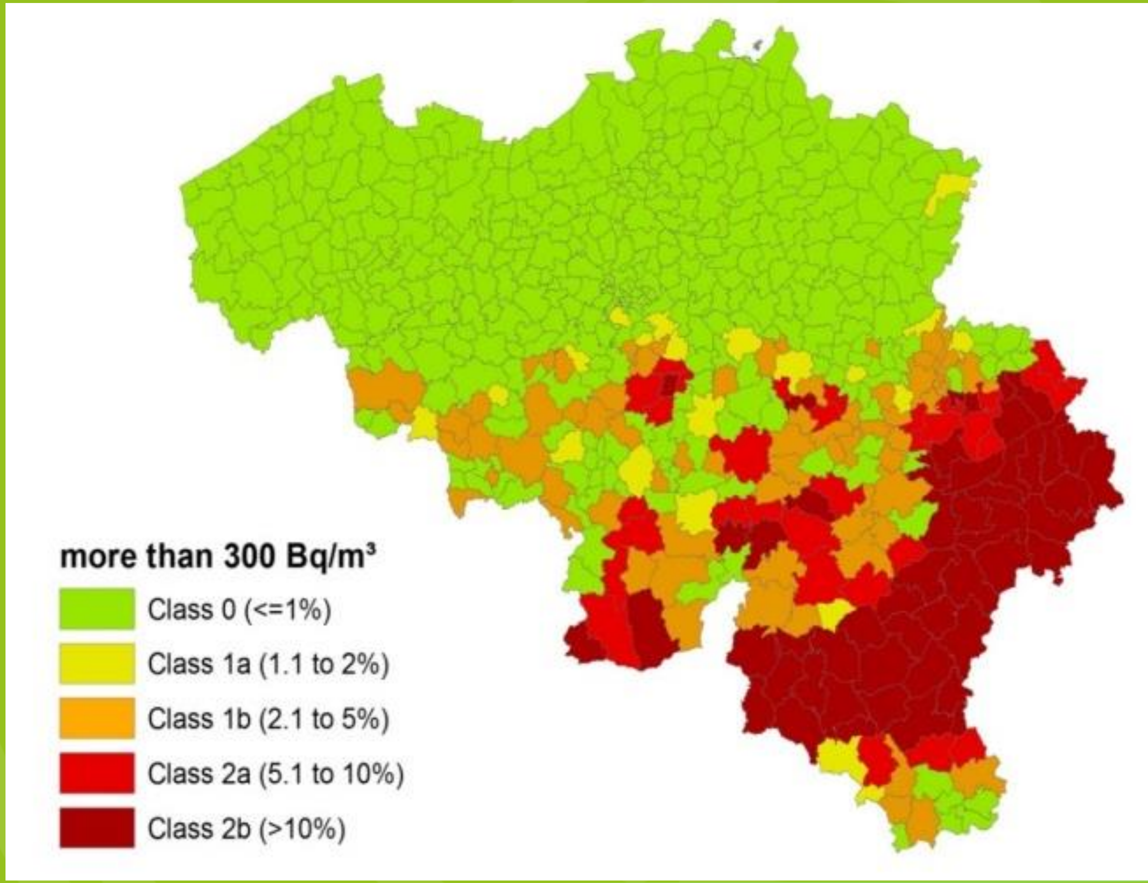
**Low Rn Potential**

# Ardenne region (Belgium)

RESPIRE
Radon real time monitoring system

Indoor $^{222}$Rn measured data (the value is calculated at municipality level)



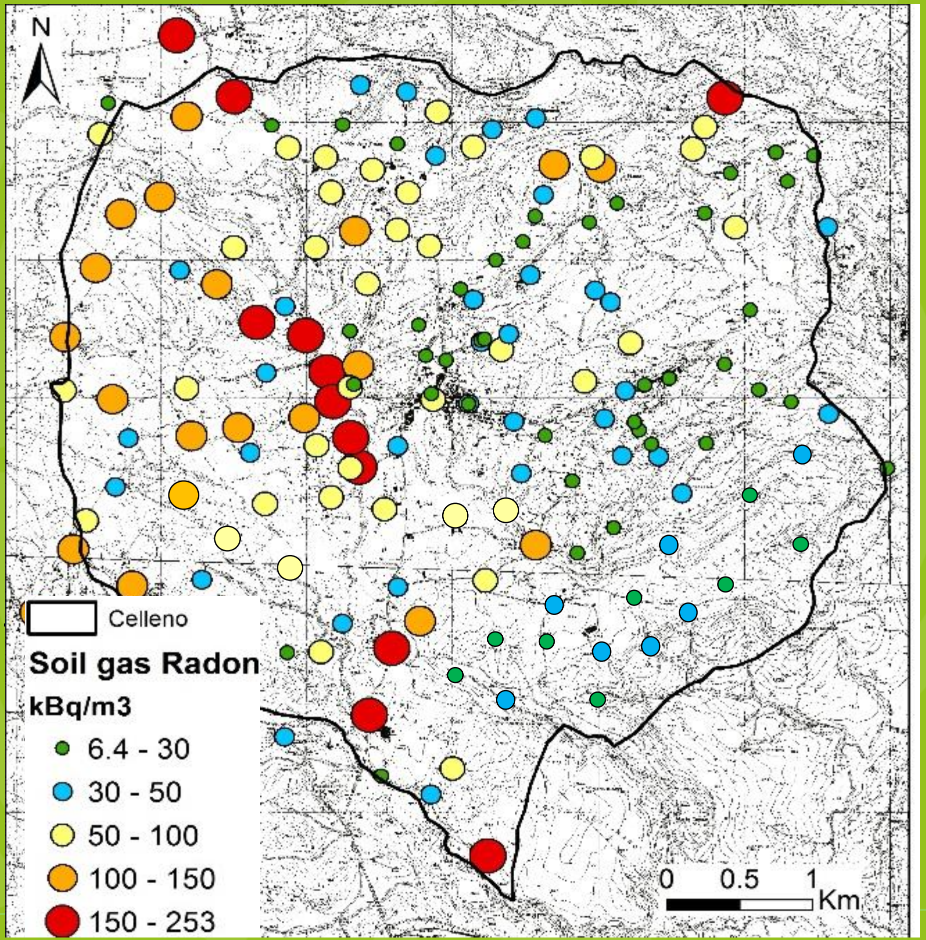
# Municipality of Celleno (VT, Italy)

| | Samples | Variables | Results |
|---|---|---|---|
| Soil gas (CERI, CNR-IGAG) | 204 | $^{222}Rn$, $^{220}Rn$, $CO_2$, $O_2$, $CO_2$ flux | Maps of soil gas concentrations |
| High-resolution gamma spectrometry (CNR-IGAG) | 20 | activity concentrations of radionuclides $^{238}U$, $^{226}Ra$, $^{232}Th$ e $^{40}K$ in soil/rock samples | Maps of activity concentrations of radionuclides |
| Terrestrial gamma dose (CNR-IGAG) | 77 | TGDR | Map of terrestrial gamma dose rate |
| Groundwater (CERI, INGV) | 17 | Chemical composition of water samples (major, minor and trace elements); dissolved Rn | Dissolved Rn in groundwater |
| Indoor Rn (CNR-IGAG) | 40 private and public dwellings | $^{222}Rn$ | Preliminary evaluation of indoor radon levels for the selection of buildings |

# Response variable: soil gas radon

## Soil gas radon samples

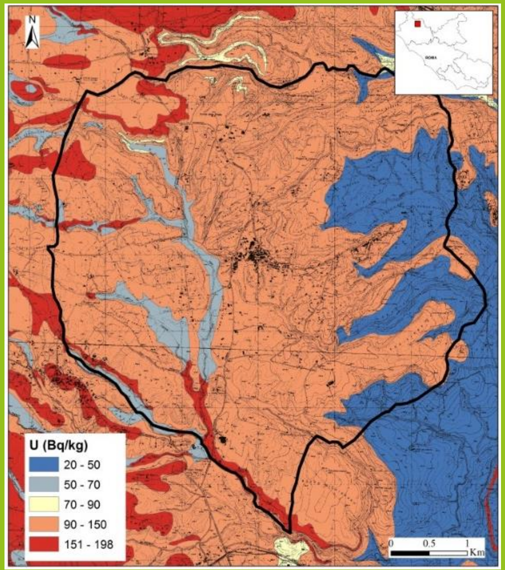
| | N | Mean (95% CI) | Min | Max | Stdev |
|---|---|---|---|---|---|
| $^{222}Rn$ (kBq/m$^3$) | 230 | 60 (52.8-66.8) | 6.4 | 253 | 48.75 |
| $CO_2$ (%, v/v) | 230 | 3.3 (3.0-3.6) | 0.3 | 11.0 | 2.2 |
| TGDR (mSv/h) | 80 | 0.229 (0.218-0.239) | 0.130 | 0.417 | 0.046 |
| $^{226}Ra$ (Bq/kg) | 20 | 122.2 (90.1-154.3) | 46 | 295 | 68.6 |
| $^{238}U$ (Bq/kg) | 20 | 124.1 (93.9-154.2) | 42 | 281 | 64.3 |
| $^{232}Th$ (Bq/kg) | 20 | 222.1 (186-258.2) | 78 | 365 | 77.1 |
| $^{40}K$ (Bq/kg) | 20 | 965.9 (716.1-1216) | 299 | 2480 | 533.5 |
| $^{222}Rn$ Emanation | 20 | 0.109 (0.069-0.148) | 0.033 | 0.38 | 0.085 |
| $^{222}Rn$ flux (Bq/m$^2$/day) | 20 | 6284 (4684-7883) | 1866 | 17779 | 3417 |

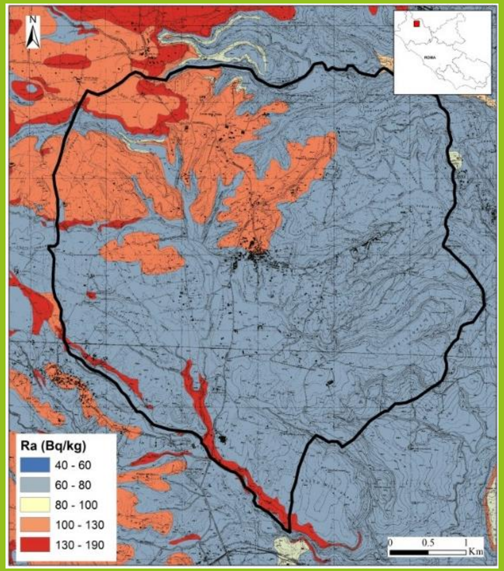


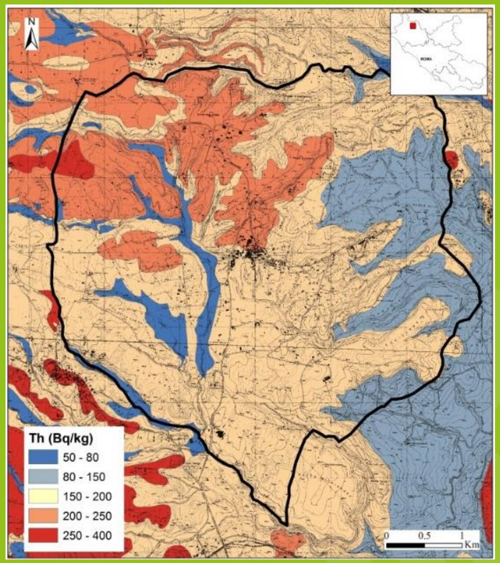
RESPIRE

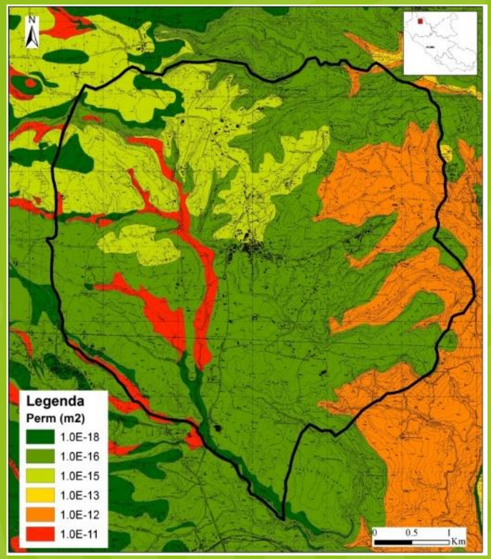
Radon real time monitoring system

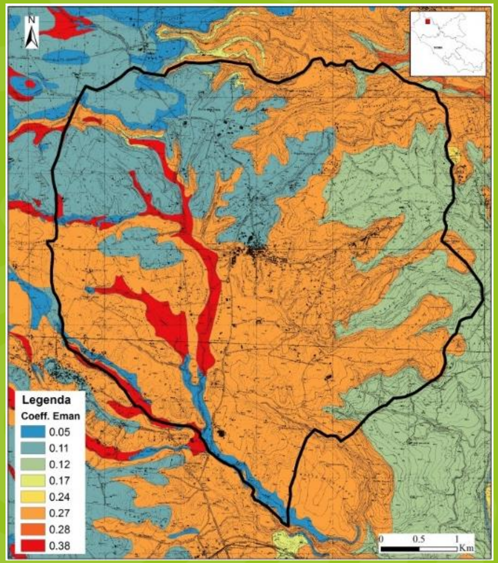
# Celleno (VT, central Italy) – Proxy variables




**Radionuclide content (U, Ra, Th)**

**Permeability (m2)**

**Emanation coefficient**

Giustini F., Ciotoli G., Rinaldini A., Ruggiero L., Voltaggio M.

**Mapping the geogenic radon potential and radon risk by using Empirical Bayesian Kriging regression: a case study from a volcanic area of central Italy.**

Science of Total Environment (2019)

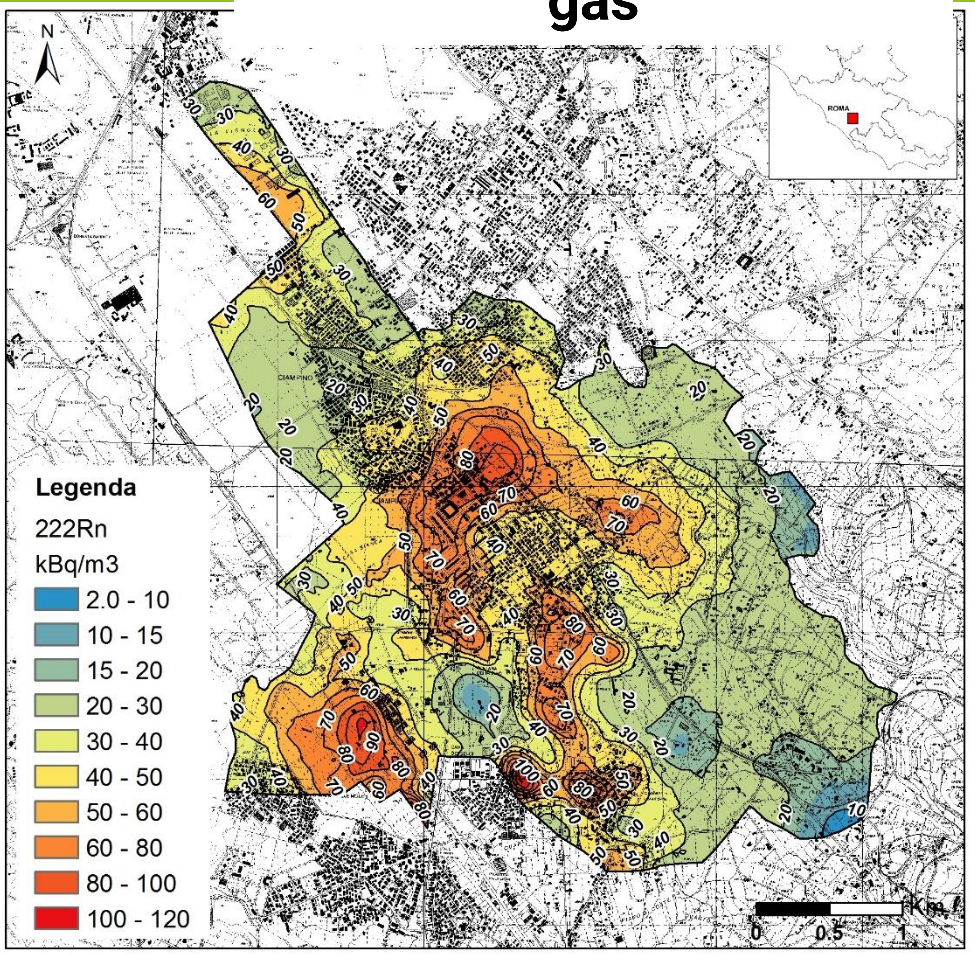
# Municipality of Ciampino (Rome, Italy)

| | Samples | Variables | Results |
|---|---|---|---|
| Soil gas (CERI) | 425 | $^{222}Rn$, $CO_2$, He, $CH_4$, $CO_2$ flux | Maps of soil gas concentrations |
| High-resolution gamma spectrometry | Data from literature | $^{238}U$, $^{226}Ra$, $^{232}Th$ | Maps of activity concentrations of radionuclides |
| Groundwater (INGV) | 86 | T, pH, redox potential and alkalinity; dissolved Rn and $CO_2$ | Dissolved Rn in groundwater |
| Indoor Rn (INGV) | 67 private and public dwellings | $^{222}Rn$ | Preliminary evaluation of indoor radon levels for the selection of buildings |

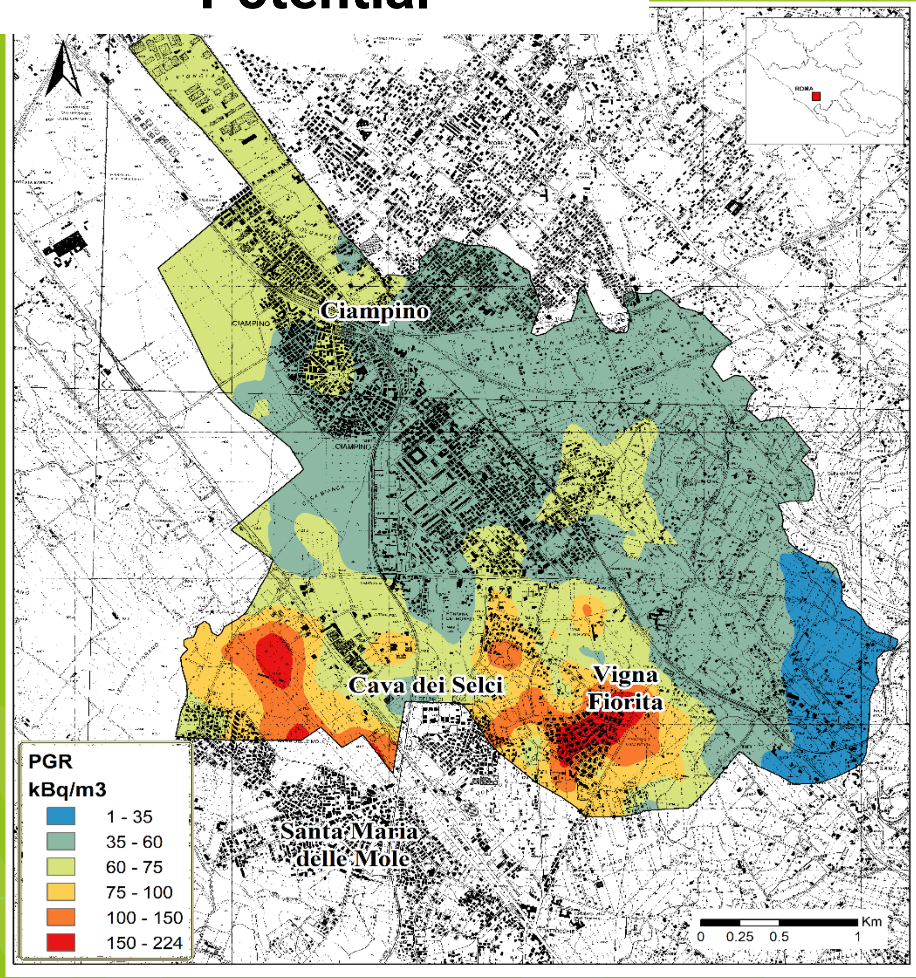
# Comune di Ciampino (Roma, Italia)

RESPIRE
Radon real time monitoring system

## Rn concentration in soil gas




## Geogenic Radon Potential



# Municipality of Caprarola (~ 50 $km^2$)

| Survey | Samples | Variables | Results |
|---|---|---|---|
| Soil gas (CERI, IGAG) | 181 | $^{222}Rn$, $^{220}Rn$, $CO_2$, $O_2$, flusso di $CO_2$ | Maps of soil gas concentrations |
| Soil permeability (CERI with University of ROMA TRE - Prof.ssa P. Tuccimei) | 181 | Permeability | Map of soil permeability |
| • High-resolution gamma spectrometry (IGAG)<br>• Terrestrial gamma dose (IGAG)<br>• Gamma Indoor (IGAG) | 19<br>187<br>117 | Activity concentrations of radionuclides $^{238}U$, $^{226}Ra$, $^{232}Th$ e $^{40}K$ in soil/rock samples, emanation coefficient, TGDR | Maps of activity concentrations of radionuclides<br>Map of terrestrial gamma dose rate |
| Groundwater (CERI, INGV) | 38 | Chemical composition of water samples (major, minor and trace elements); dissolved Rn | Dissolved Rn in groundwater |
| Indoor Rn (CERI, INGV, IGAG) | 80 (34 public and private sites) | $^{222}Rn$ | Preliminary evaluation of indoor radon levels for the selection of buildings |

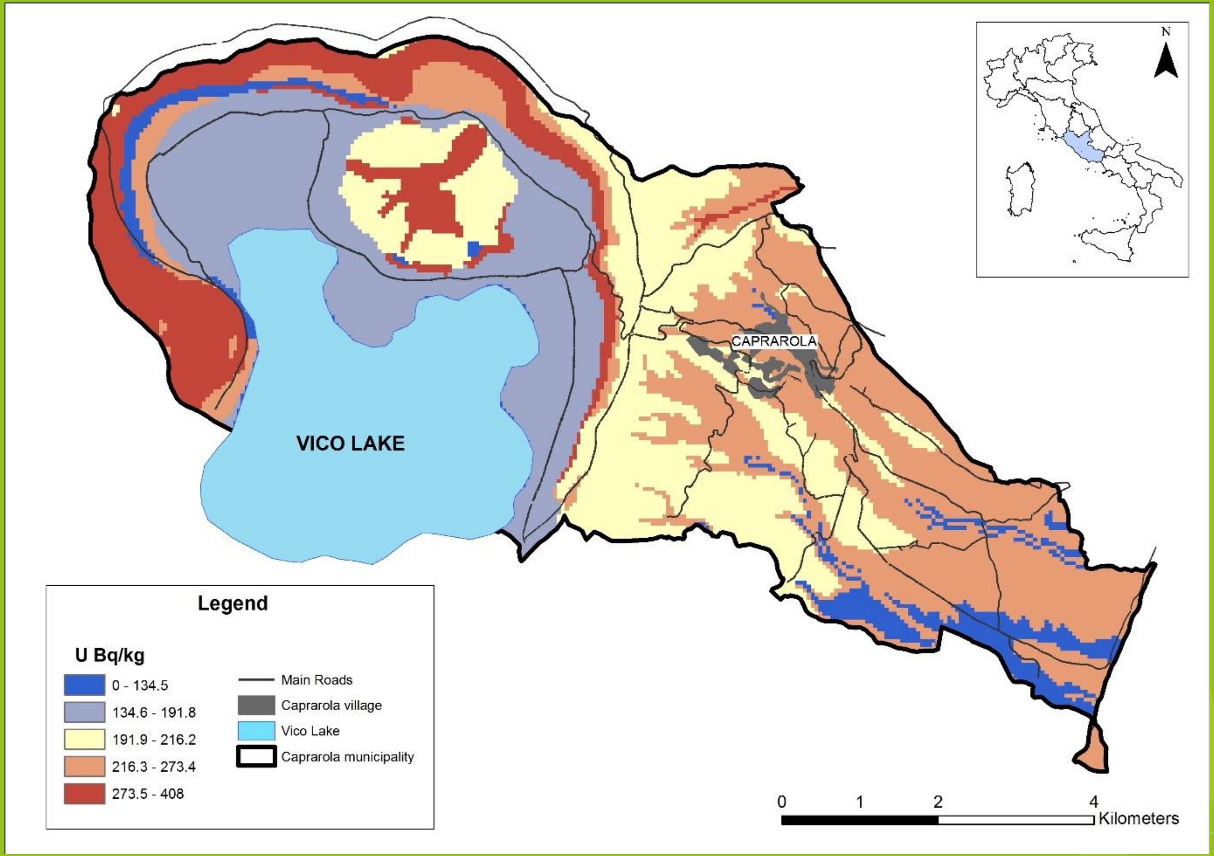
# Field surveys and laboratory analysis

Soil gas sampling (181 sites)
Measurements in the field of $CO_2$, $O_2$, $CH_4$, $H_2$, $H_2S$ concentrations, $^{222}Rn$, $^{220}Rn$, $CO_2$ flux and soil permeability
Collection of soil and rock samples in order to determine the activity concentrations of radionuclides $^{238}U$, $^{226}Ra$, $^{232}Th$ and $^{40}K$
Laboratory measurements of $CO_2$, $N_2$, $O_2$, He, Ne, $CH_4$ concentrations

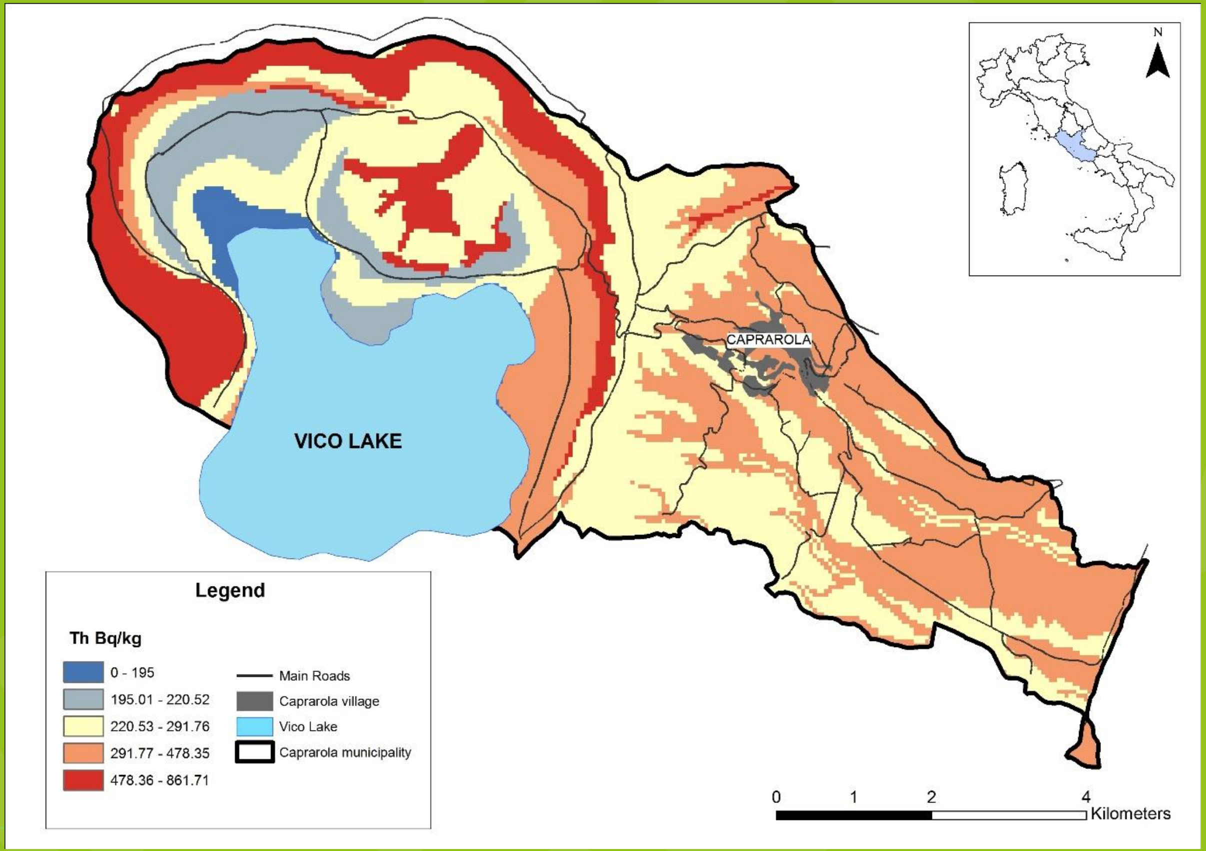
# Proxy Variables

RESPIRE

## Map of the Uranium content in the different lithologies

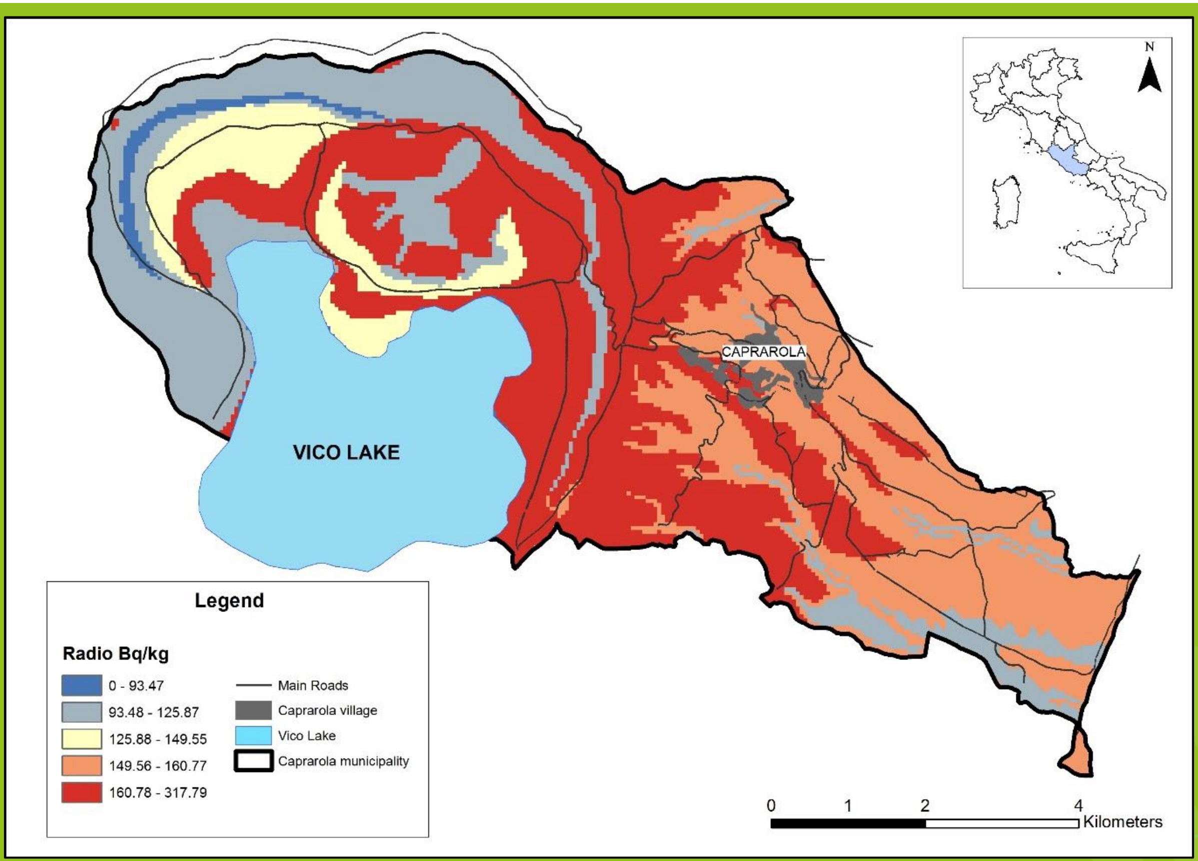



## Map of the Thorium content in the different lithologies

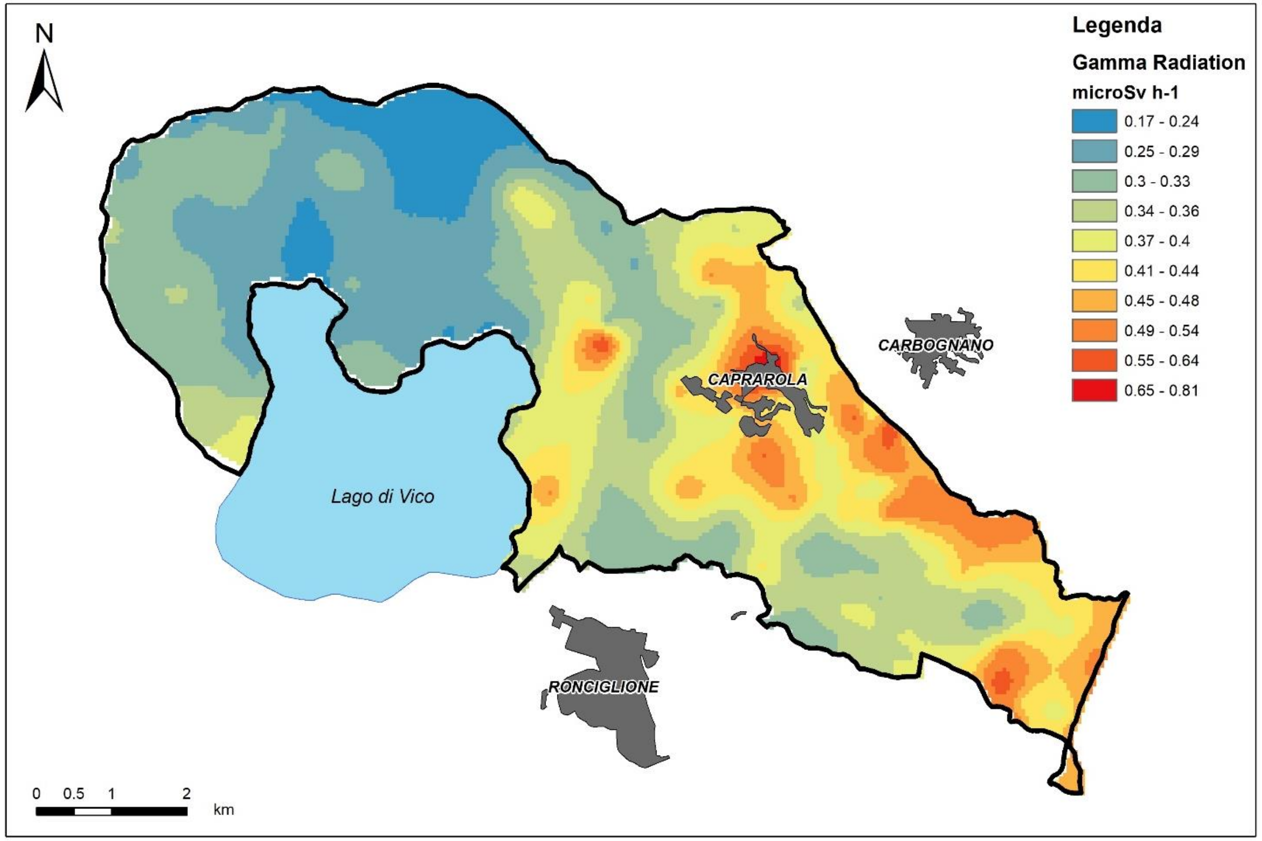


# Proxy Variables

## Map of the Radio content in the different lithologies




## Map of the terrestrial gamma dose rate

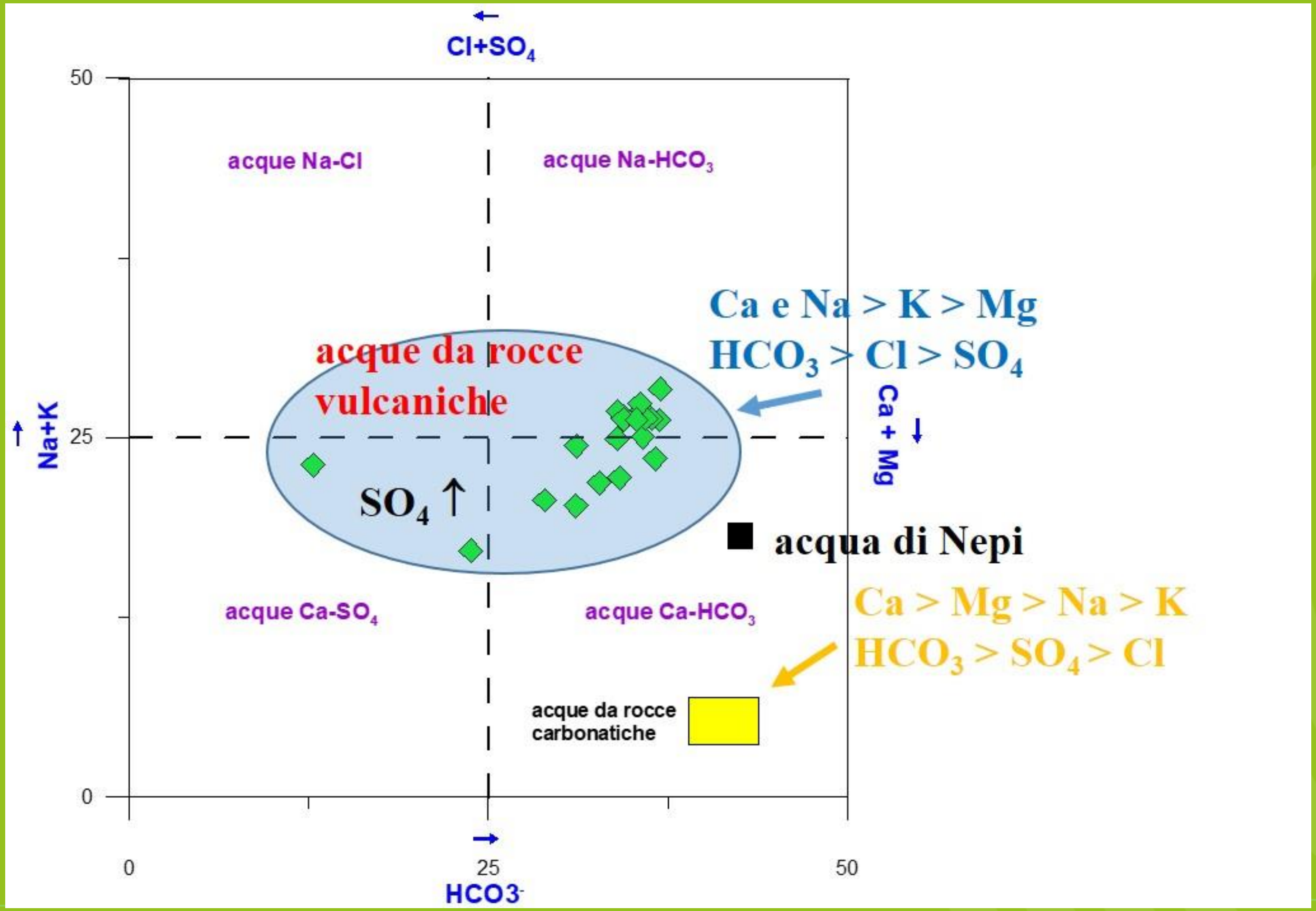


RESPIRE
Radon real time monitoring system

# Groundwater

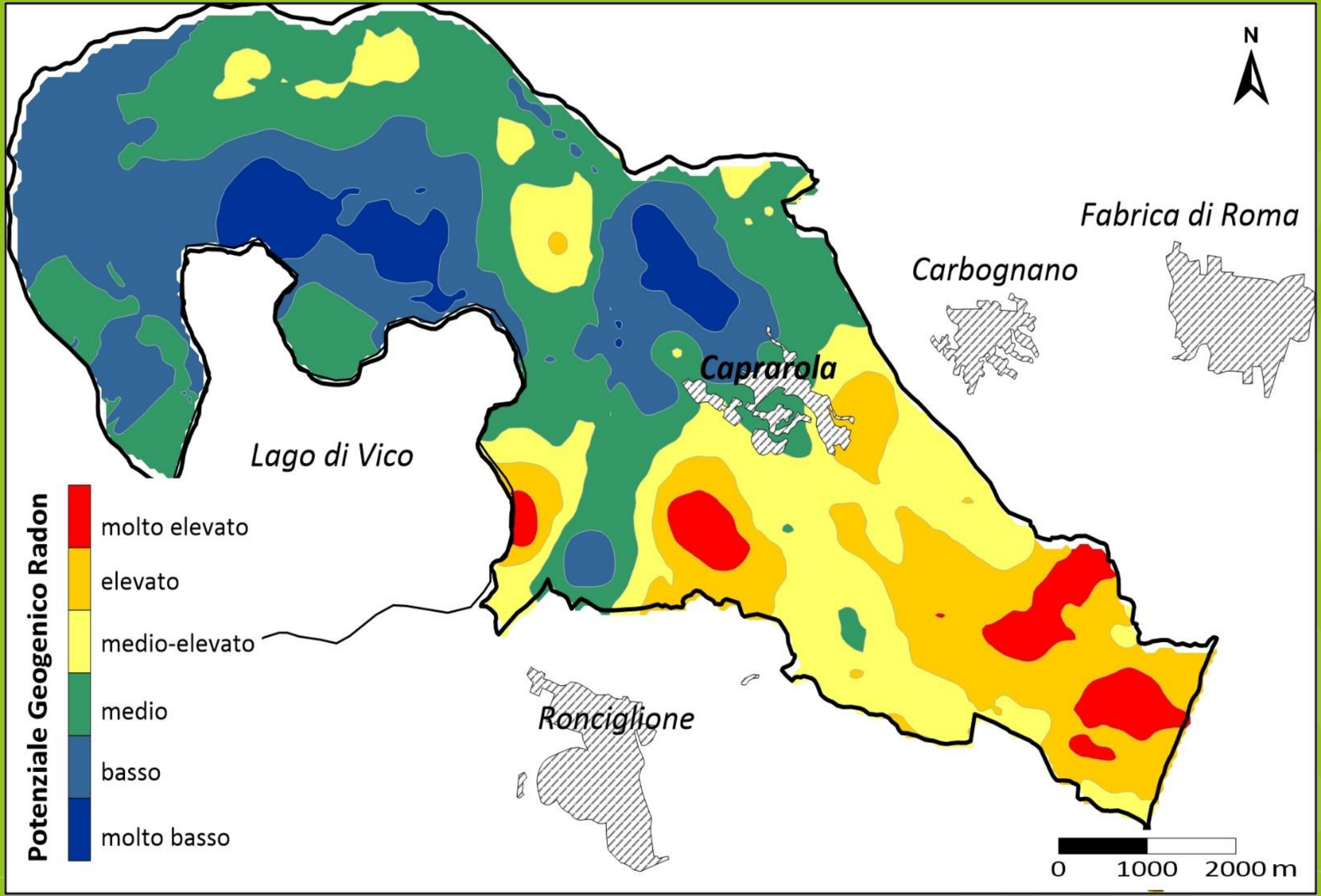
19 water samples were collected from 2 springs and 17 domestic and agricultural wells;
Water temperature, pH, electrical conductivity, alkalinity were determined in situ;
Major anions and cations (Ca, Mg, K, Na, Cl, $SO_4$), minor and trace elements (Al, B, Ba, SiO2, Li, Fe, Mn, U, As and Sr) were measured to determine the levels of natural contaminants;
Stable isotopes of C (to identify the source of dissolved $CO_2$), O e H (to determine the origin of water);
Analysis of dissolved gases ($CO_2$, $N_2$, $O_2$, He, Ne, $CH_4$, $H_2$);
Analysis of dissolved radon.

# Groundwater chemistry




Groundwaters display low salinity and pH from slightly basic to slightly acid (from 6.5 to 7.5); their temperatures range between 9 and 16°C. Groundwaters interact with volcanic rocks and result enriched in Na e K.

# Municipality of Caprarola (VT, Italy)



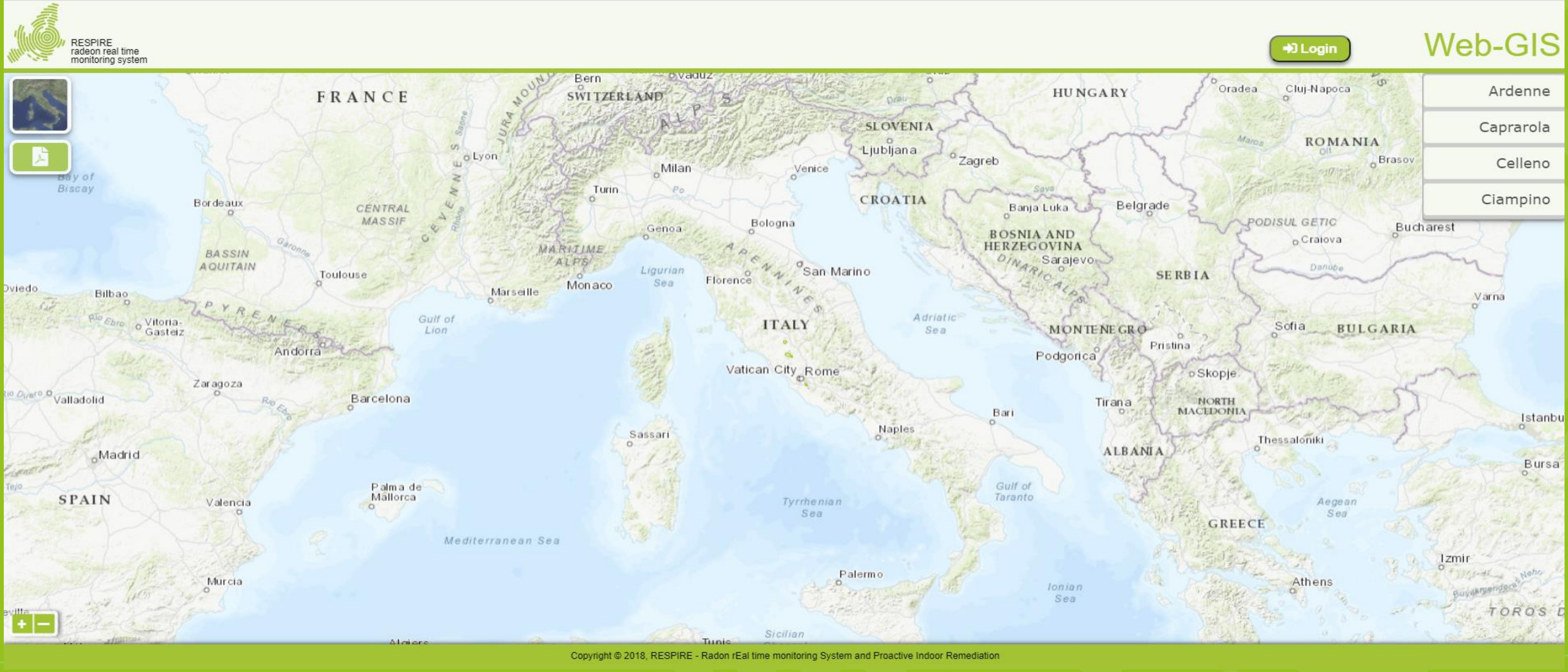

**Map of Geogenic Radon Potential of the Caprarola municipality**

RESPIRE

Radon real time monitoring system

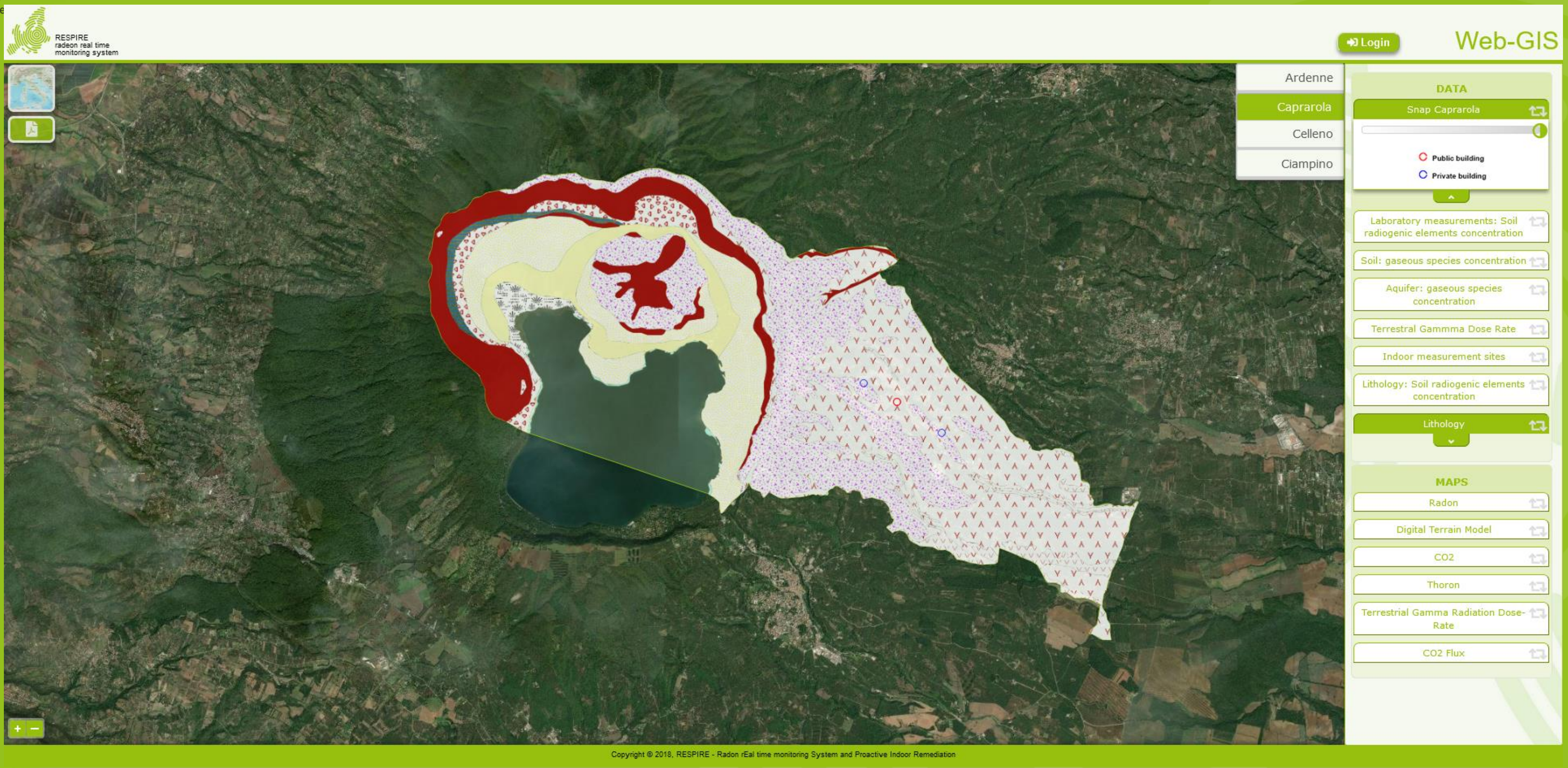
# Web-GIS: Interface

http://www.liferespire.eu/webgis/



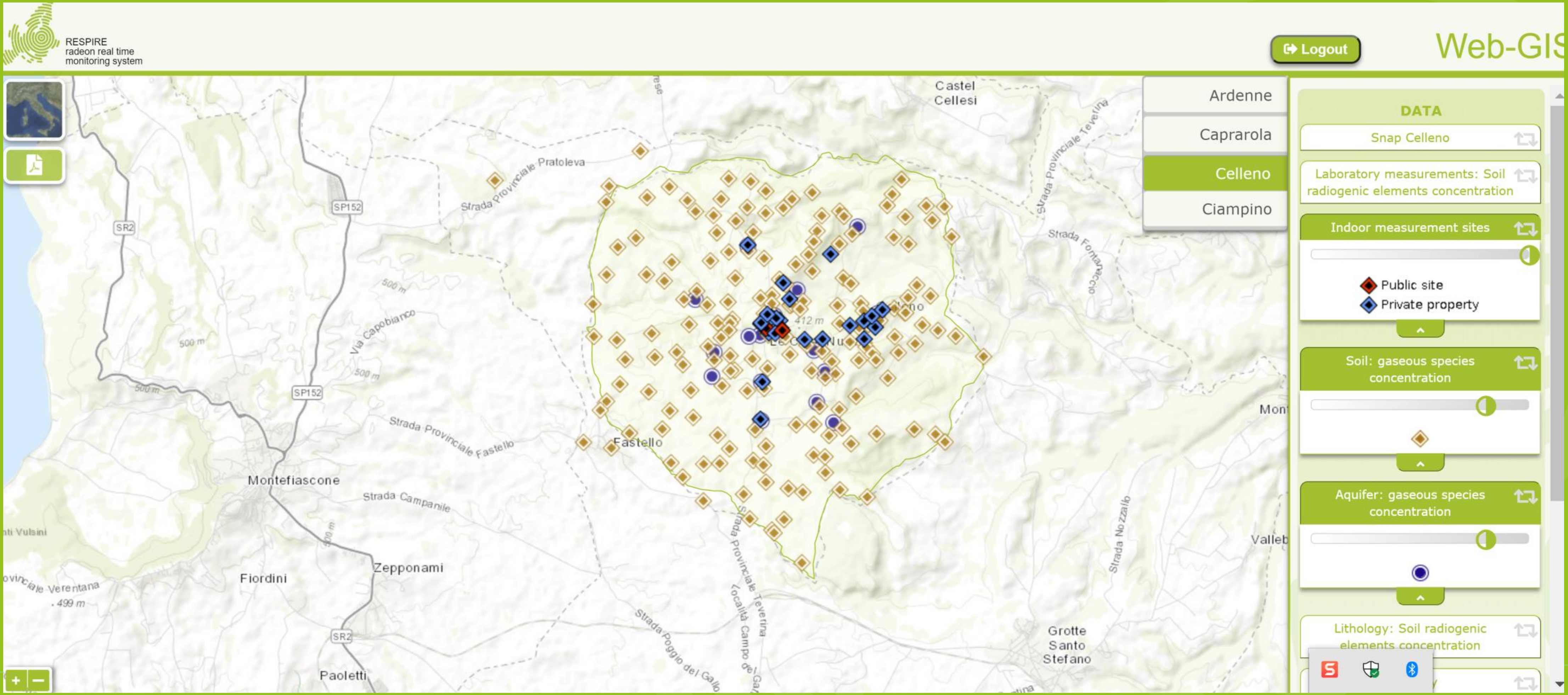
# Web-GIS: Interface

RESPIRE



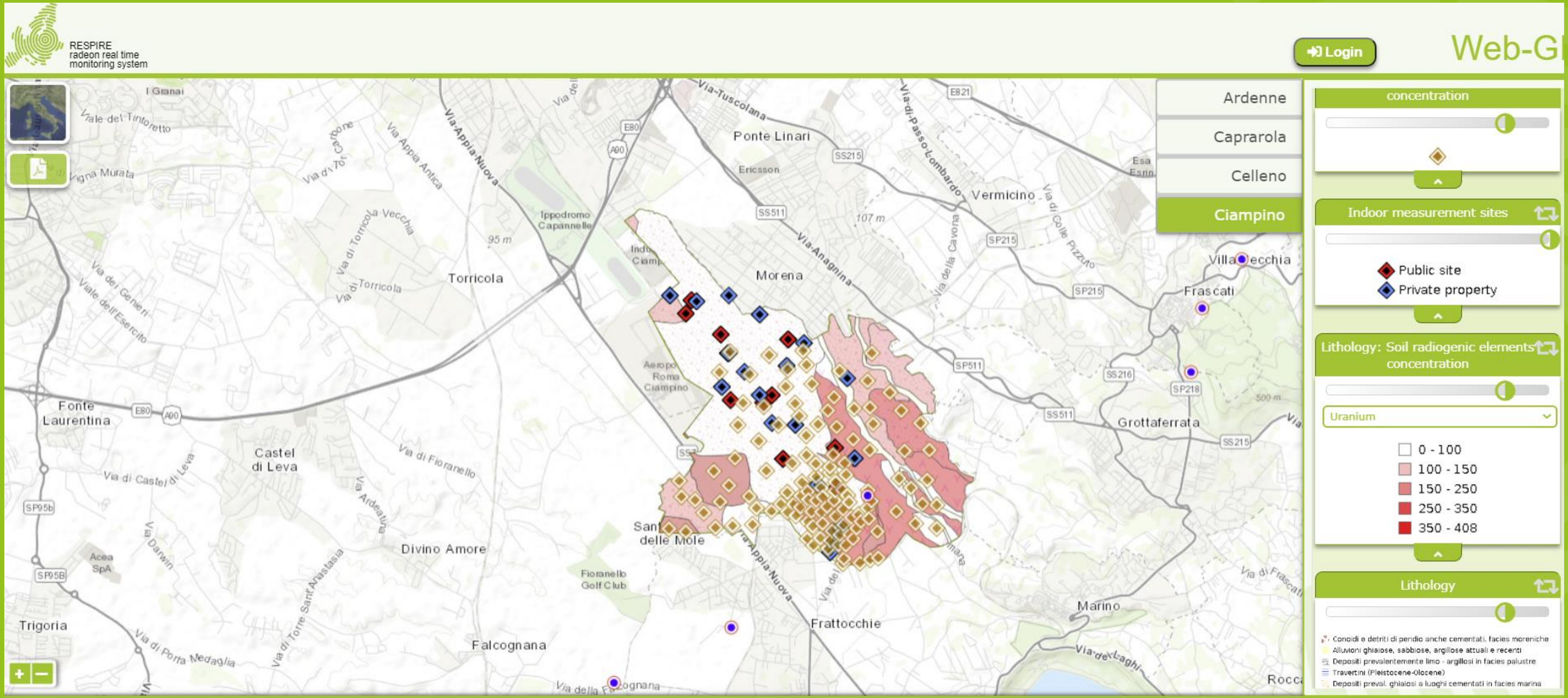
# Web-GIS: Interface-Functions

RESPIRE
Radon real time
monitoring system

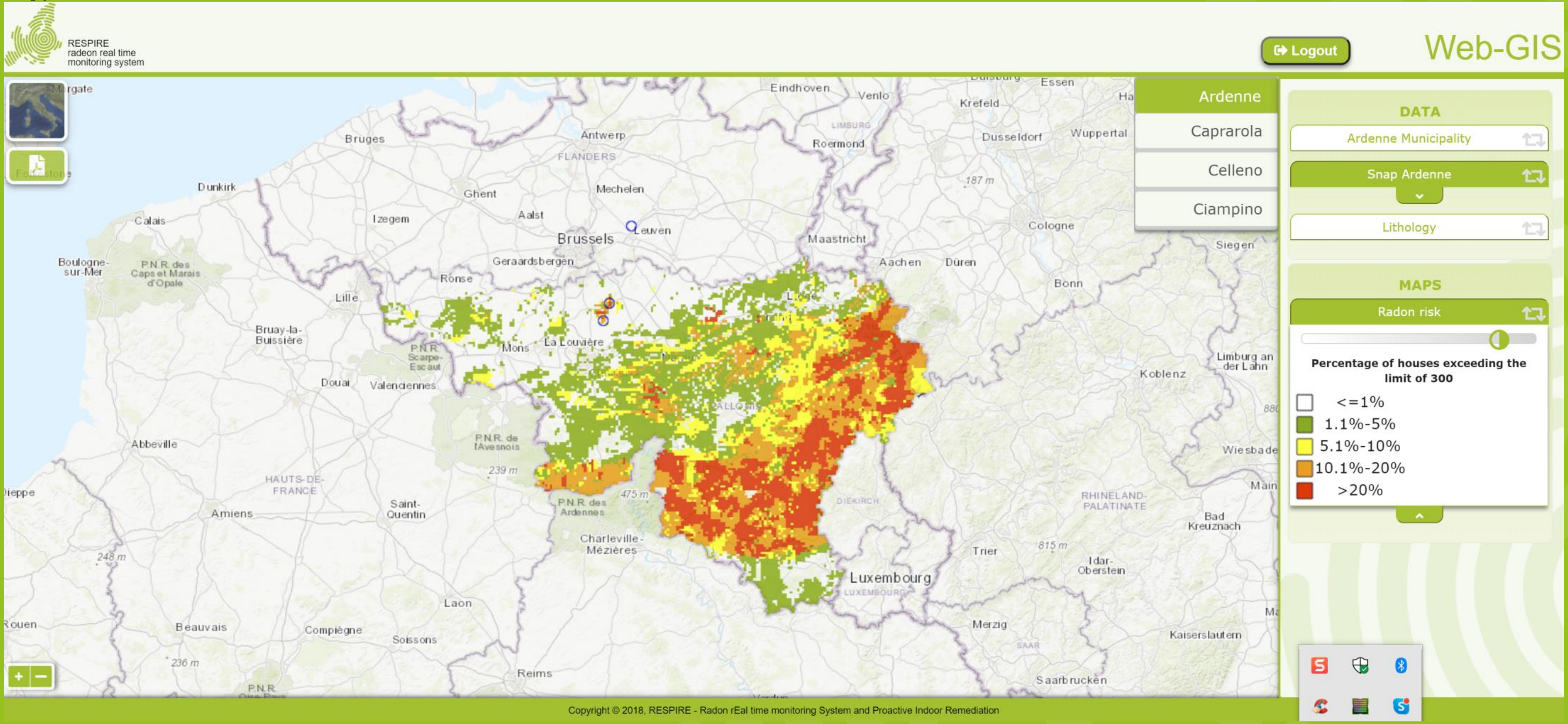


RESPIRE
Radon real time monitoring system

# Web-GIS: Interface-Functions



# Web-GIS: Interface-Functions



RESPIRE
Radon real time
monitoring system

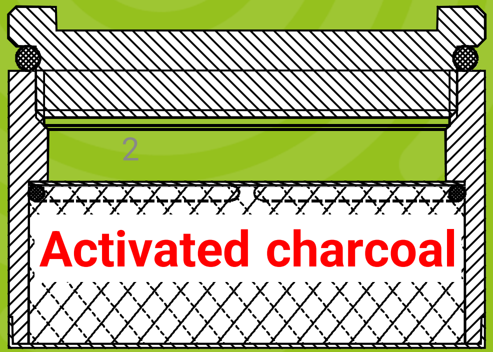
# Monitoring (short and long term) (Action B)

# radon indoor measurement techniques

## PASSIVE Detectors

**Track-etch**. Suitable for prolonged exposition (**months**). Their employment fulfils European Directive 2013/59 Euratom of 5/12/2013 that European countries must transpose before 6/2/2018

**Activated charcoal canisters**.
Suitable for short exposition (**48h**), activity measurements in laboratory by means of γ spectrometry



# Indoor radon long-term passive monitoring at Caprarola, Celleno and Ciampino municipalities

RESPIRE
Radon real time monitoring system

In the period from 15th November to 7th December 2018, long-term indoor radon surveys by using passive detectors (Radosys RSK) were carried out in public and private buildings of the Municipality of Caprarola, Celleno (VT) and Ciampino (RM) municipalities.



In the 3 municipalities involved in the Respire project, after a campaign of awareness and information to citizens, it was offered the opportunity to participate in the monitoring of indoor radon in their homes for free.

RESPIRE
Radon real time monitoring system

# Indoor radon long-term passive monitoring at Caprarola, Celleno and Ciampino municipalities

This initiative was successful and dosimeters were placed in almost **150** private homes and **18 public buildings**, including 12 schools:

- **Caprarola: 100 private and 5 public buildings;**
- **Ciampino: 19 private and 11 public buildings;**
- **Celleno: 22 private and 2 public buildings.**

The surveys was replicated in the same buildings during the spring-summer period, in order to have a wide spectrum of measurement values and to highlight a possible seasonality in the variation of the average values of the indoor radon concentration.

RESULTS were communicated directly to each private owner  by mail or by paper letter, including in the text some advices and suggestion about remediation actions (taking as reference the legislation).

RESPIRE
Radon real time monitoring system

Oggetto:

**Progetto Life RESPIRE**

**MISURA DI CONCENTRAZIONE DI RADON IN ARIA**

**Destinatario:** [redacted]

Gentile [redacted]

desideriamo prima di tutto ringraziarla per aver partecipato al progetto di ricerca Life RESPIRE, aiutandoci ad aumentare le nostre conoscenze circa la presenza del radon nelle abitazioni della zona.

I dati rilevati hanno evidenziato che circa l'8% delle abitazioni monitorate presenta una media annuale con valori inferiori a 150Bq, il 25% presenta valori tra 100 e 300 Bq, il 32% presenta valori tra 300 e 500 Bq, e il 35% presenta valori superiori a 500 Bq.

Con questa lettera le inviamo i risultati del monitoraggio effettuato presso la sua abitazione.

Il valore medio annuale della concentrazione di radon nella sua abitazione di via Nicolai è 425 Bq/m3 e in quella di via Roma è di 607. Più in dettaglio:

| Luogo di esposizione | Periodo esposizione | Data inizio esposizione | Data fine esposizione | Concentrazione radon (Bq/m$^3$) |
|---|---|---|---|---|
| Via Nicolai | Invernale | 16/11/2018 | 14/02/2019 | 346 |
| Via Nicolai | Estivo | 03/07/2019 | 24/09/2019 | 505 |
| Via Roma | Invernale | 16/11/2018 | 14/02/2019 | 1032 |
| Via Roma | Estivo | 03/07/2019 | 24/09/2019 | 183 |

Si tratta di valori che, come può vedere nella tabella qui sotto, richiedono una certa attenzione nella gestione quotidiana della casa.

| Valori rilevati | Azioni da compiere |
|---|---|
| Valori inferiori a 100 Bq/m3 | Condizione ottimale, arieggiare normalmente i locali |
| Valori compresi tra 100 e 300 Bq/m3 | Condizione buona, a scopo precauzionale arieggiare i locali per mantenere i valori al di sotto dei 100 Bq/m3 |
| Valori compresi tra 300 e 500 Bq/m3 | Condizione limite, arieggiare il più possibile il/i locale/i interessato/i, in particolar modo durante il periodo invernale |
| Valori superiori a 500 Bq/m3 | Condizione di attenzione che richiede l'intervento di tecnici specializzati |

Il monitoraggio annuale della concentrazione di radon all'interno della sua abitazione è stato effettuato con dosimetri del tipo CR-39 della Radosys.

Le analisi dei dosimetri sono state realizzate con un sistema di lettura automatico. Il laboratorio dove sono state eseguite le letture dei dosimetri impiegati per questo progetto non ha una certificazione specifica, quindi il dato finale è da considerarsi indicativo e inerente al progetto di ricerca LIFE RESPIRE.

La Direttiva 2013/59/EURATOM stabilisce un livello di riferimento per la media annua della concentrazione di radon in ambienti chiusi (abitazioni private e strutture pubbliche), pari a 300 Bq/m$^3$ (art. 74 2013/59/EURATOM):

a) se il dato medio annuo ottenuto da questo monitoraggio è inferiore a 300 Bq/m$^3$ non si prevede alcuna azione di intervento;

b) se il dato medio annuo ottenuto da questo monitoraggio è compreso tra 300 e 500 Bq/m$^3$, si consiglia di areare il più possibile il locale interessato dalla misura in particolar modo durante il periodo invernale.

c) se il dato medio annuo ottenuto da questo monitoraggio è superiore a 500 Bq/m$^3$, si consiglia di intraprendere delle azioni di rimedio, volte a migliorare la qualità dell'aria negli ambienti, con il supporto di un tecnico qualificato che suggerisca quale azione di rimedio sia più appropriata per risolvere la problematica. A titolo di esempio, alcune azioni di rimedio potrebbero essere: la depressurizzazione del suolo, realizzando sotto o accanto all'edificio un pozzetto per la raccolta del radon, collegato a un ventilatore; la pressurizzazione dell'edificio, immettendo aria dall'esterno; l'impermeabilizzazione del pavimento e la sigillatura di crepe e fessure; l'isolamento delle porte comunicanti con le cantine.

In ogni caso, l'areazione dei locali è il metodo più veloce e efficace per diminuire la concentrazione del radon negli ambienti chiusi, sebbene soprattutto in inverno ciò comporti una dispersione di calore. **Al fine di arieggiare correttamente i locali, si consiglia di aprire le finestre almeno tre volte al giorno per dieci minuti, iniziando dai locali posti ai livelli più bassi; al contrario, la chiusura delle finestre deve iniziare dai piani più alti, per limitare l'effetto "camino".**

Grazie per la vostra partecipazione al progetto LIFE RESPIRE.

Con i più cordiali saluti da parte di tutto il team

Prof.ssa Sabina Bigi

Coordinatrice progetto Life RESPIRE

# *Long term survey:*

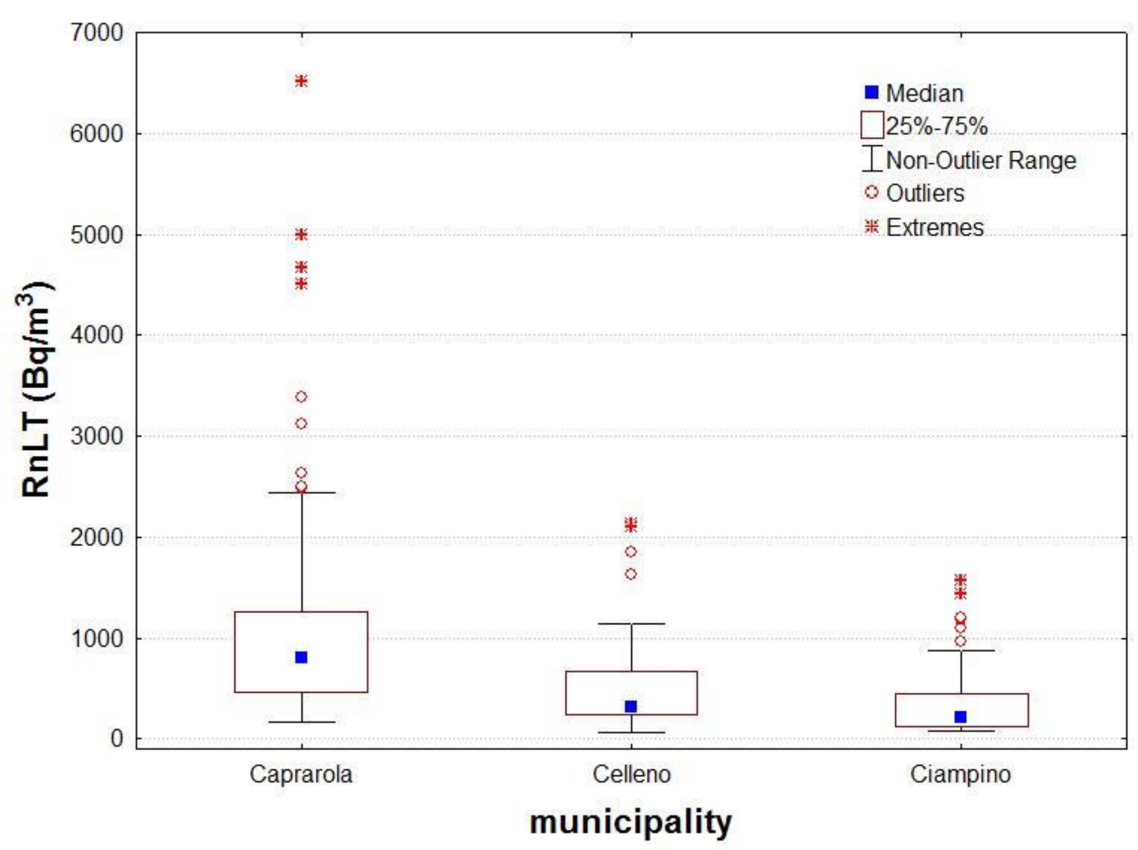
## *Dosimeter (Track-etches)*

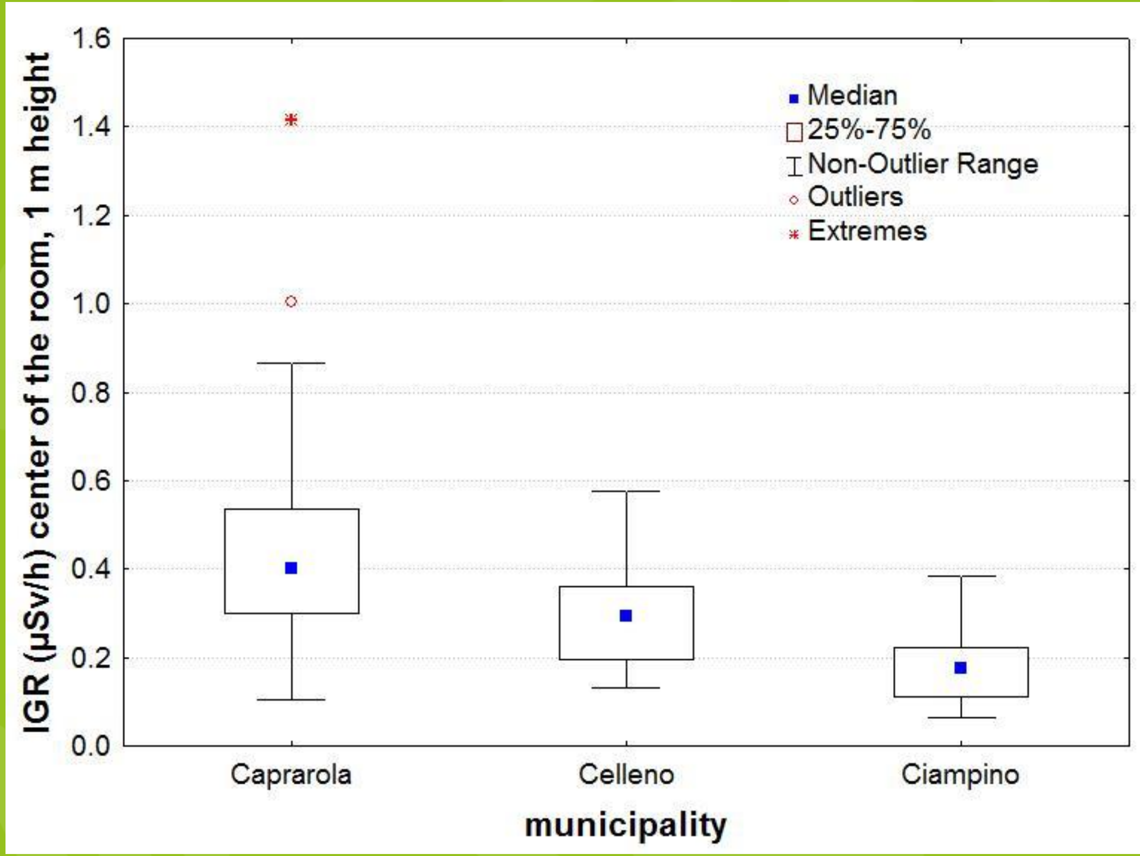
| CIAMPINO | Mean | Median | Min | Max | Lower Quartile | Upper Quartile | Dev. Std. |
|---|---|---|---|---|---|---|---|
| **Rn (Bq/m$^3$)** | 362 | 209 | 74 | 1575 | 129 | 434 | 329 |
| **77** Rn indoor measurements: **19 private dwellings** and **11** in **public buildings** | | | | | | | |

| CELLENO | Mean | Median | Min | Max | Lower Quartile | Upper Quartile | Dev. Std. |
|---|---|---|---|---|---|---|---|
| **Rn (Bq/m$^3$)** | 557 | 360 | 57 | 2126 | 250 | 684 | 529 |
| **80** Rn indoor measurements: **22 private dwellings** and **3 public buildings** | | | | | | | |

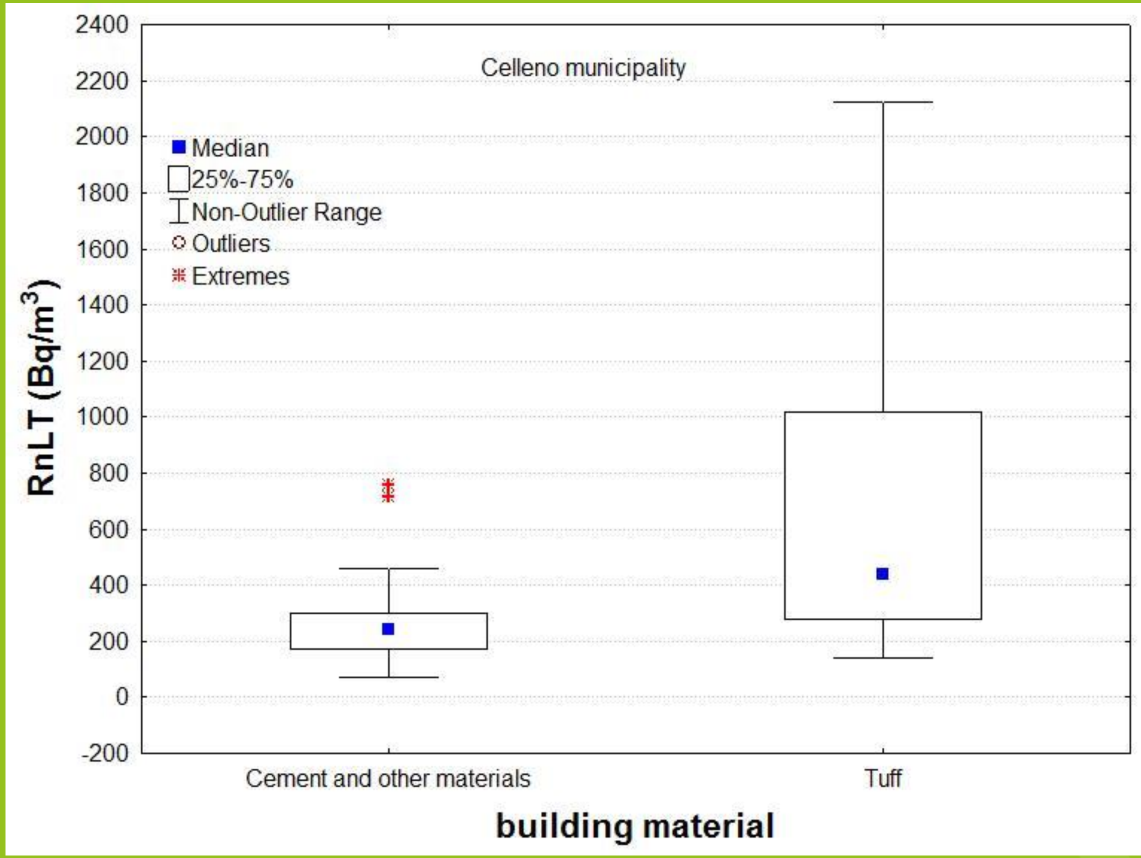
| CAPRAROLA | Mean | Median | Min | Max | Lower Quartile | Upper Quartile | Dev. Std. |
|---|---|---|---|---|---|---|---|
| **Rn (Bq/m$^3$)** | 962 | 696 | 89 | 5682 | 236 | 1246 | 969 |
| **178** Rn indoor measurements: **94 private dwellings** and **5 public buildings** | | | | | | | |

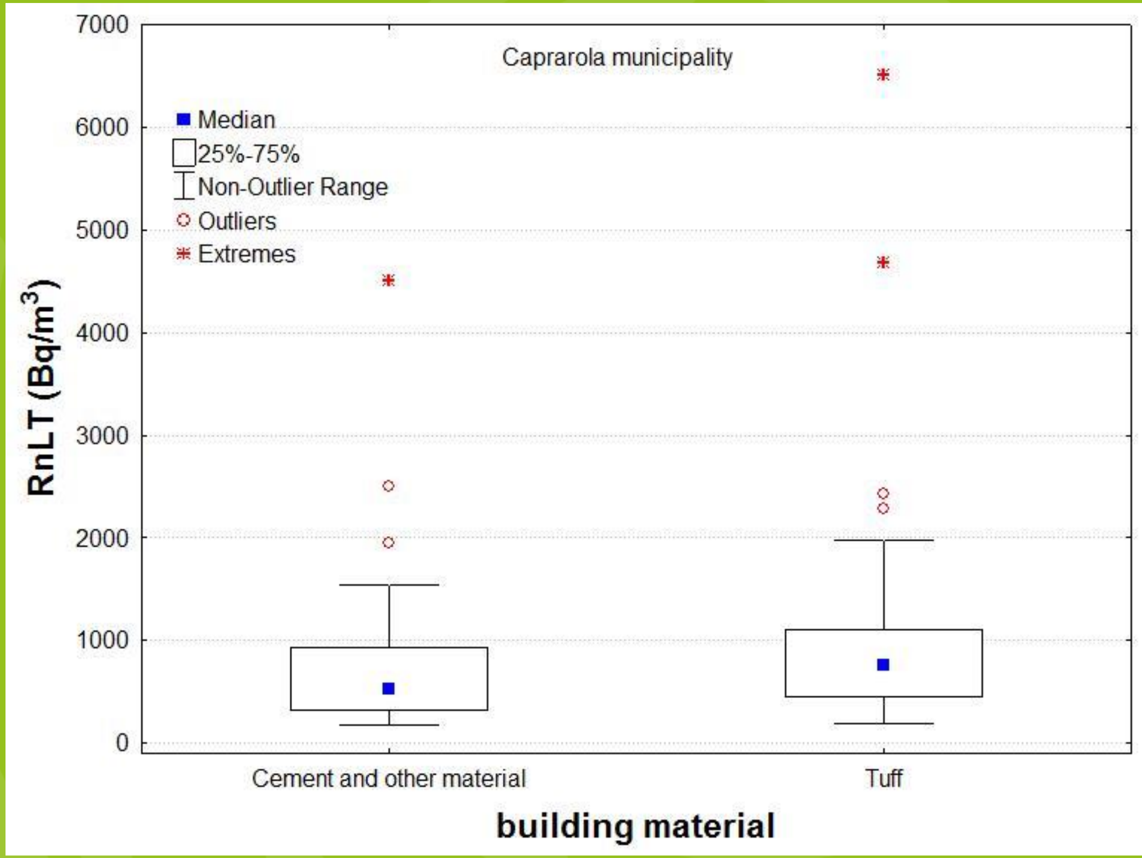
# Long-term survey



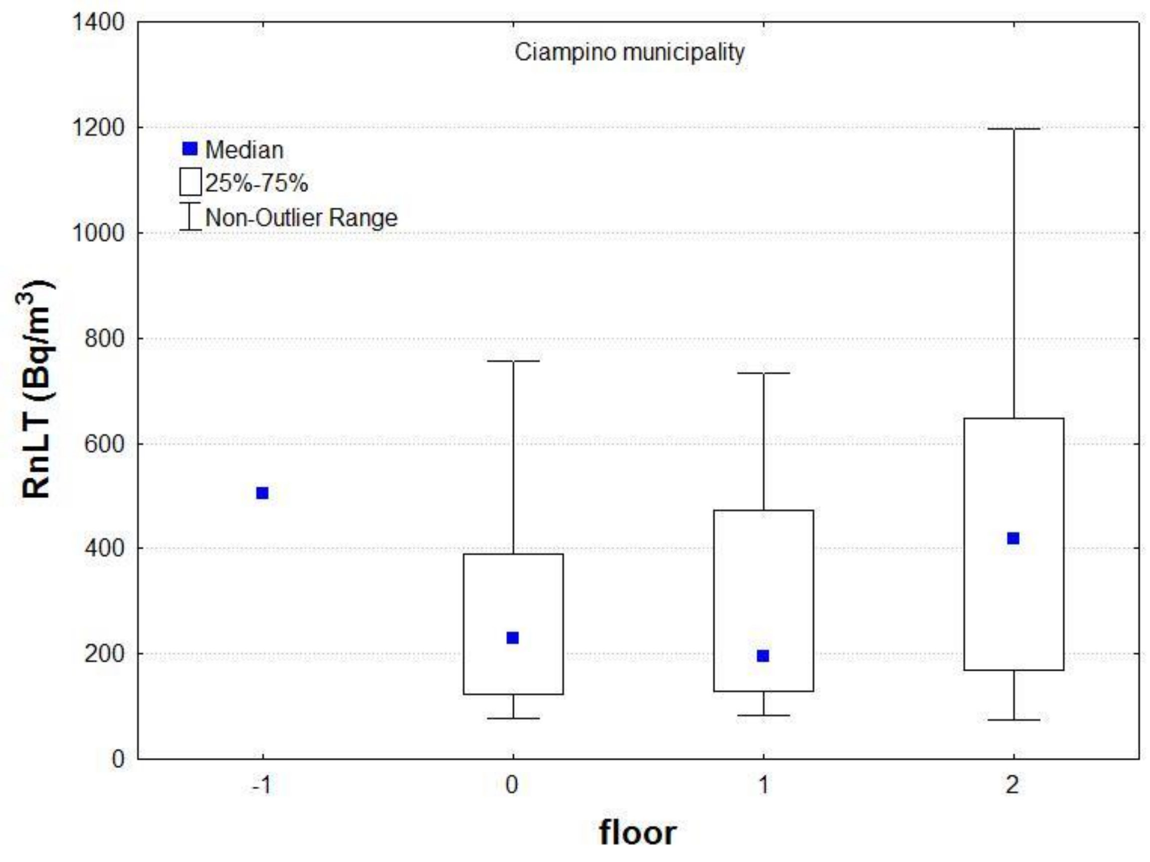



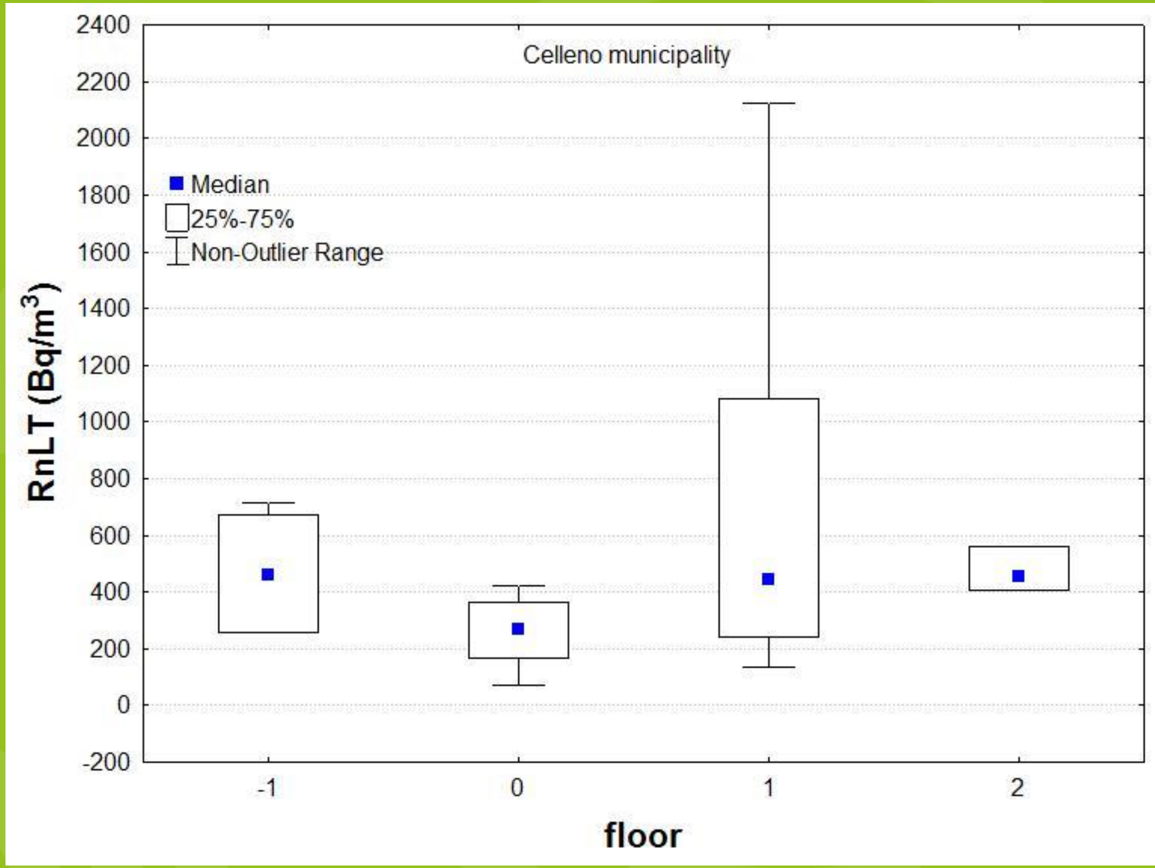
# Long-term survey:
## Radon concentration vs Building material



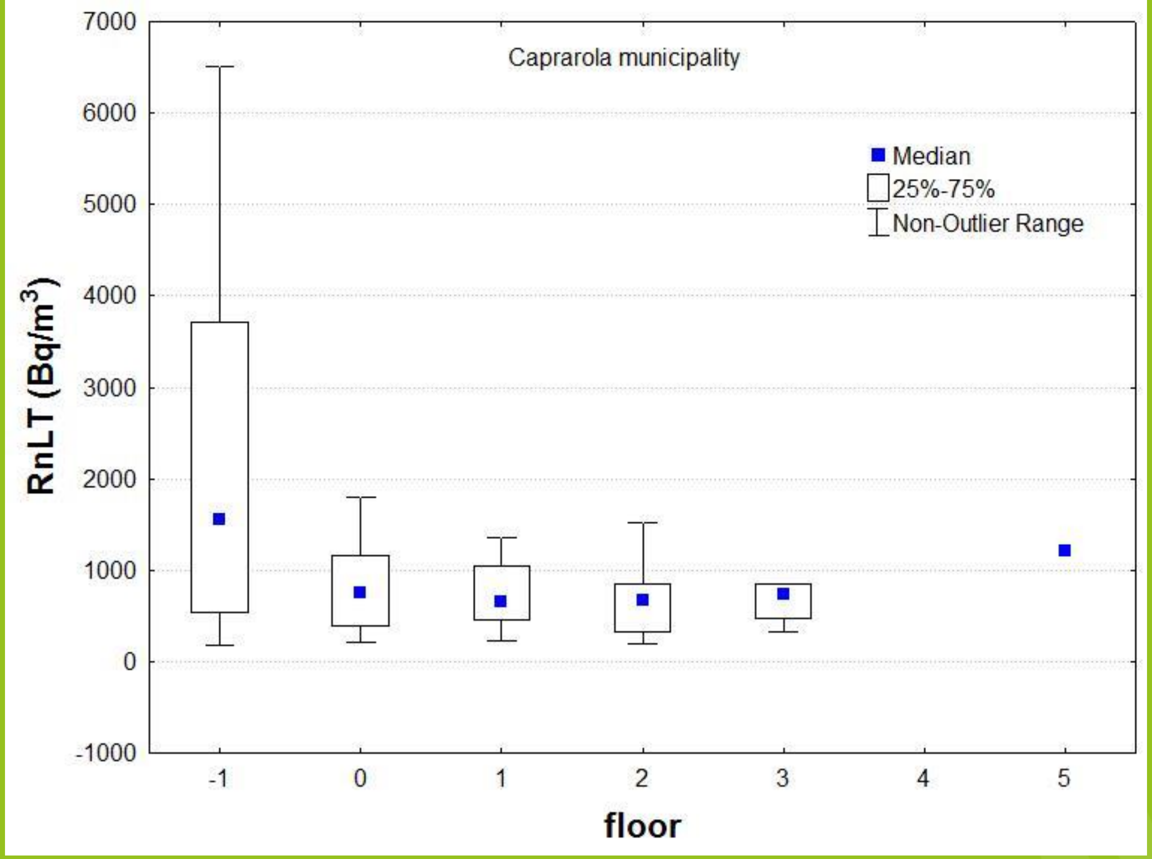



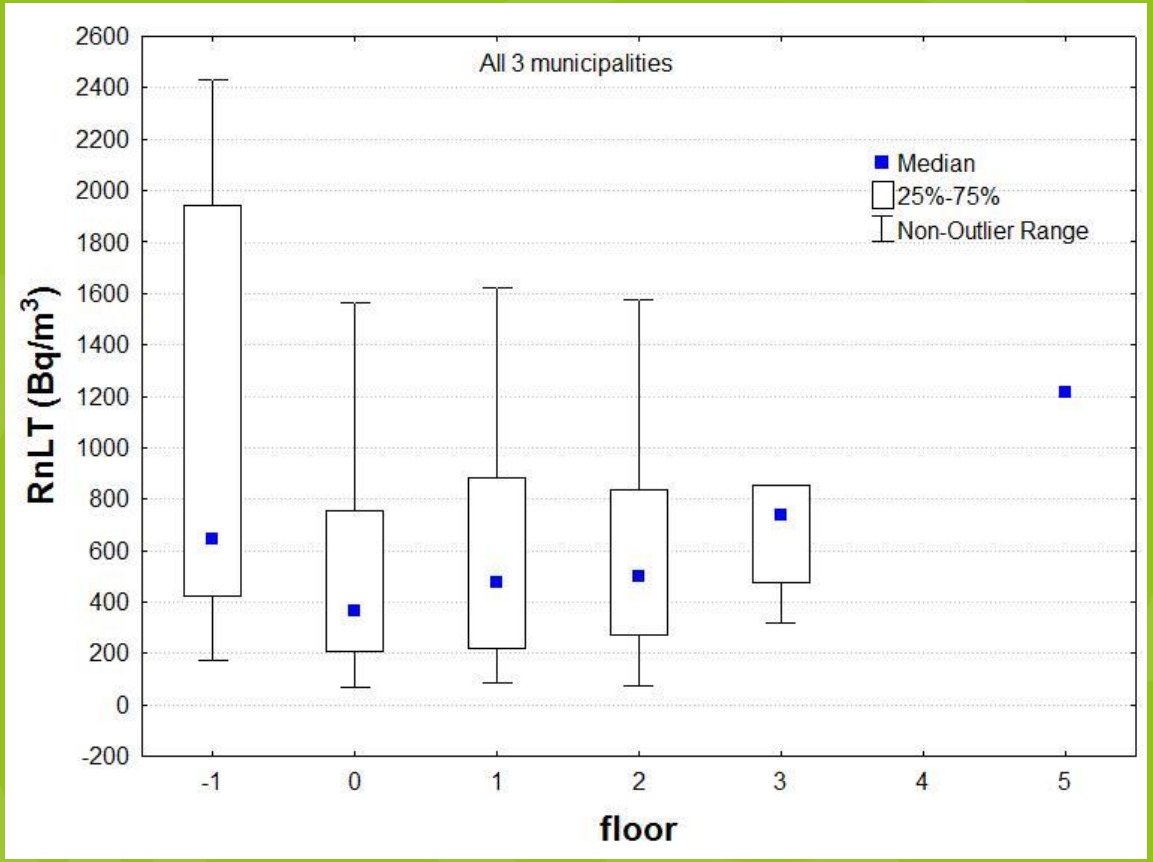
# Long-term survey:
## Radon concentration vs floor



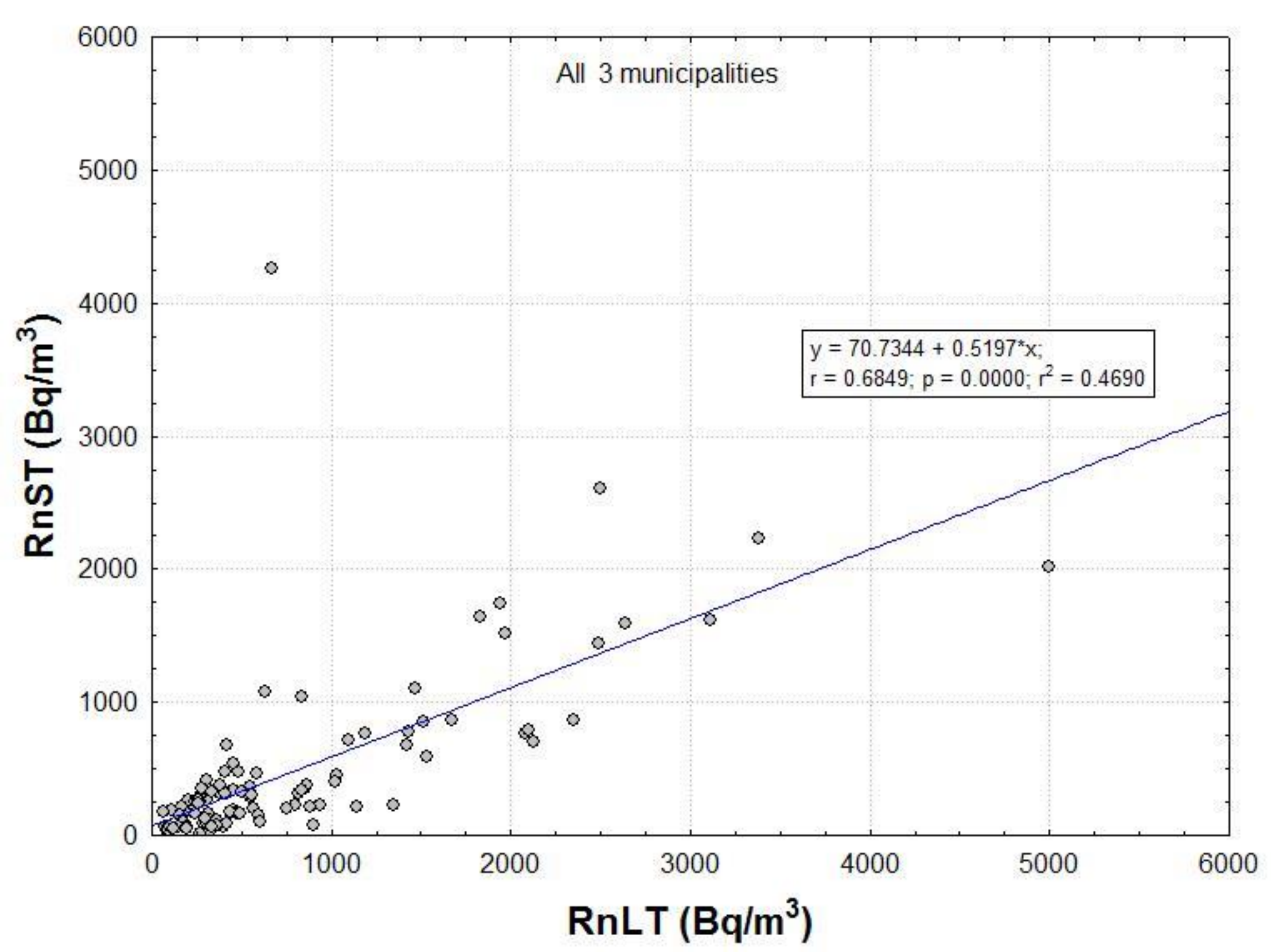
# Long-term survey:
## Radon concentration vs floor



RESPIRE
Radon real time monitoring system

# Short-term vs Long-term

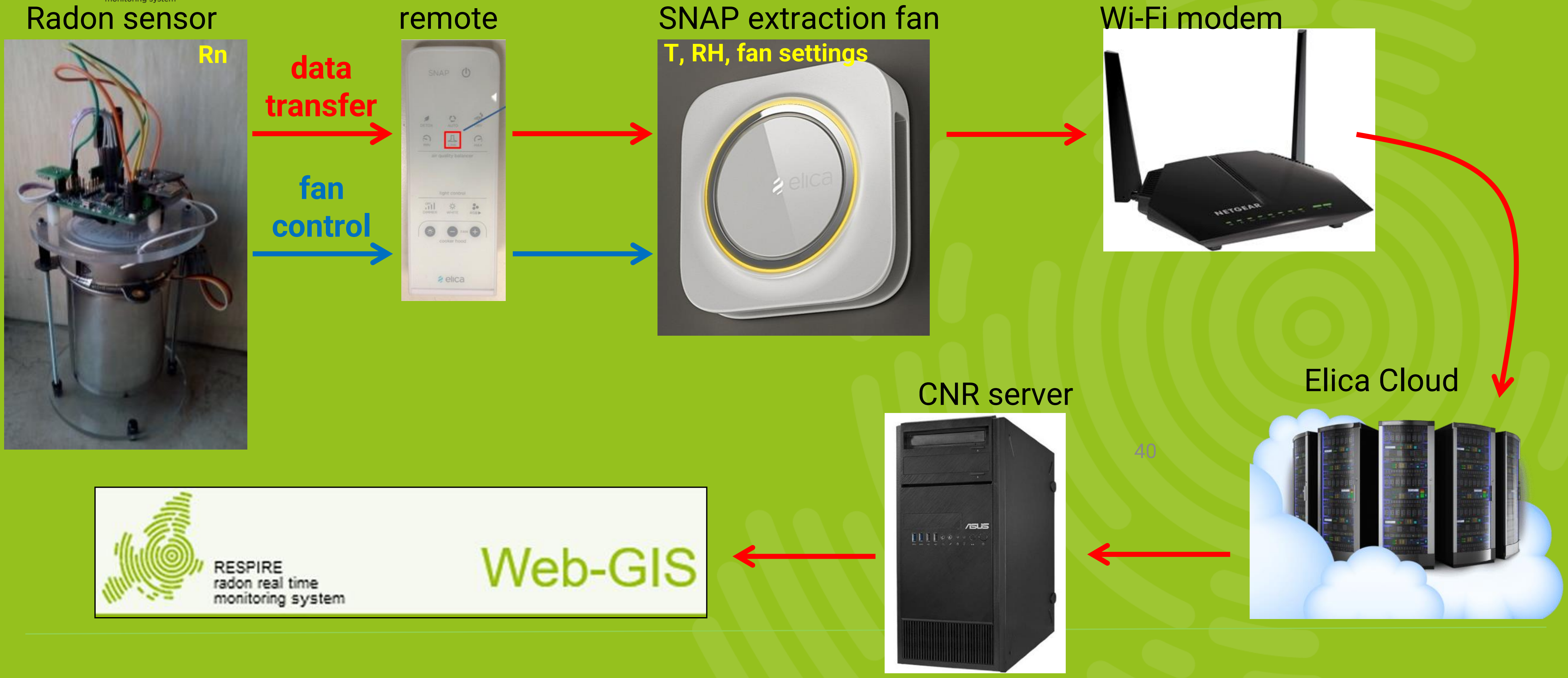


RESPIRE

Radon real time monitoring system

# Respire remediation systems (Action B)

# Version 1 – SNAP Rn



# Version 2 – R3S

RESPIRE
Radon real time

Radon, T, P, RH sensor

Raspberry Pi mini-computer

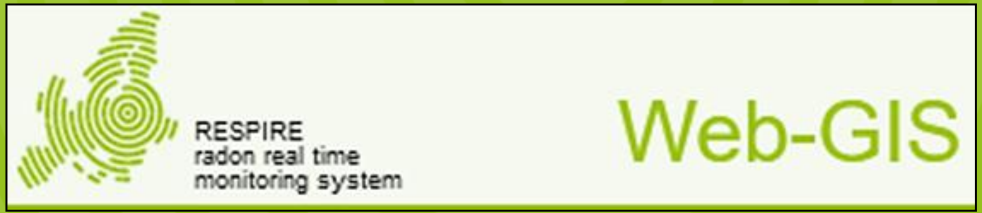
fan control
wireless or cable

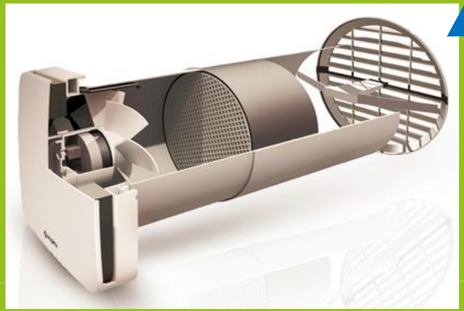
data transfer

data storage

Wi-Fi modem


CNR server

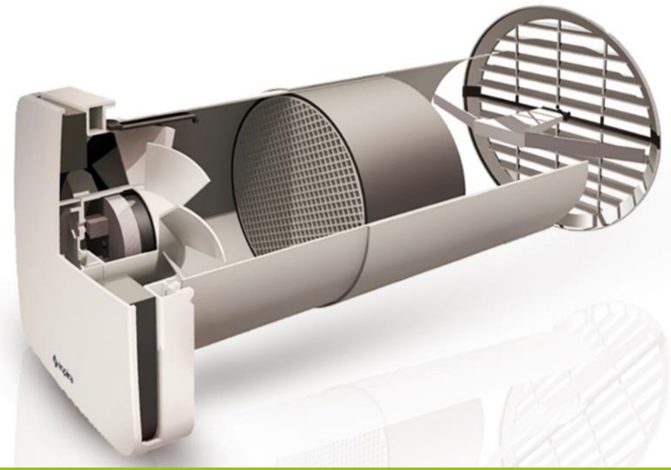



Heat recovery fan


Heat exchange fan

# The others ventilation systems



**<u>Heat recovery systems</u>**. Fan pushes air outside for 70 seconds then pulls air in for 70 seconds. Air is drawn through a porous ceramic cylinder that transfers some heat from exiting to entering air.

•Push-pull approach means fresh air enters only half of the time

•Reported efficiency is high, but can decrease the longer the unit is on

•simple, inexpensive, and compact

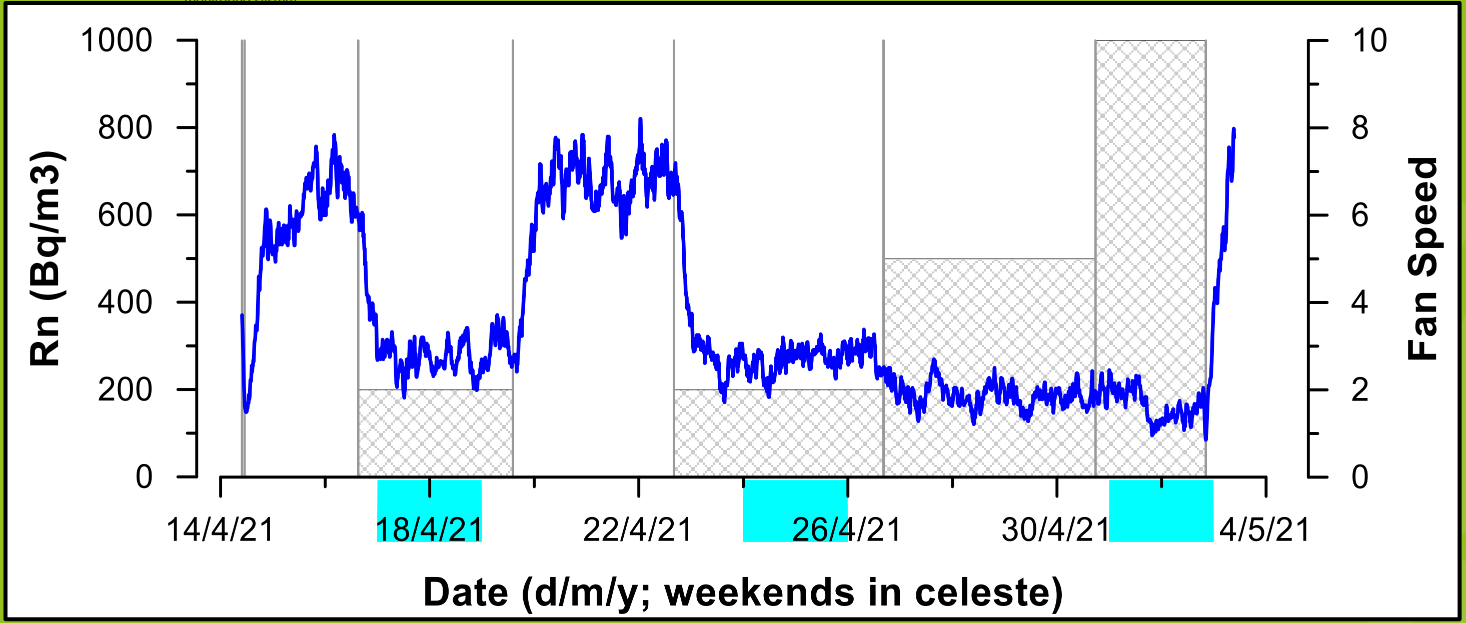
•Low noise

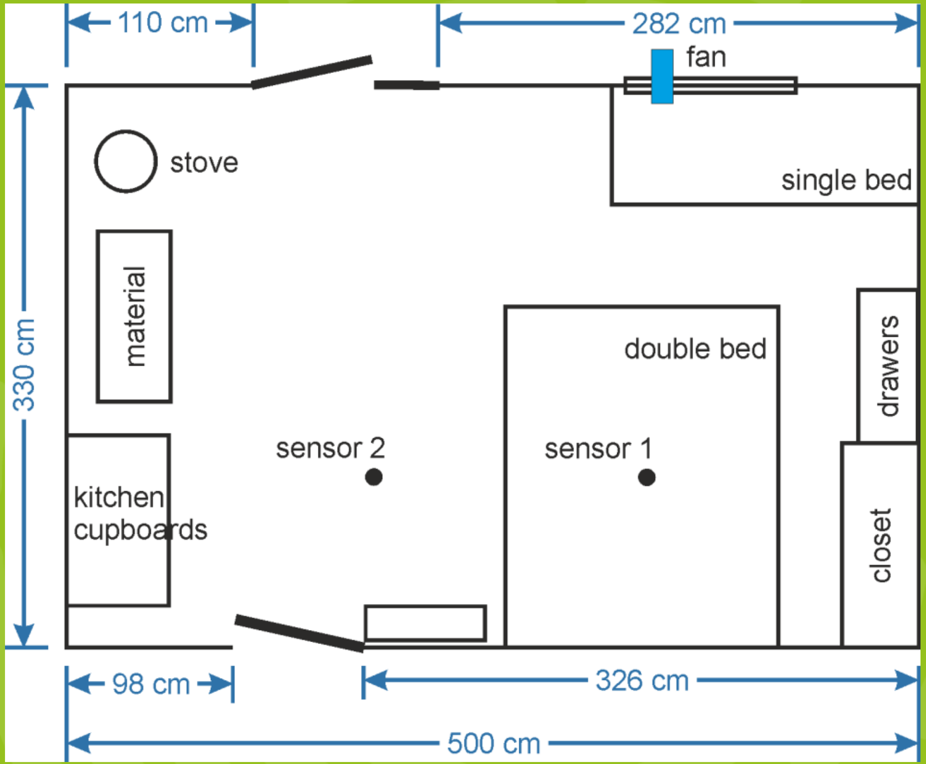
Chosen model: Fantini Cosmi - Ecocomfort 100

- Manual control allows for easier control (no need for remote control codes)
- Slightly smaller diameter than SNAP thus can be installed in the same hole

# Tests – Bassano guest house

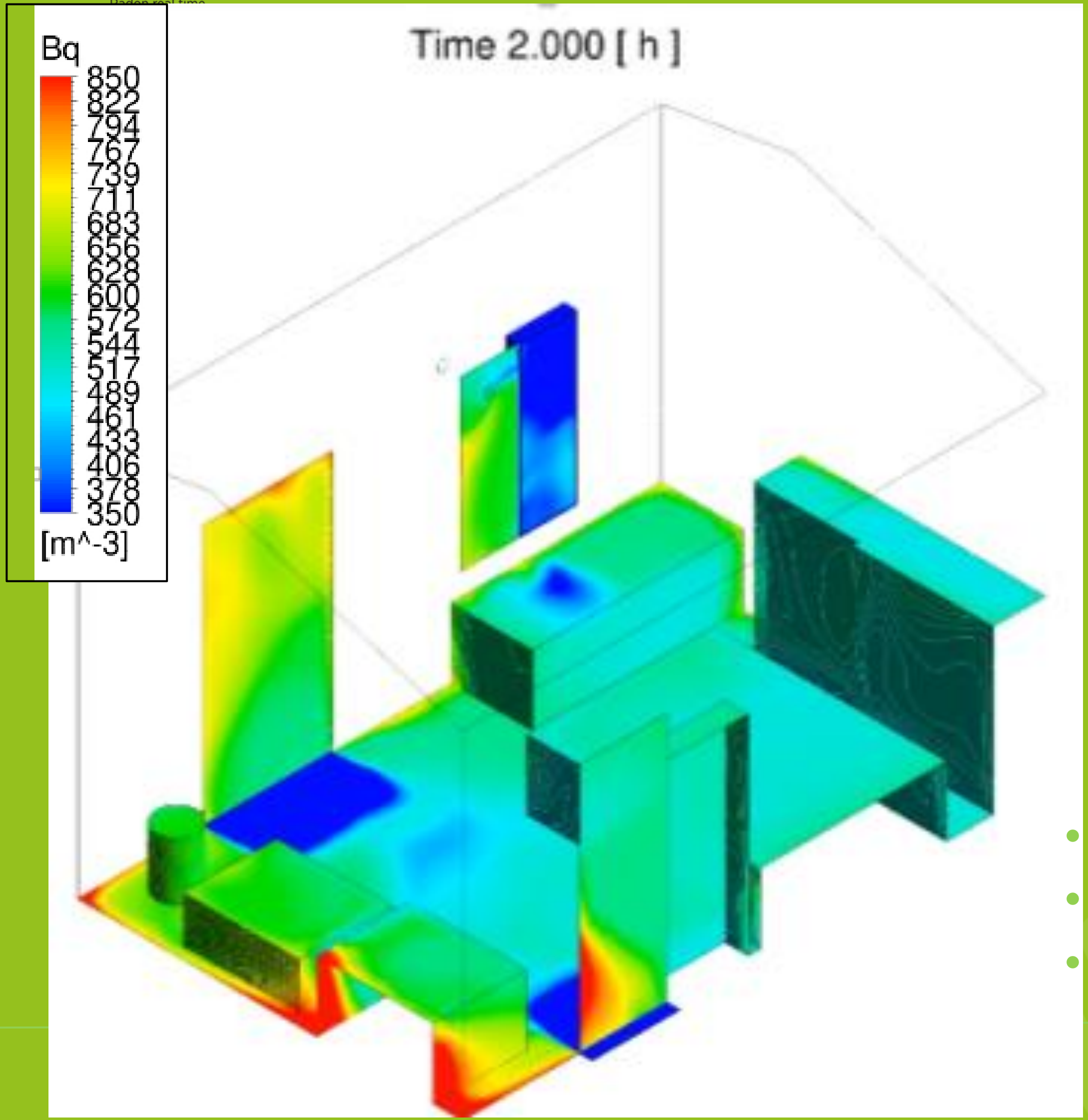
RESPIRE
Radon real time monitoring system

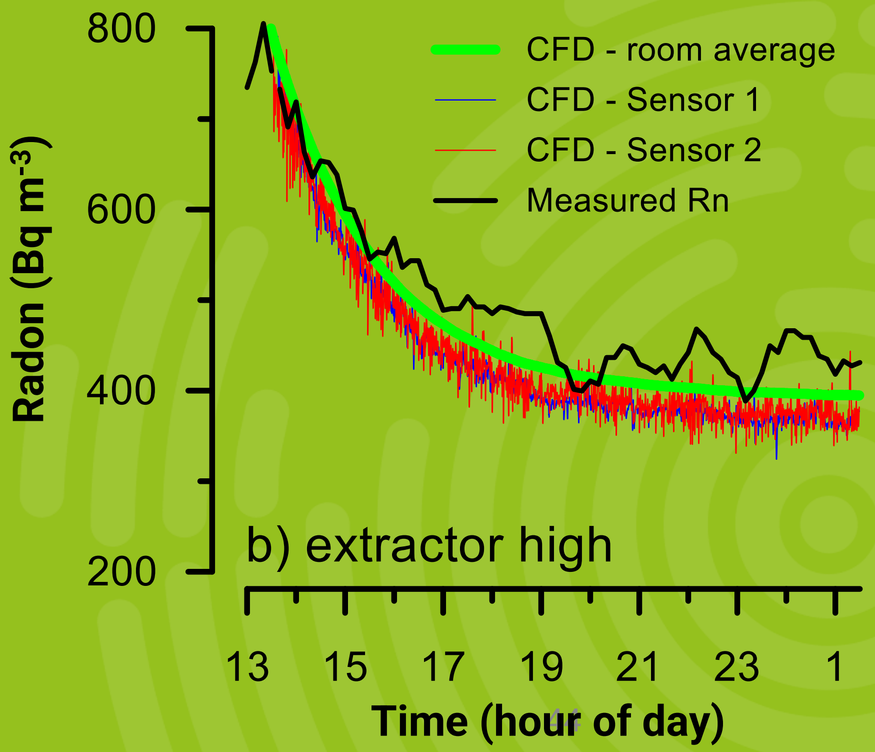



- Simple, closed volume
- Step-wise decrease in Rn, subsequent increase in fan speed has smaller percentage impact

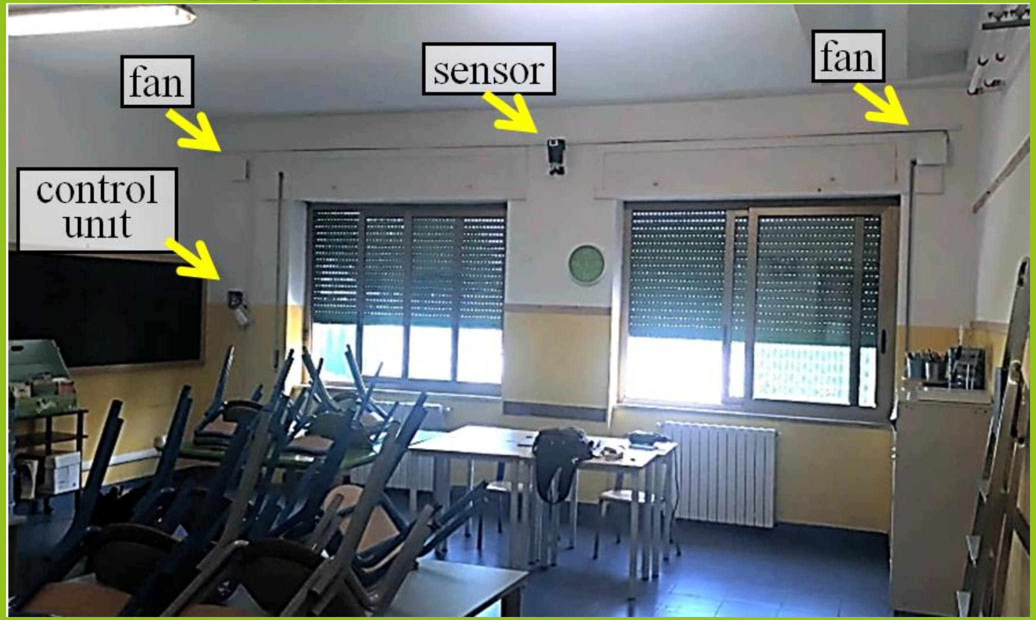
# Simulations – Bassano guest house

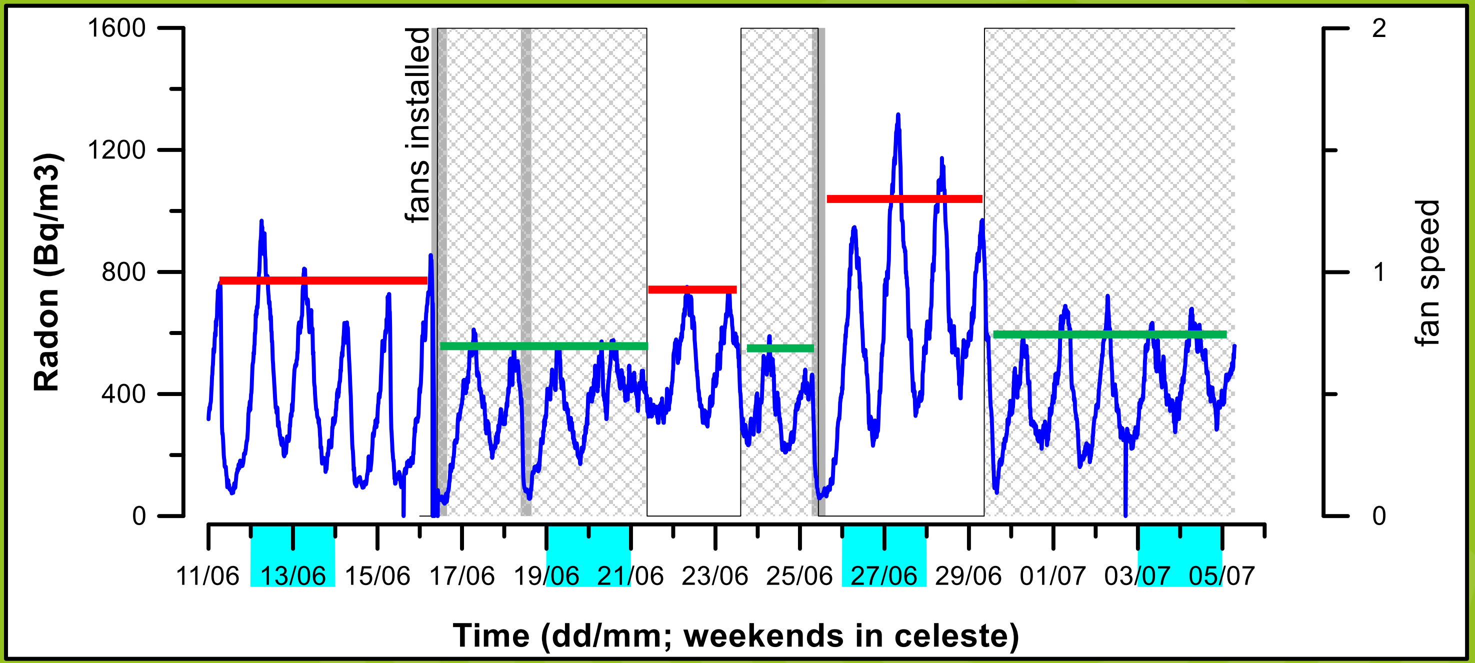


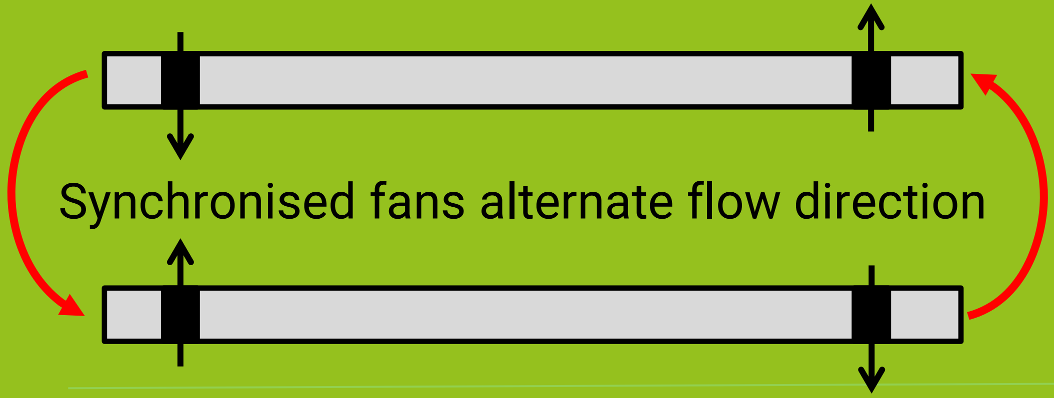




- 3D Computational Fluid Dynamics (CFD) modelling
- Reproduces trend of real data
- Shows areas where flow and mixing is poor

# Tests – Pomezia classroom




- Complex daily variability, fans reduce Rn by 25-50%
- Use of two fans guarantees ingress of clean outdoor air and no under-pressurisation

RESPIRE

Radon real time monitoring system

# Replication and further development

The system keeps the approach to connect a continuous monitoring and a remediation system (that can be activated when Radon values is higher than a threshold).

A better shaping of the ventilation system can improve results keeping this remediation system to a very low impact

The experience in Belgium is presented by Respire partner FANC

# Some conclusions

RESPIRE
Radon real time monitoring system

**The integrated RESPIRE remediation system is able to reduce the average values of indoor Rn concentration when the system is correctly set with respect the dimension of the room/house. The effect due to humidity, the interaction with other spaces of the house / building can mitigate the effect; in other cases they act together in a positive way.**

**The approach of the system that is active only when needed allows to recover ~80% of heat from the air expelled and to reduce energy consumption**

The RESPIRE remediation is at present installed in 24 selected public buildings and 5 private houses of 4 municipalities (Ciampino, Celleno, Caprarola and Pomezia). The real time monitoring is available for Authorities and private citizen via WebGis.

Information and dissemination material integrating field data and modeling results, to inform local authorities with respect to Rn and Rn-prevention measures during remediation activities and new construction. >80% of population at Demonstration sites will be informed about the project and Rn risks.

RESPIRE

Radon real time
monitoring system

Thanks for your attention