FACTORS AFFECTING RESIDENTIAL RADON CONCENTRATION IN ROMANIA

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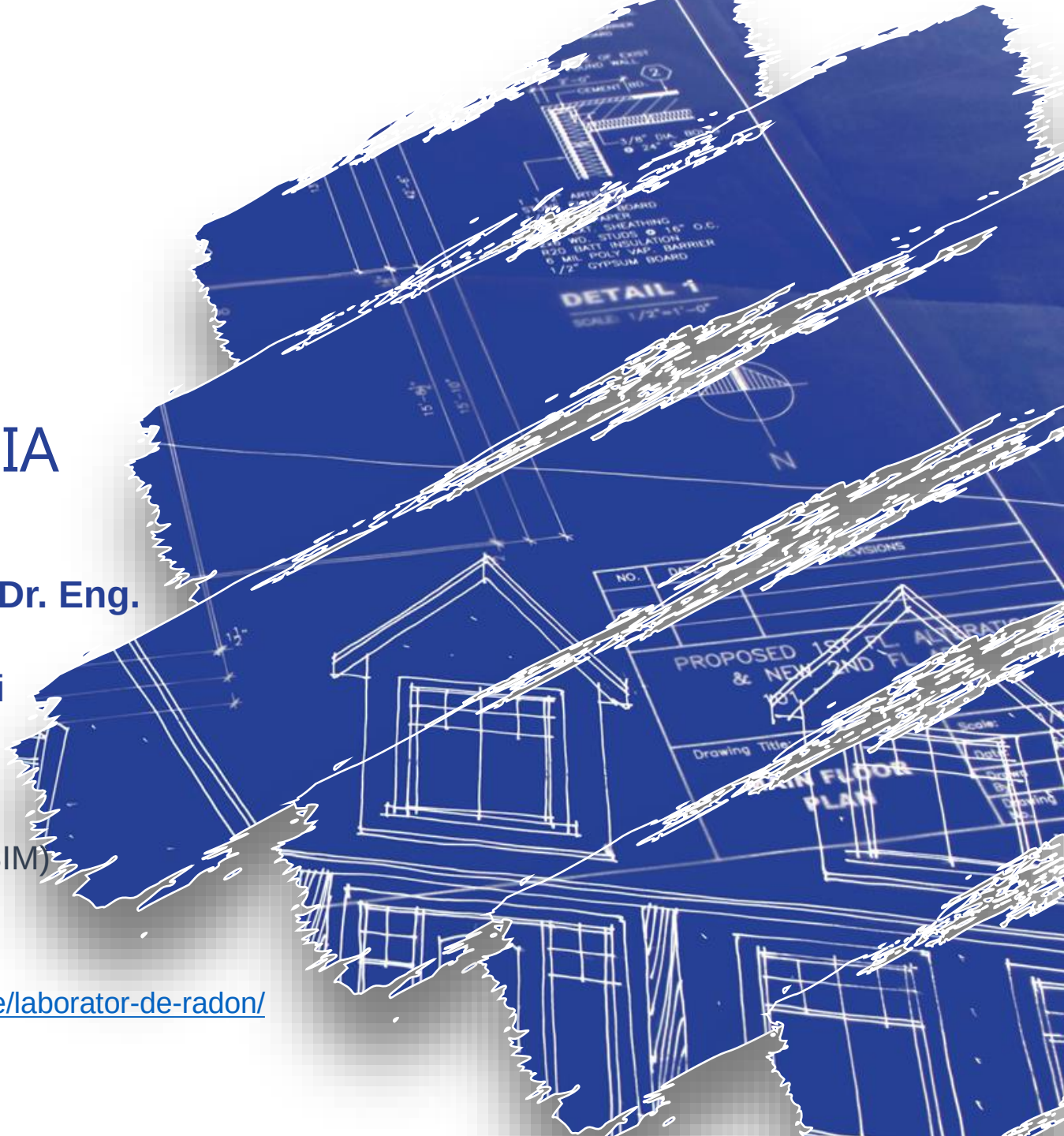


Smart Systems for Public Safety through Control and Mitigation of Residential Radon linked with Energy Efficiency Optimization of Buildings in Romanian Major Urban Agglomerations – SMART-RAD-EN

SmartRADON

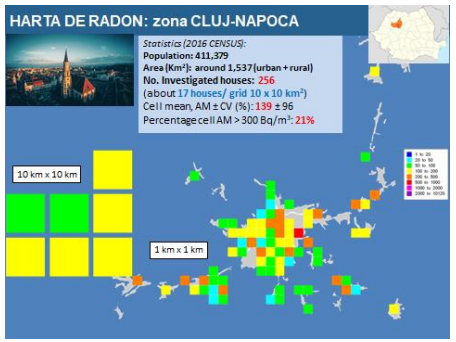
2016-2020 – Budget: 2.000.000 Euro

Manager: Dr. Alexandra Cucoş Dinu

Scientific/ Technical coordinators: prof. C. Sainz, Dr. T. Dicu

General Objective: Improve the Indoor Air Quality in houses with energy saving systems, thus contributing to increase the safety and health of the population. URBAN APPROACH: Bucuresti, Cluj Napoca, Iasi, Sibiu and Timisoara

Based on innovative scientific research



Smart Rad_En Project

ICA INNOVATIVE PROTOTYPE

Innovative prototype (ICA) monitoring system to control indoor air quality (Radon, CO2, CO, VOC, temperature, pressure, humidity) with remote data transmission,

National development, International testing, validation and certification

Additionally, a novel application was also developed for the continuous analysis of the data sets provided by ICA and the control of radon mitigation system.

During the project, the implementation of radon mitigation solutions and the integration with ICA prototype were completed at **100 houses participating in the project**.

2023 At present - ICA Prototype studies

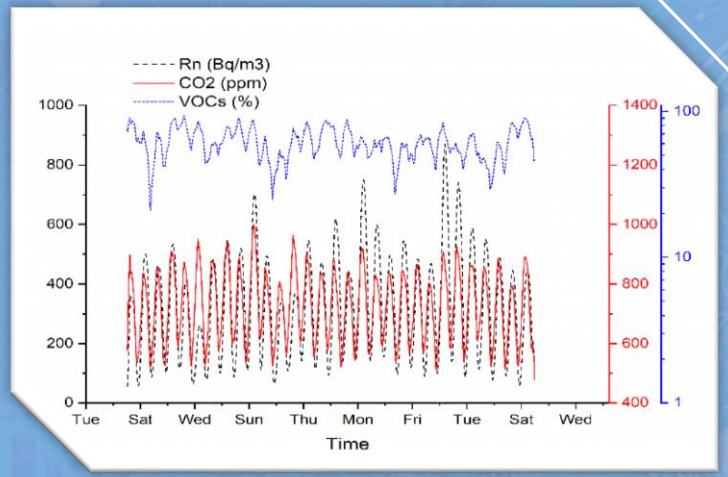
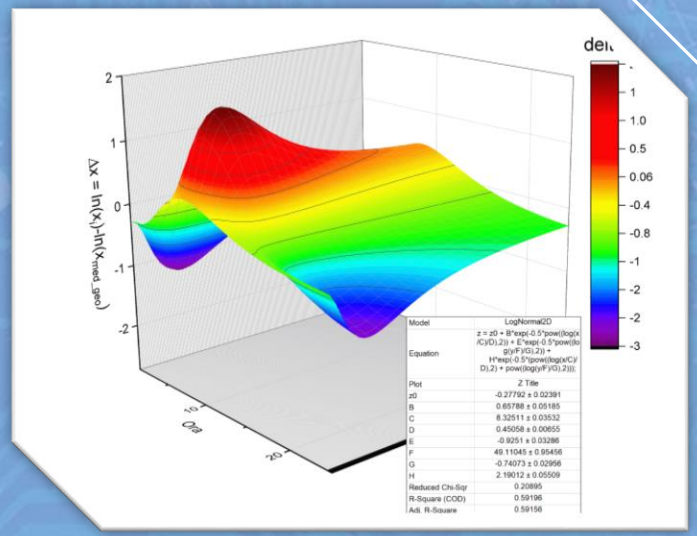
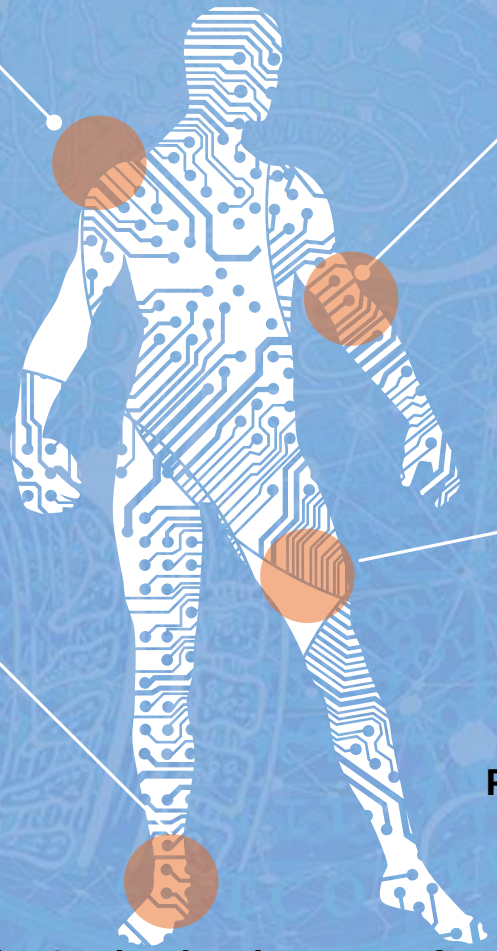


Fig. 1. *Time series for radon, CO_2 and VOC*





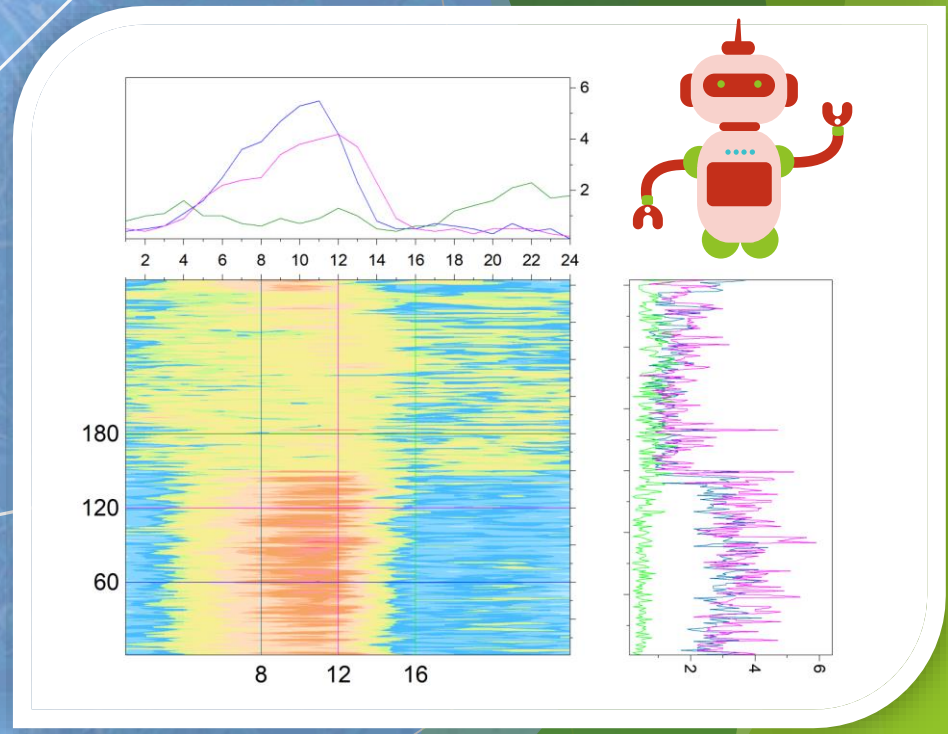


Fig. 2. *Establishing a "heatmap" for identification "hot" periods from the perspective of the analyzed polluter*

Fig. 3. *The development of mathematical models for predicting the evolution of the pollutant and anticipating periods with high concentrations*

Intelligent Indoor Air Quality Monitoring System - ICA

- Radon, CO2, CO, VOC, Temperature, Pressure, Humidity
- Online Monitoring Platform
- Compatible with Smart House/Office
- Validated Solution - Smart Health 2019 Award + PATENT

Design of survey

To complete INDOOR RADON MAP

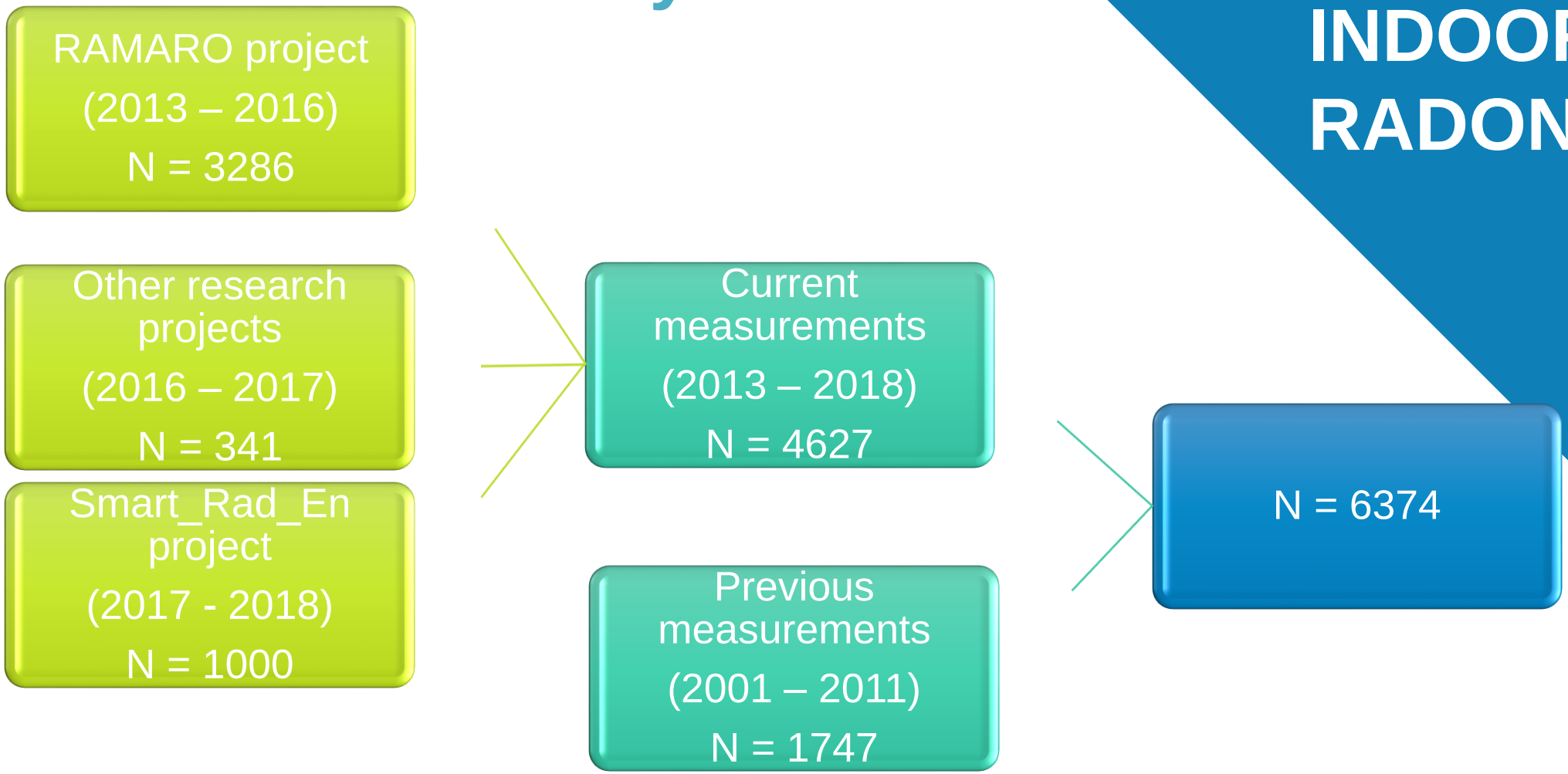
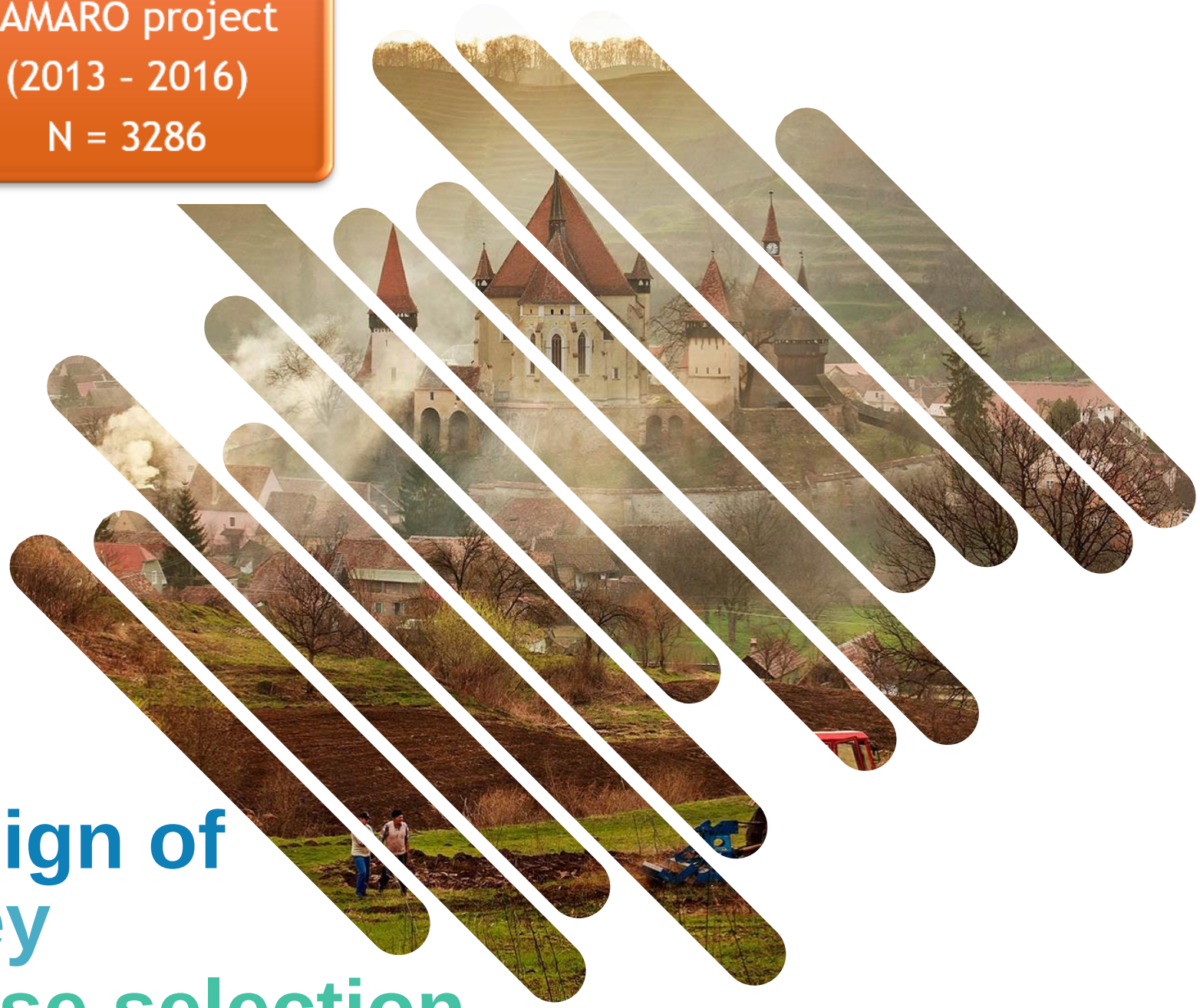


Fig. 4. The main monitoring campaigns for indoor radon measurements in Romania

The RAMARO project (n = 3286) aimed for systematic radon measurements in indoor air, soil, and water samples in 16 Romanian counties. The methodology used in RAMARO project involved 5 indoor radon determinations, 3 measurements of radon in soil and 3 radon measurements in water samples in each inhabited cell of an area of 10 × 10 km.

RAMARO project
(2013 - 2016)
N = 3286



No geological stratification was considered for the mentioned radon measurements. In cities with high density of population, the number of measurements increased to 15-20 per grid cell to be representative of the surveyed region.

Design of survey house selection

Design of survey and house selection

Within **SMART_RAD_EN project**, a detailed screening was carried out in 5 urban agglomerations in Romania (Bucureşti, Cluj-Napoca, Iaşi, Sibiu and Timişoara).

For data acquisition, the house selection methodology included different strategies as follows:

- **the use of previous databases**, referral-based approach by neighbors/friends,
- **door-to-door methodology** of detectors distribution,
- the use of **on-line campaigns** and the recruitment of volunteers on the project webpage.

Smart_Rad_En project
(2017 - 2018)
N = 1000

- From the efficiency perspective, the first two allowed more than 85% of the projected measurements (n = 1000), the most inefficient and time-consuming approach being the door-to-door approach.

Indoor radon measurements

- All indoor radon measurements were performed by using CR-39 track detectors (Radosys Ltd., Hungary)
- **RAMARO project** the detectors **were exposed for 3 to 6 months**. As such, temporal correction factors were applied to estimate the annual indoor radon concentration
- **SMART_RAD_EN project**, the detectors were placed in **two successive campaigns of 6 months each**, which allowed direct calculation of the annual indoor radon activity concentration
- In the case of those recovered by the research team, **the recovery rate was approximately 97%**, while in the case of the detectors sent by mail by the homeowners approximately 10% of the exposed detectors were lost.

Results - global analysis of IRC

- Range: 10 – 3653 Bq/m^3
- AM = 181 Bq/m^3
- GM = 121 Bq/m^3, GSD = 2.4 Bq/m^3
- 58% of the monitored buildings > 100 Bq/m^3
- 15% of the monitored buildings > 300 Bq/m^3

- D'Agostino-Pearson test applied on the log-transformed data confirms the normal distribution of the indoor radon concentrations

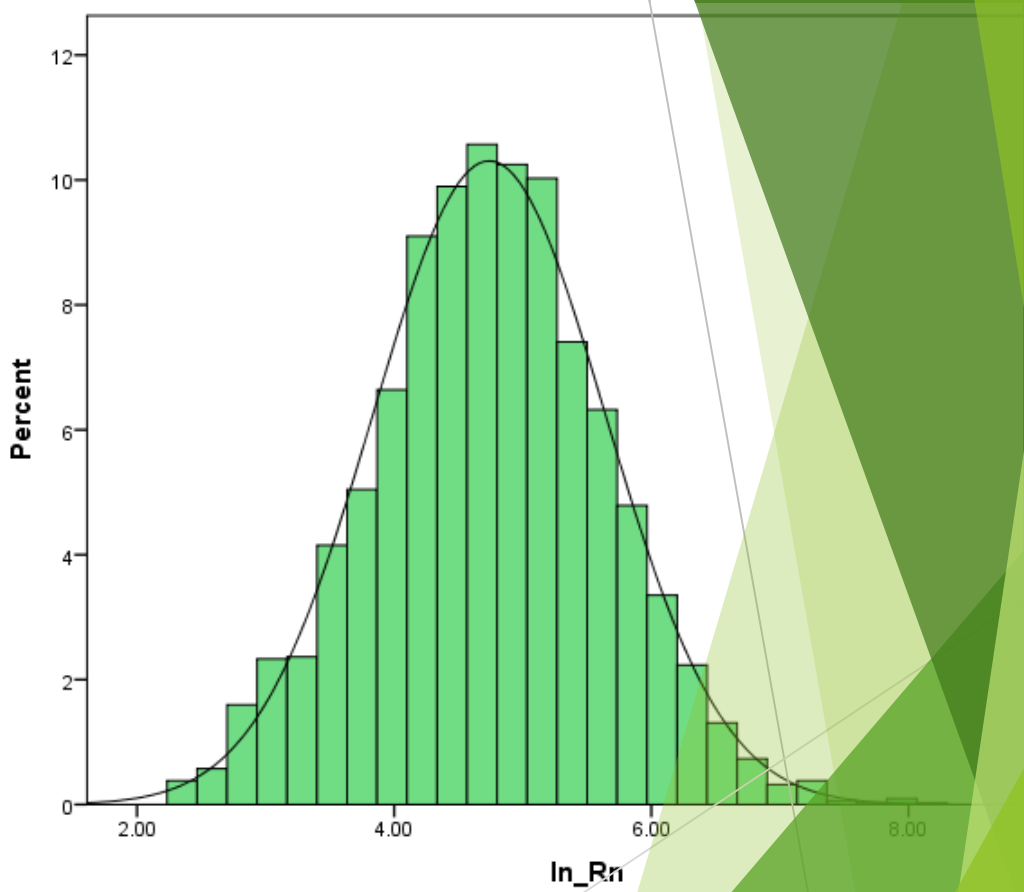


Fig. 5. The normal distribution of log-transformed data

Results-construction characteristics impact on IRC(1)

Table 1. Descriptive statistics on the impact of the investigated parameters from the construction feature on the indoor radon activity concentrations (Bq/m³)

Characteristic	Description	Median	GM (GSD)	p
Study area	Rural	114	112 (2.39)	<0.01
	Urban	101	106 (2.30)	
Construction period	Before 1941	128	125 (2.33)	
	1941 - 1962	133	129 (2.31)	<0.001
	1963 - 1977	128	122 (2.47)	
	1978 - 1991	100	99 (2.36)	
	1992 - 2006	90	91 (2.34)	
	After 2006	82	85 (2.09)	
Cellar under investigated room	Yes	88	87 (2.29)	<0.001
	No	115	115 (2.35)	
Concrete slab under the floor	Yes	110	110 (2.39)	0.01

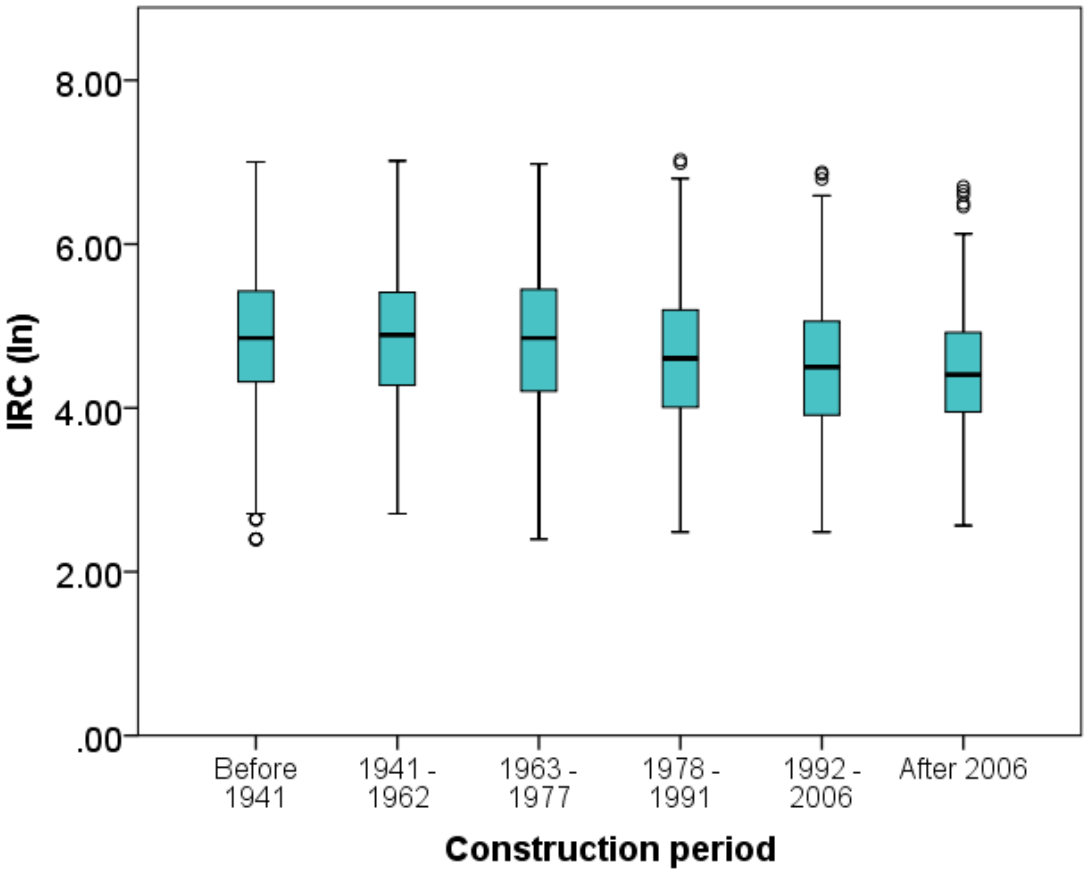


Fig. 6. The impact of the construction period on IRC

Results - construction characteristics impact on IRC (2)

Table 2. Descriptive statistics on the impact of the investigated parameters from the construction features on the indoor radon activity concentrations (Bq/m³)

Characteristic	Description	Median	GM (GSD)	p
Floor type	Tiles	95	95 (2.41)	<0.001
	Parquet	104	106 (2.34)	
	Wood	124	123 (2.32)	
Window type	Traditional	106	106 (2.34)	0.10
	Thermo-isolated	112	112 (2.36)	
Main construction material	Wood	73	77 (2.44)	<0.001
	Bricks	109	110 (2.33)	
	Adobe	154	143 (2.35)	
Room type	Kitchen	103	103 (2.44)	
	Living	103	105 (2.32)	<0.01
	Bedroom	116	115 (2.35)	

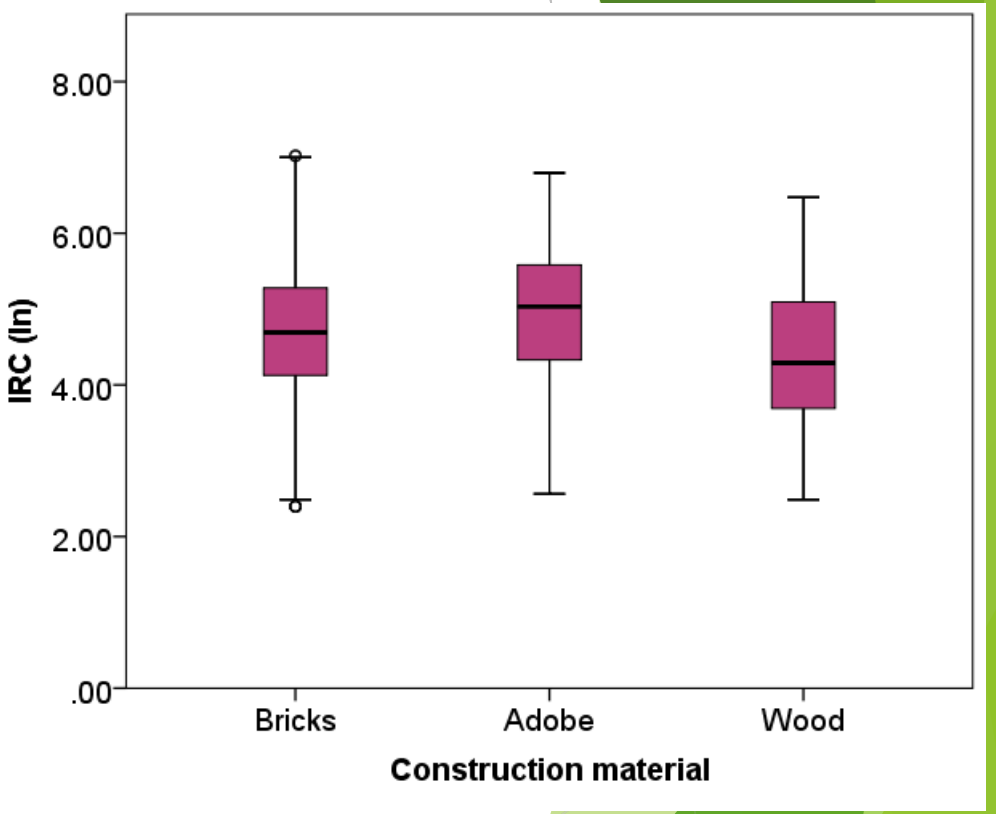
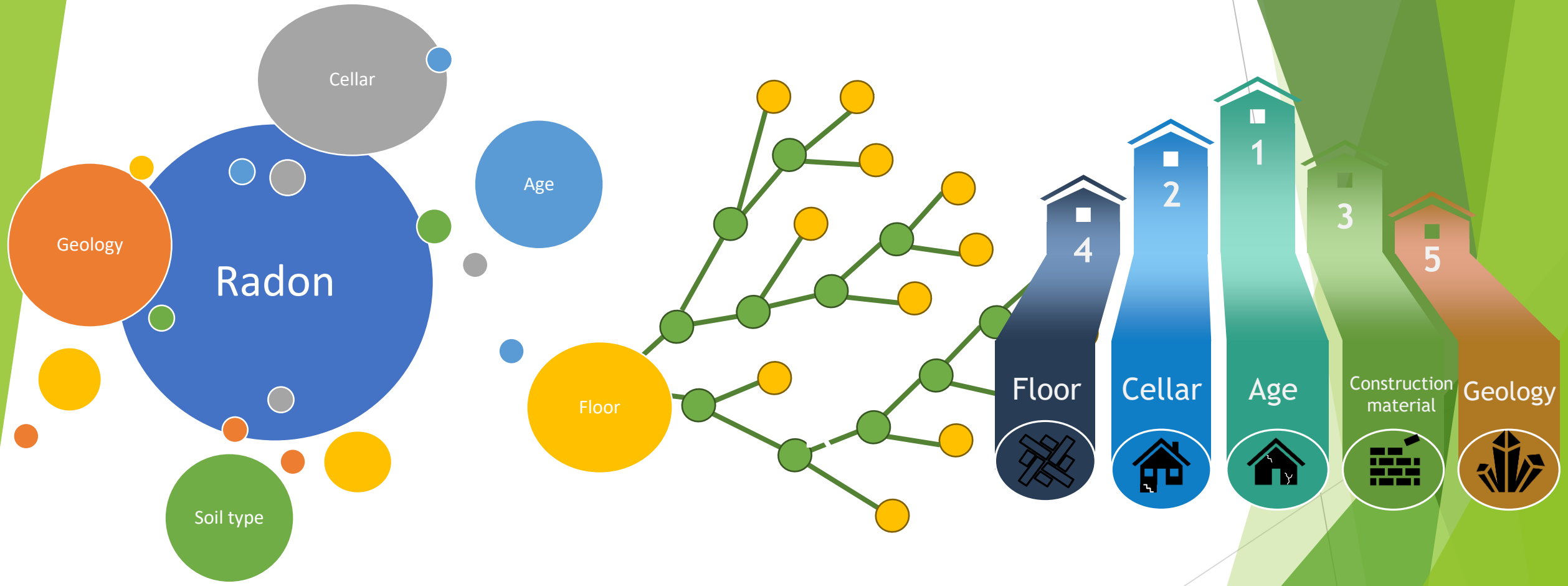


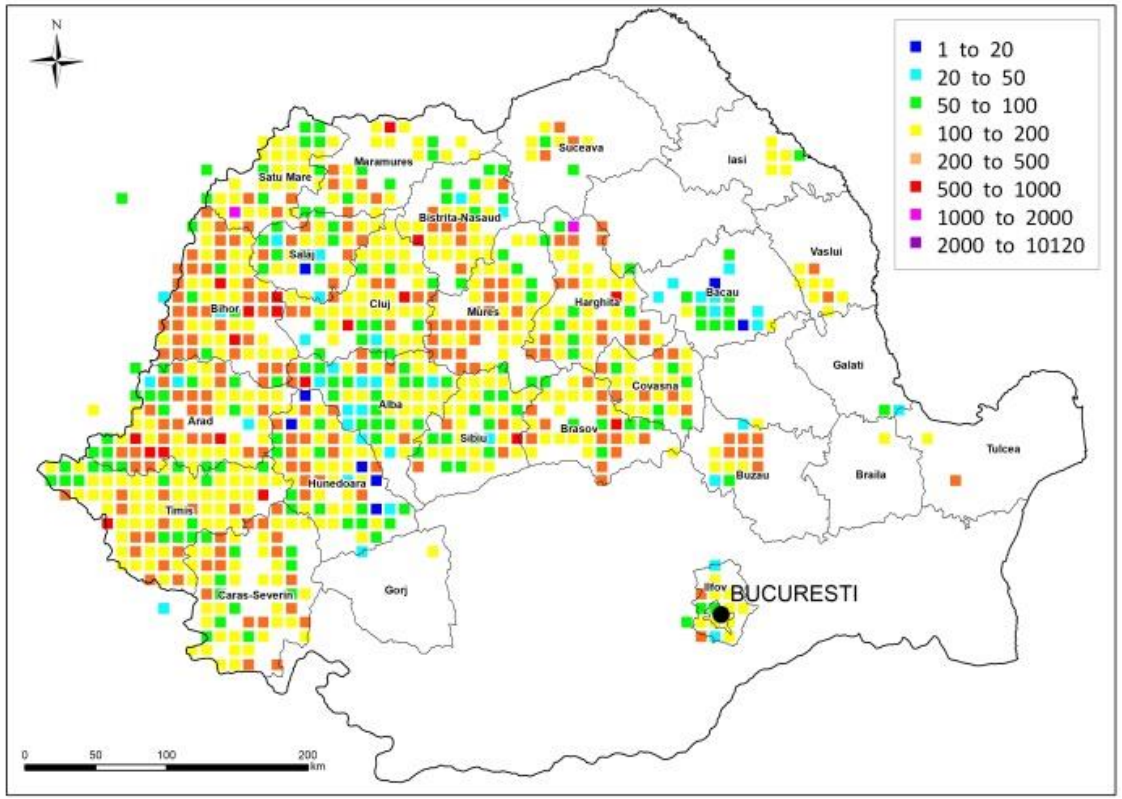
Fig. 7. The impact of the construction material on IRC

Results – multivariate analysis



By applying **multivariate linear regression**, a coefficient of determination of 9% was obtained, the main contributors being the **age of the building**, the **presence of the cellar** under the house, the **construction material**, the **type of floor** and **geology.**

Indoor radon map – Romania (1)



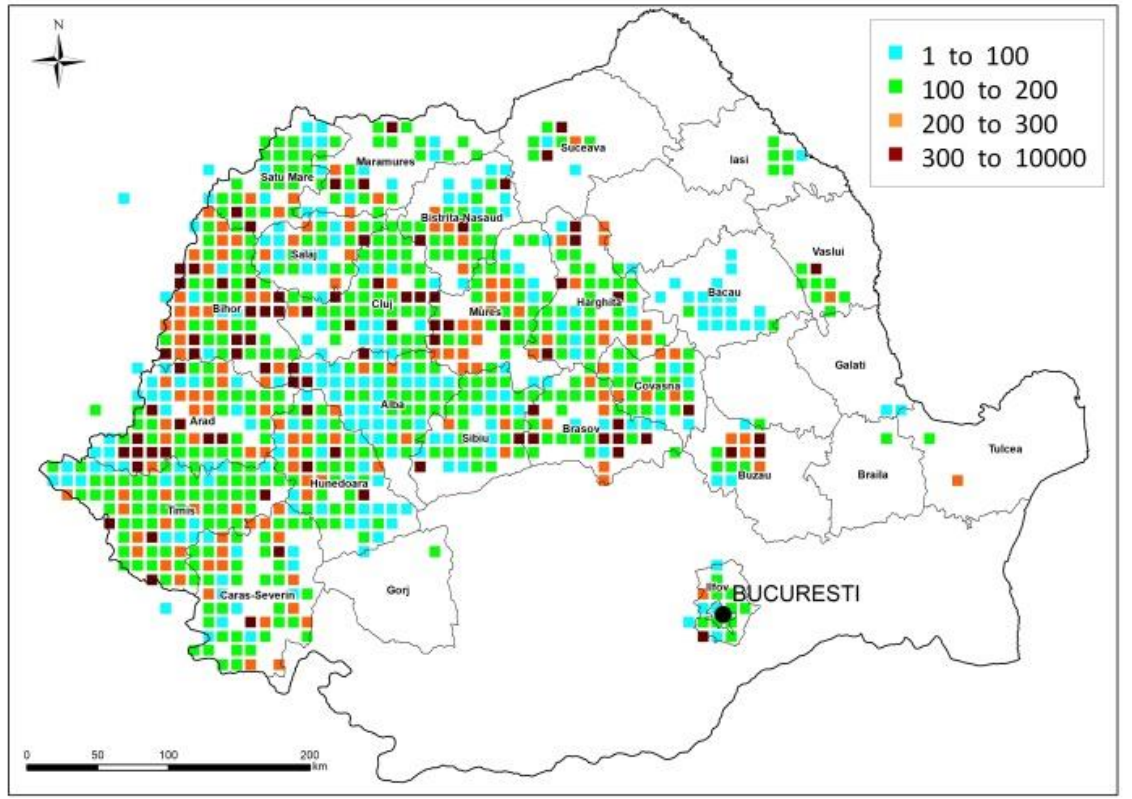


Fig. 8. Average concentration per each 10 × 10 km grid cell for indoor radon in Romania according to: (a) the thresholds provided by the JRC, (b) the thresholds of 100 and 300 Bq/m^3, respectively.

Indoor radon map – Romania (2)

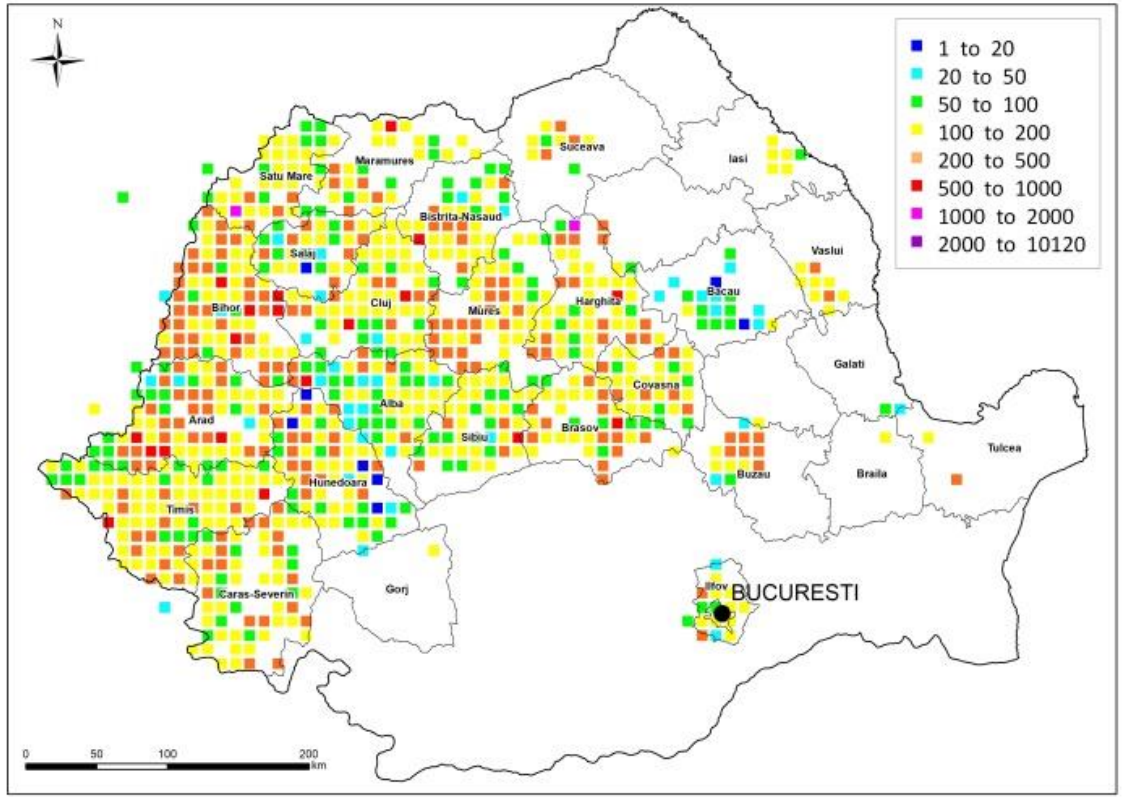
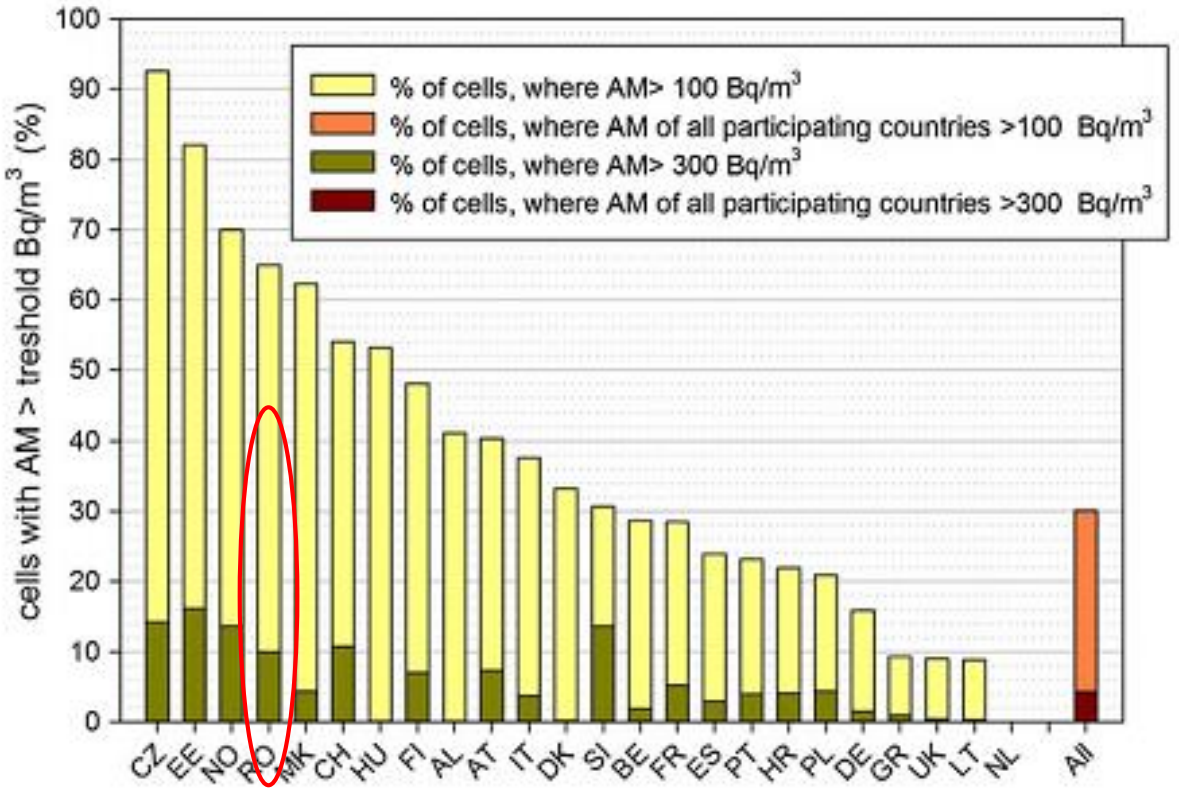


Fig. 9. Average concentration per each 10 × 10 km grid cell for indoor radon in Romania according to the thresholds provided by the JRC

- 6374 measurements which filled 878 inhabited cells of 10 x 10 km
- 44% of Romanian teritory
- Average number of measurement: 4
- Min/max: 1/426

- **> 100 Bq/m³**: 653 cells (**75%**)
- **> 300 Bq/m³**: 85 cells (**10%**)

Comparison: European Indoor Radon Map



The percentage of cells with an area of 10 x 10 km that exceed the reference thresholds, depending on the country, (100, resp. 300 Bq/m³) Joint Research Center(JRC) European Commission (CE) (Tollefsen et al., 2014).

Romania (2020)

AM ± CV (%): 181 ± 76 Bq/m³

Median: 148 Bq/m³

Percentage of cells with AM > 300 Bq/m³: 10%

Percentage of cells with AM > 100 Bq/m³: 75%

Europa (2019)

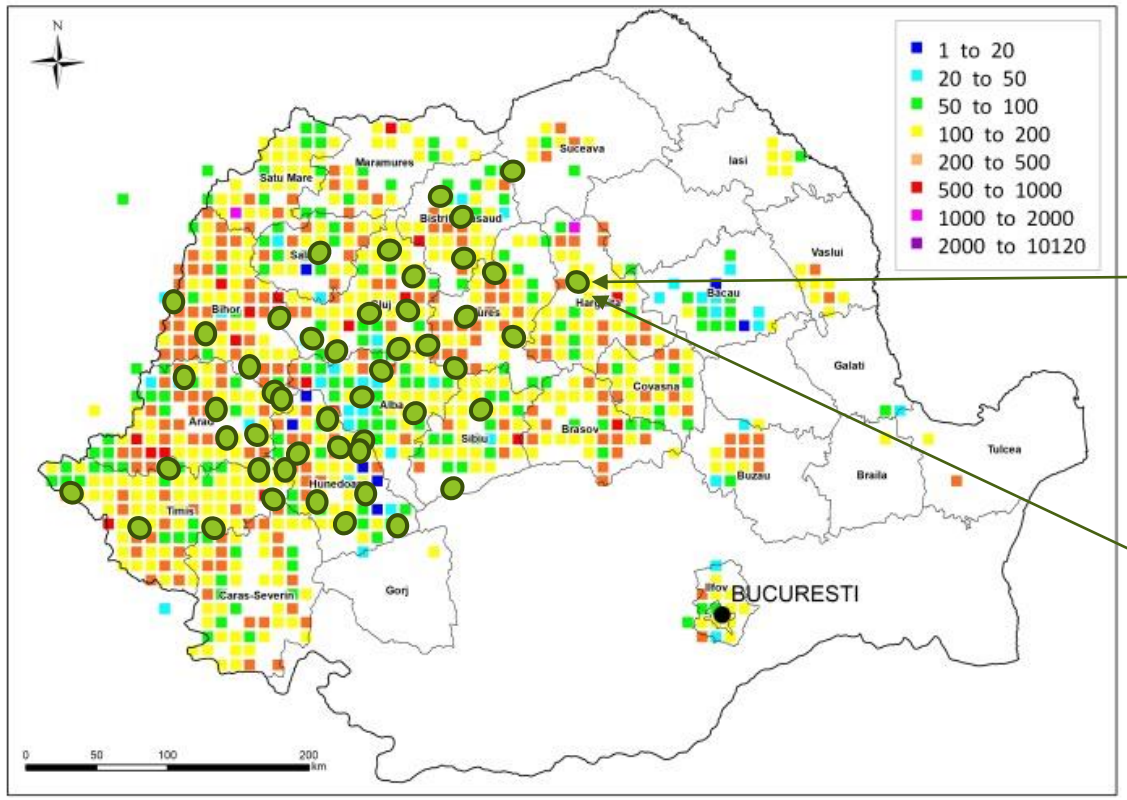
AM ± CV (%): 103 ± 138 Bq/m³

Median: 60 Bq/m³

Percentage of cells with AM > 300 Bq/m³: 4,24 %

Percentage of cells with AM > 100 Bq/m³: 34,1 %

Indoor radon map – Romania (3)



Current measurements (2013 - 2018) N = 4627

Previous measurements (2001 - 2011) N = 1747

N = 6374

Only in 75 cells, out of the total of 878 completed cells, the radon measurements were carried out in both campaign: ***"Previous measurements"*** and ***"Current measurements"***.

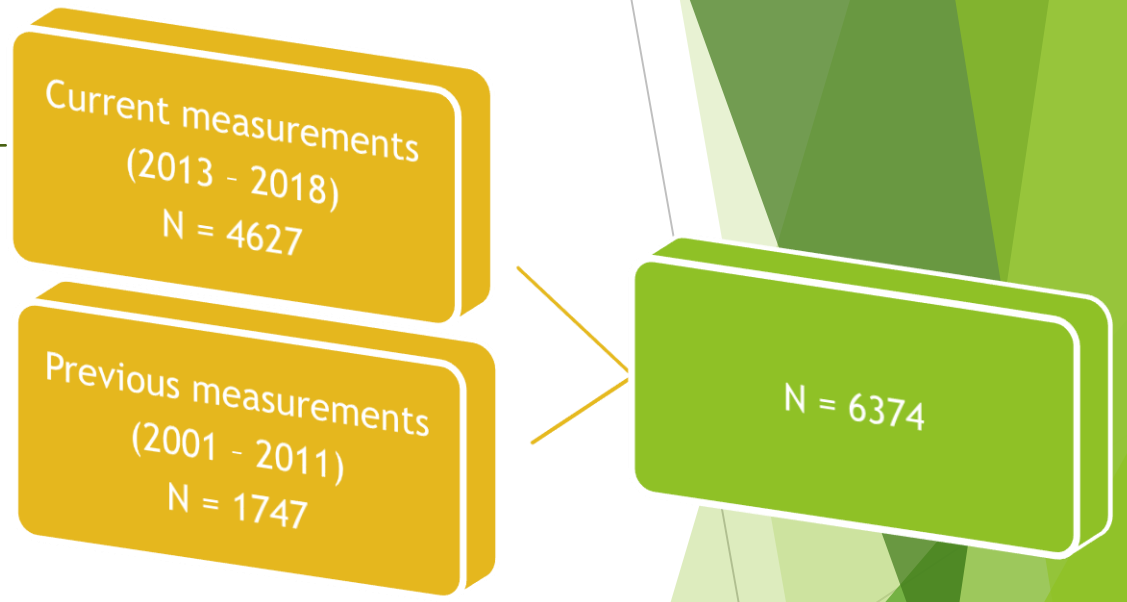
Indoor radon map – Romania (3)

This result indicates the consistency of the campaigns conducted over time in Romania regarding the assessment of indoor radon concentration

GM current measurements:
148 Bq/m³

GM previous measurements:
130 Bq/m³

by applying the t test on pairwise samples there was no statistically significant difference



Out of the total of 878 completed cells, only in 75 cells, the radon measurements were carried out in both campaign: "Previous measurements" and "Current measurements".

Conclusion

Approximately 18 % of the dwellings in ROMANIA exceeded the reference level of 300 Bq/m^3.

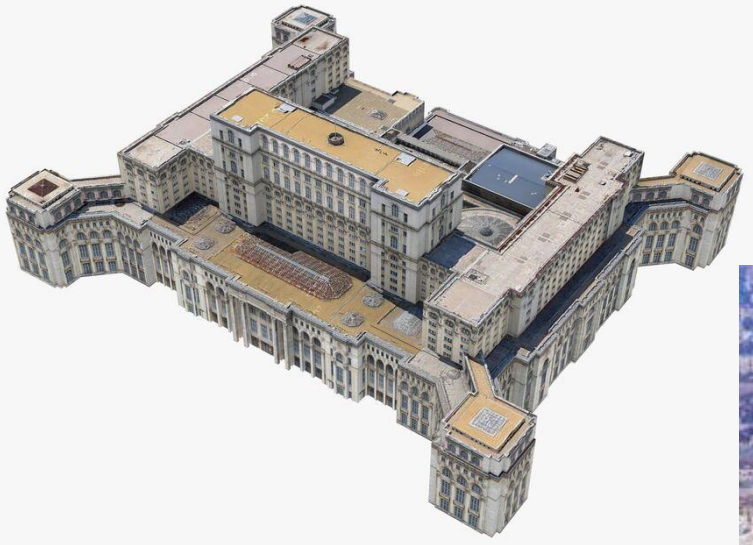
Ten variables were used, one related to **lithology**, one to **pedology**, one indicating the location of the house in relation to sea level and **7 related to the characteristics of the house**.

The **multivariate linear regression** identified the **age of the building**, the presence of the **cellar** under the house, **the construction material**, the **type of floor** and **geology** as the *primary predictors for IRC*.

Radon levels were found to be higher in older dwellings constructed with adobe material, having wooden flooring, thermo-insulated windows, and lacking a cellar beneath the investigated room.

According to the results, **the majority of the predictors were not emphasized**.
By integrating additional data, related to soil permeability, uranium content, weather conditions, and resident behavior, to name a few explanatory variables, the prediction models could be enhanced.

Ongoing Projects



- Exhaustive project on the **Radon Pollution investigation at The Palace of the Parliament and the Government of Romania - 2023**
- Evaluation of the INDOOR Air Quality Index and proposal of a management program for main indoor air pollutants - Radon, Co2, VOC

LiRaCC

RADON MEASUREMENT CERTIFIED LABORATORY
20 YEARS EXPERIENCE

THANK YOU

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