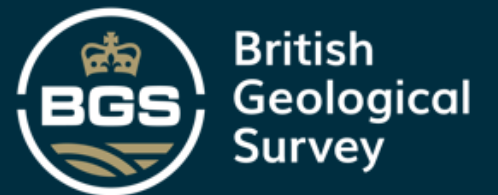




ANTONIO FERREIRA

# RADON, A SILENT GEOHAZARD



Geological Society – West Midlands Regional Group, Online Talk, 8<sup>th</sup> November 2022



# **1. What is Radon**

**2. Why is Radon a radiologic health concern**

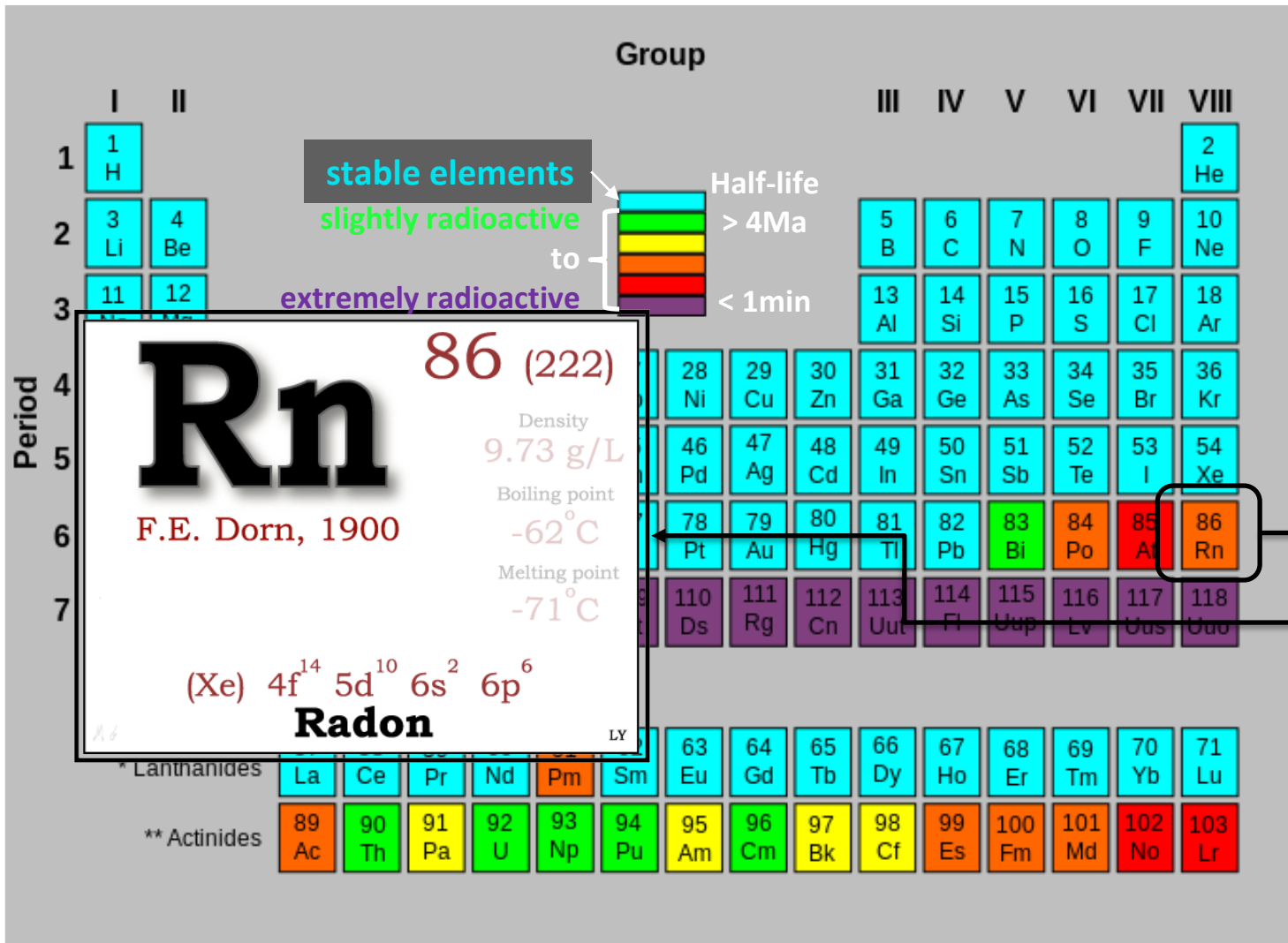
**3. Radon mapping by the UKHSA & BGS**

**4. Current options to reduce Radon levels in homes**

**5. Radon in the West Midlands**



# What is Radon?

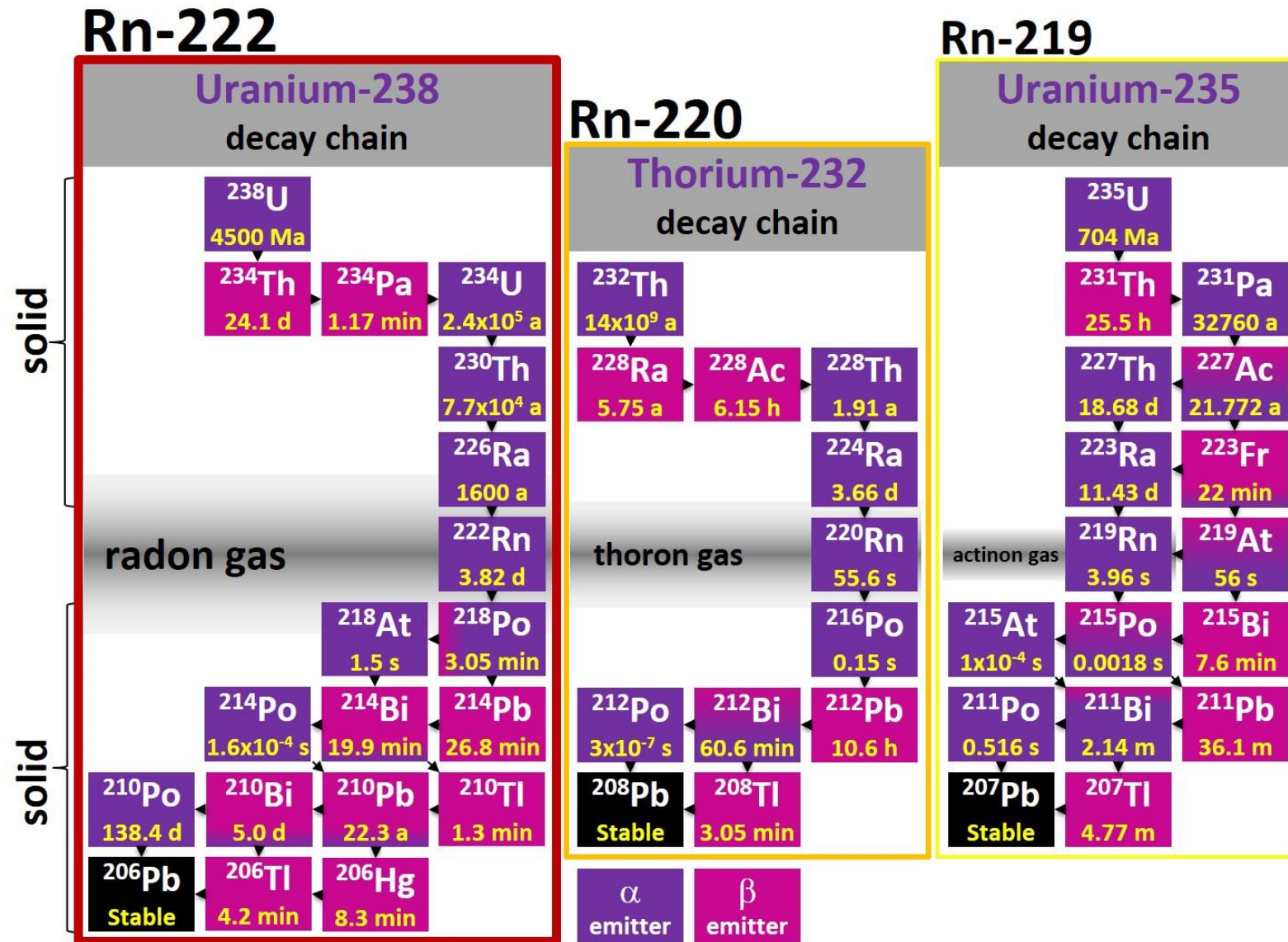


**Radon (Rn)** is a chemical element gas that sits in the right bottom end corner of the periodic table:

- **Noble** (PT VIII group),
- **Heavy** (PT 6 period)
- **Radioactive** and
- **Geogenic Gas**

This set of characteristics makes Radon a distinctive element. Its natural behaviour is driven by physics more than chemistry as it tends not to combine with other elements.

# What is Radon? ... a RADIOACTIVE gas



The 3 naturally occurring Radon isotopes:

- **Rn-222** ( $t_{1/2} = 3.82$  days), the ‘Radon gas’, from Ra-226 in the U-238 radioactive decay chain;
- **Rn-220** ( $t_{1/2} = 55.6$  sec), the ‘Thoron gas’, from Ra-224 in the Th-232 radioactive decay chain;
- **Rn-219** ( $t_{1/2} = 3.96$  sec), the ‘Actinon gas’, from Ra-223 in the U-235 radioactive decay chain.
- All SOLID isotopes, except Rn, ending up with a stable lead (Pb) isotope.



# What is Radon? ... a GEOGENIC gas

**Source:** ROCK and SOIL minerals

**Problem:** Environmental radiation

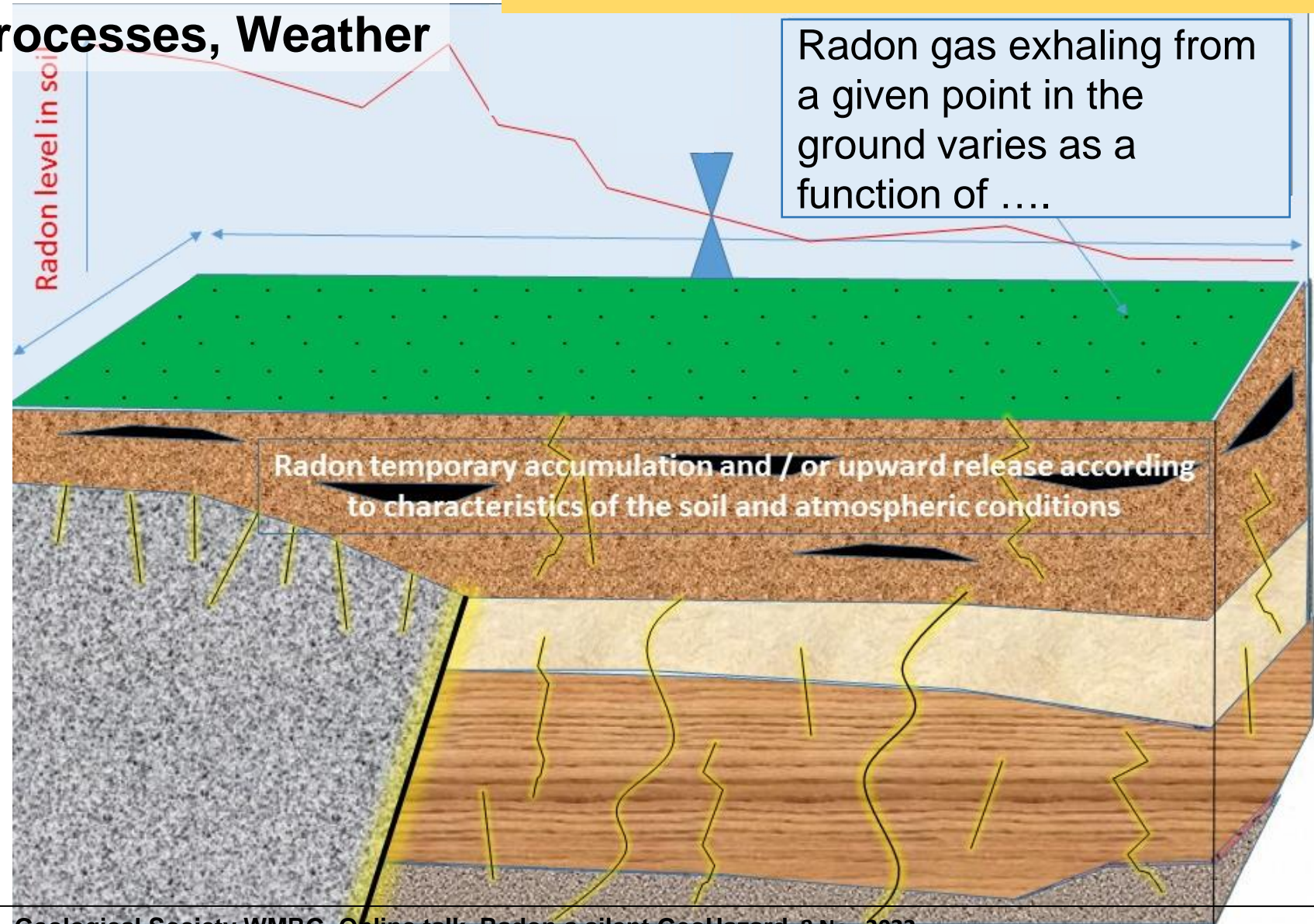
**Pathways:** Permeability, Processes, Weather

## Chemical properties:

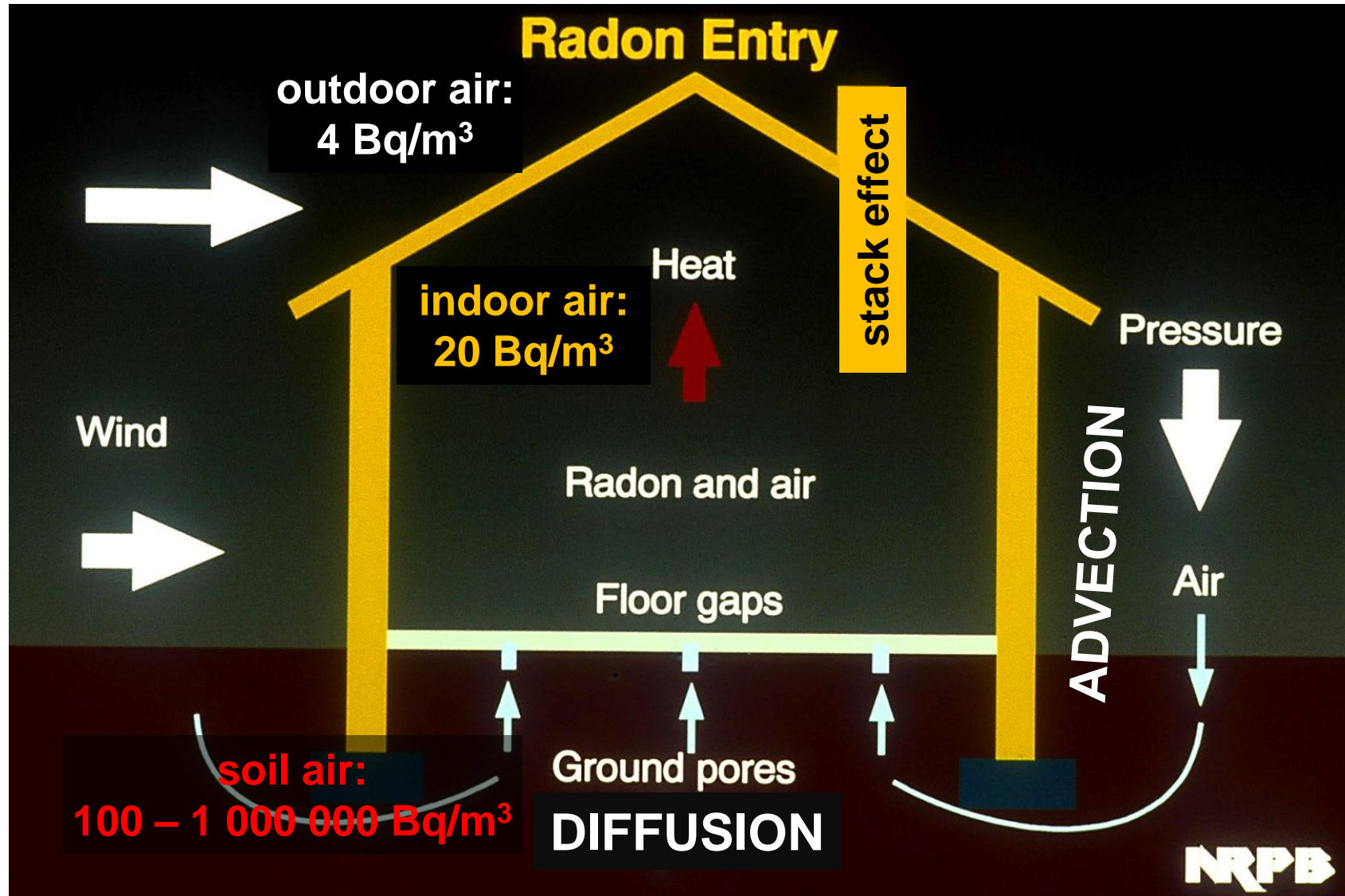
- U (Th, Ra) concentrations in soil, bedrock, groundwater, ...
- Other elements with physical-chemical interaction or co-participation in natural processes with U Th Ra (... CoDA ...)

## Physical properties:

- Soil permeability
- Soil water content
- Faults, fractures, cracks
- etc



# Pathway of concern: Radon can get into Buildings



The Rn pathways into our homes:

. **DIFFUSION**, following a difference in concentration (radon in soil air is ca. 2 to 6 orders of magnitude higher - usually measured in kBq/m<sup>3</sup> - than in the air above the ground - usually measured in Bq/m<sup>3</sup>)

. **ADVECTION**, following a difference in total pressure and temperature (Schroeder et al., 1965; Nazaroff et al., 1992; Garbesi et al., 1996; Garbesi et al., 1999). Lower P and higher T indoors.

<http://www.ukradon.org.uk/>

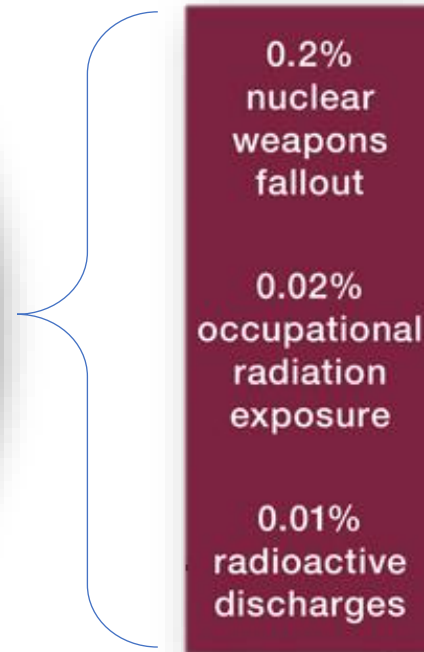
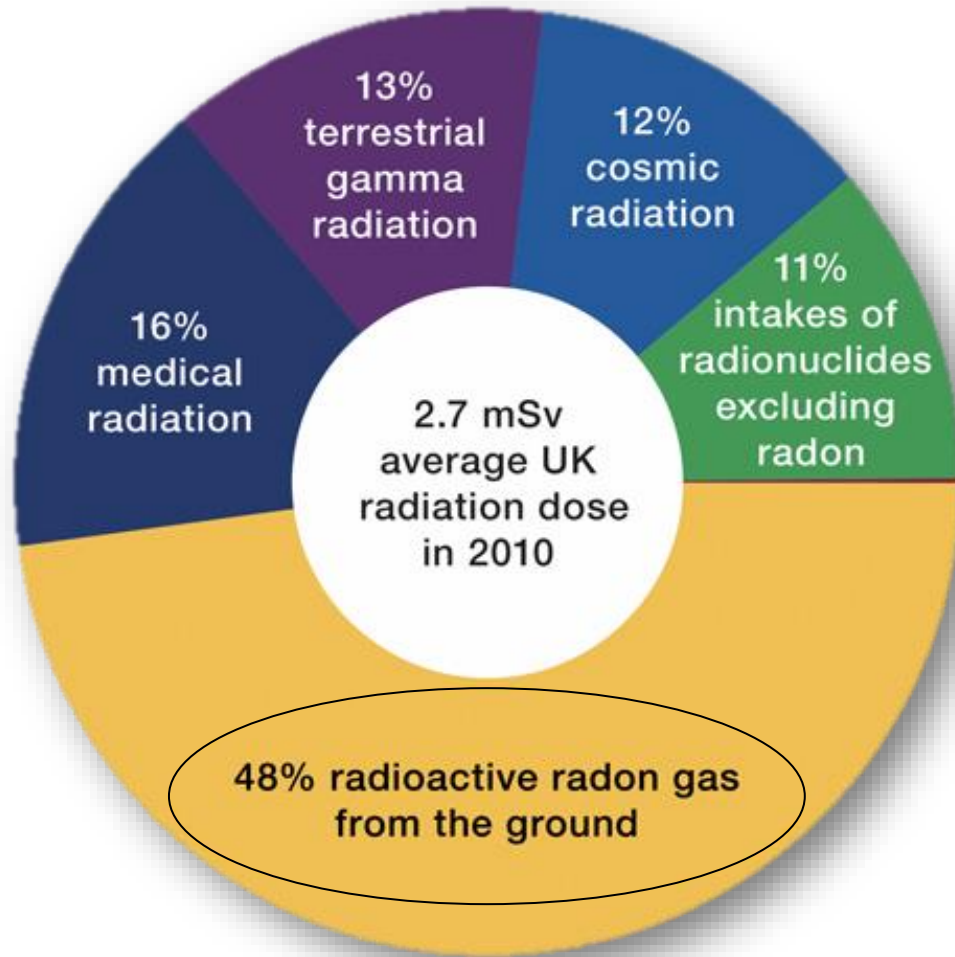
**most exposure is indoors**



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# Indoor RADON, the No 1 radiation a person is subjected to



**Breakdown of the average UK radiation dose in 2010 by source**

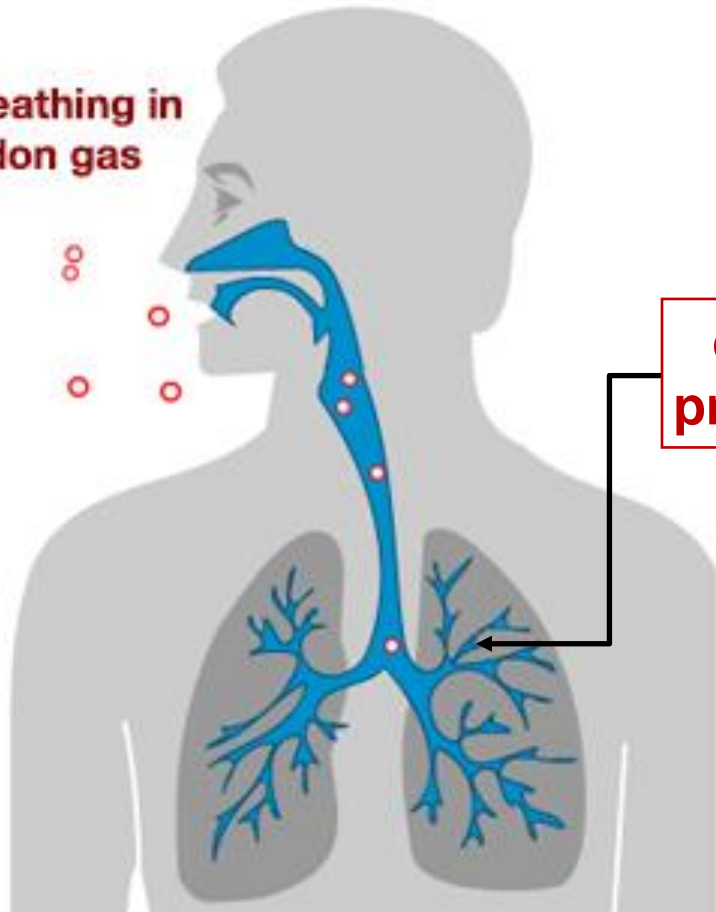
<https://www.ukradon.org/information/whatisradon>



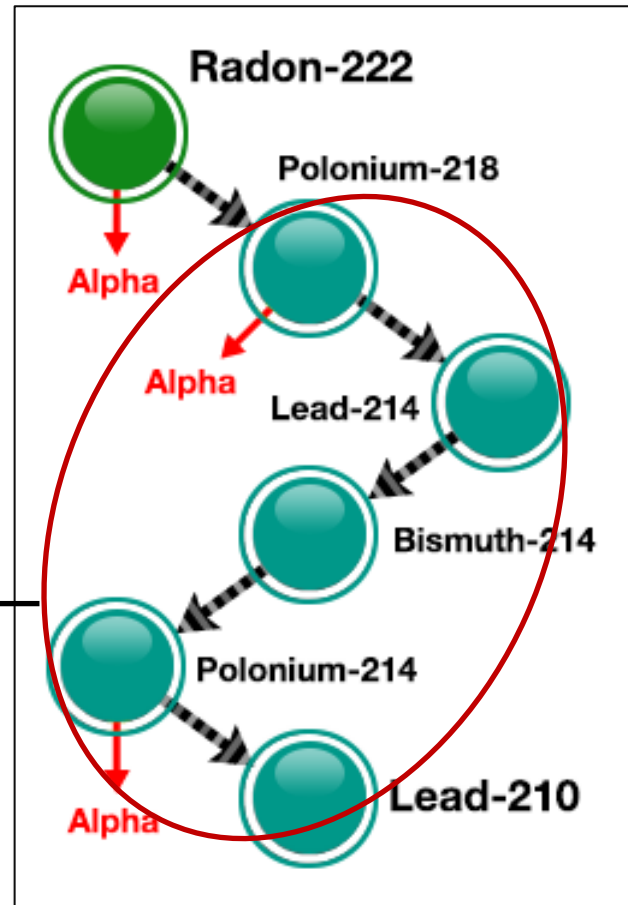
# Indoor RADON, a cause for Lung Cancer

Radon GAS  
(and its decay products)  
enter the Lungs

Breathing in  
radon gas



decay  
products



- Rn and its radioactive decay products enter the lungs through natural breathing;
- Rn itself tends to follow the 'breathe in breathe out' movement;
- while Rn decay products:
  - attach the lungs tissue as they are **solid** and **chemically active**;
  - keep emitting  $\alpha$  particles at a very high pace (**short  $t_{1/2}$** )

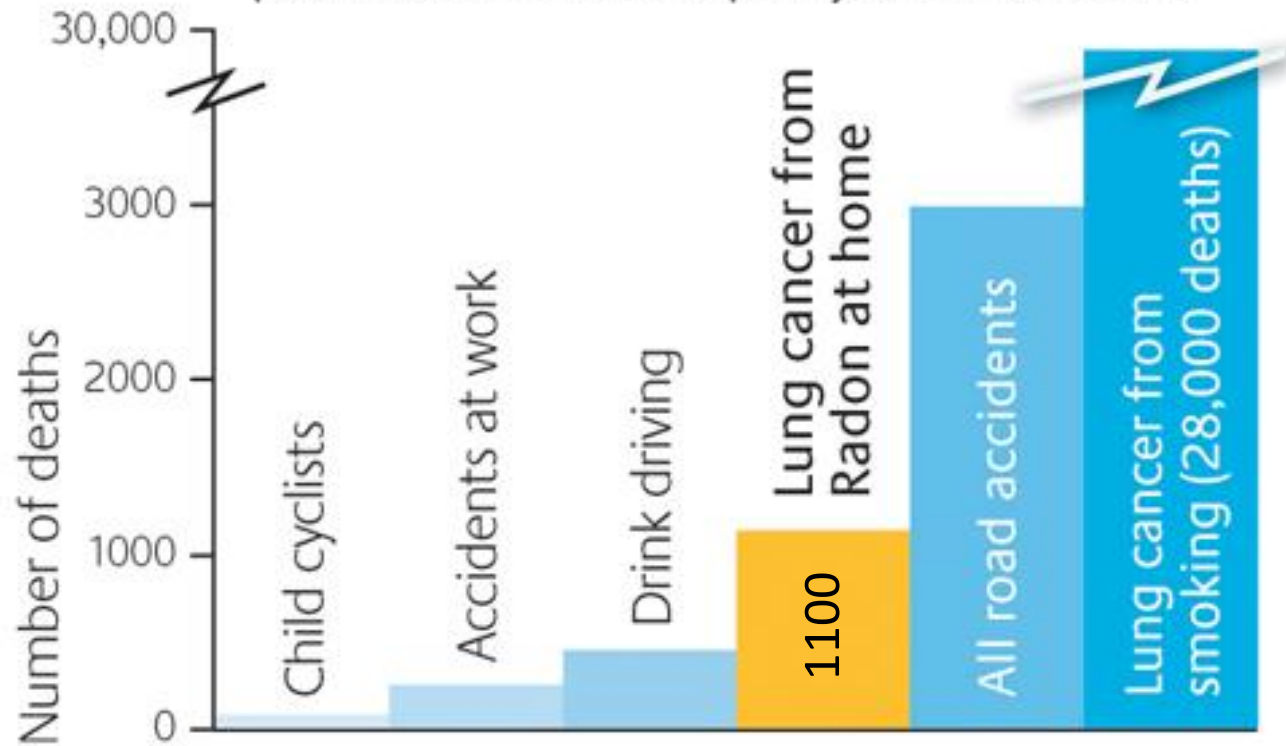
❖ **damaging DNA and potentially causing lung CANCER**

# Indoor RADON, the 2<sup>nd</sup> cause of Lung Cancer

... after **SMOKING**

## Radon deaths

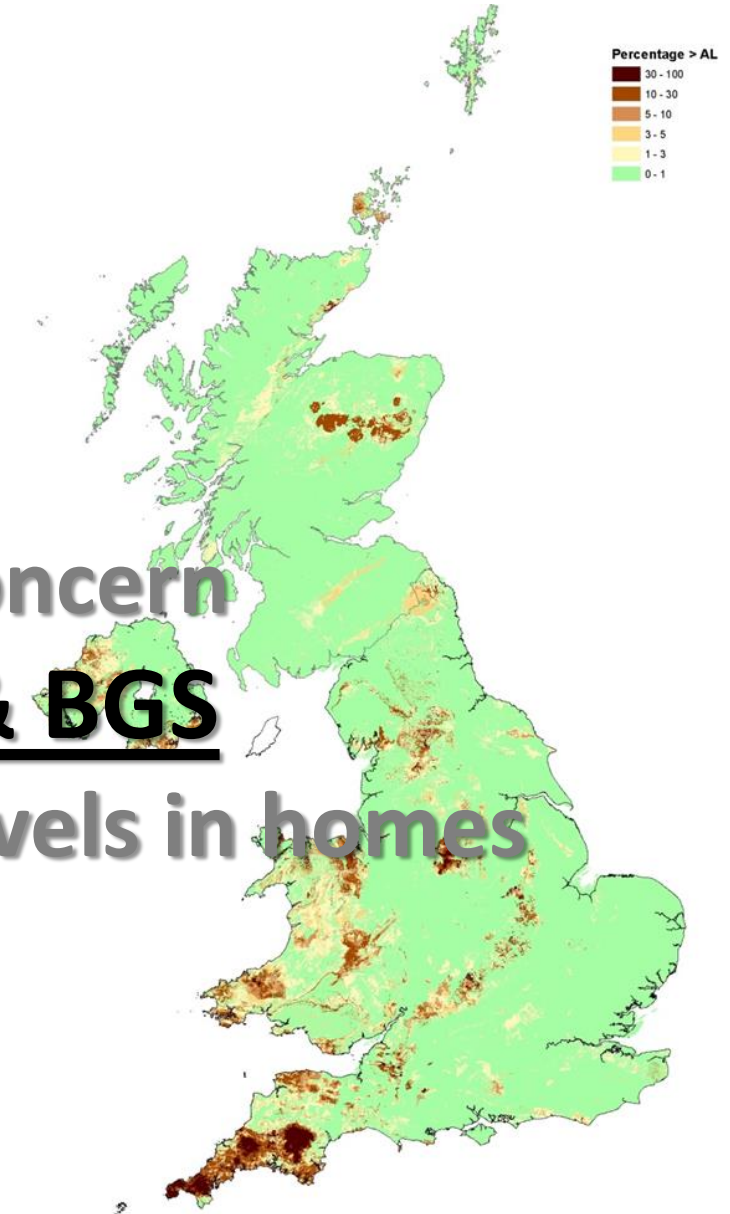
compared with other causes of premature deaths per year in the UK



- Rn is the **2<sup>nd</sup> cause** for premature deaths by lung cancer, right after smoking, at world level (3 -14%);
- In the **UK**, it is estimated that ca.1100 /yr (**3-4%**) of all deaths by lung cancer are caused by Rn inhalation.
- Rn is perhaps the **deathliest Geologic Hazard** in the UK, maybe in many parts of the world.

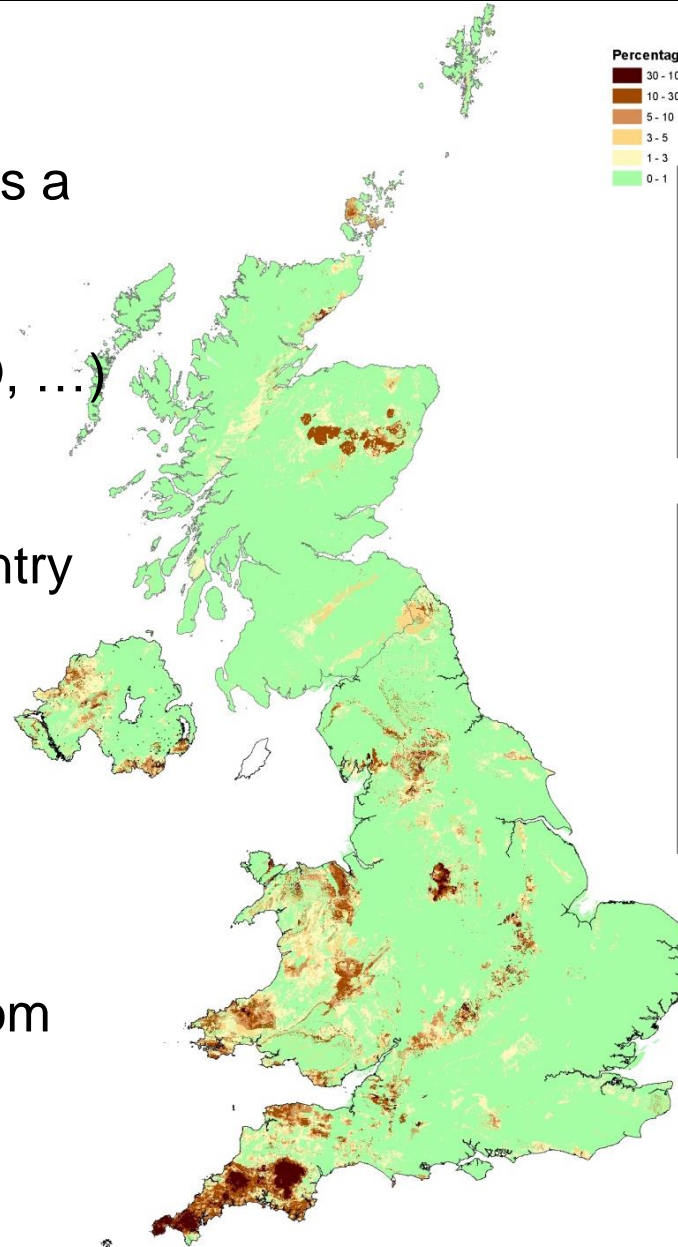


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# Radon Mapping in the UK. WHY?

- Indoor Radon is recognized as a **Public Health Hazard** nationally and internationally (UKHSA, UK, EU, USA, WHO, ...)
- a basic step forward is to identify **WHERE** in the country Indoor Rn tends to be high, that is, identifying the **RADON-PRONE AREAS** (previously know as 'Radon Affected areas') where to prioritise any further efforts to decrease life loss from Rn exposure.



Percentage > AL  
30 - 100  
10 - 30  
5 - 10  
3 - 5  
1 - 3  
0 - 1

a **Radon Map**  
provides basic information  
where indoor radon  
is likely to be high (Radon-prone areas)

allowing to prioritise  
**Remediation & Prevention**  
for old and new buildings in  
**Radon-prone Areas**  
Building REgulations: <http://www.bre.co.uk/>

aiming at  
**decreasing the No. of deaths**  
caused by indoor radon

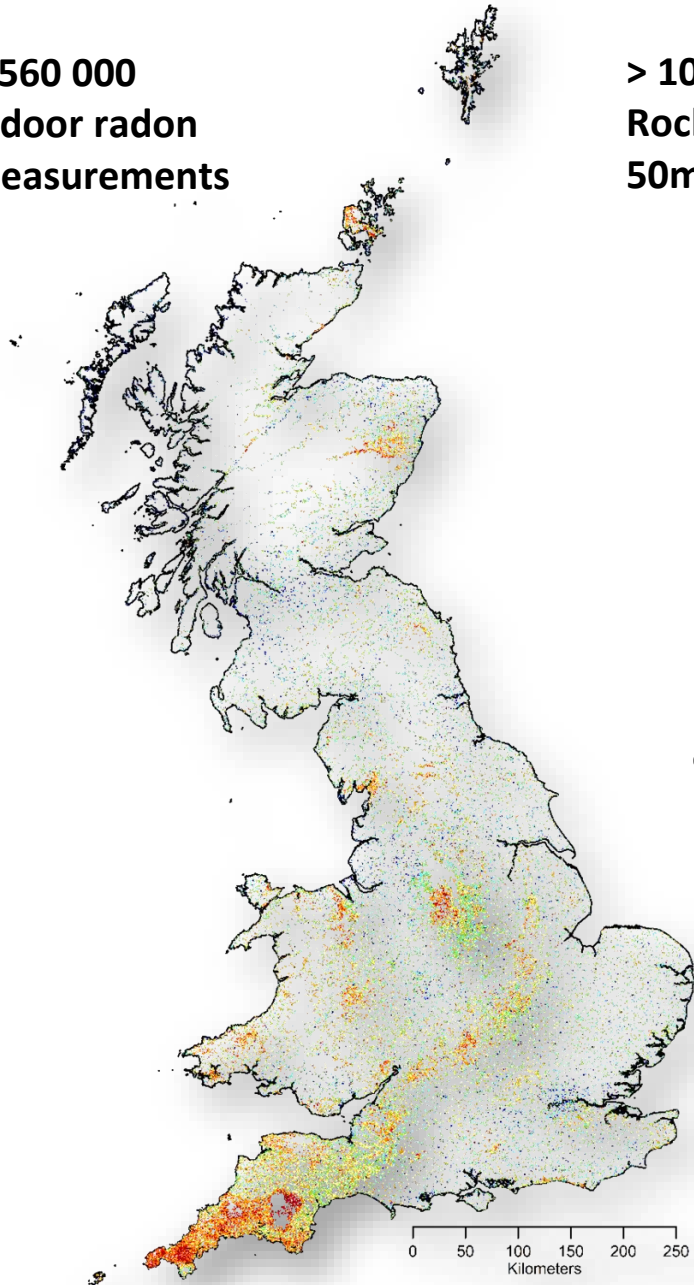


# Indoor Radon measurements + Geology for Radon Mapping

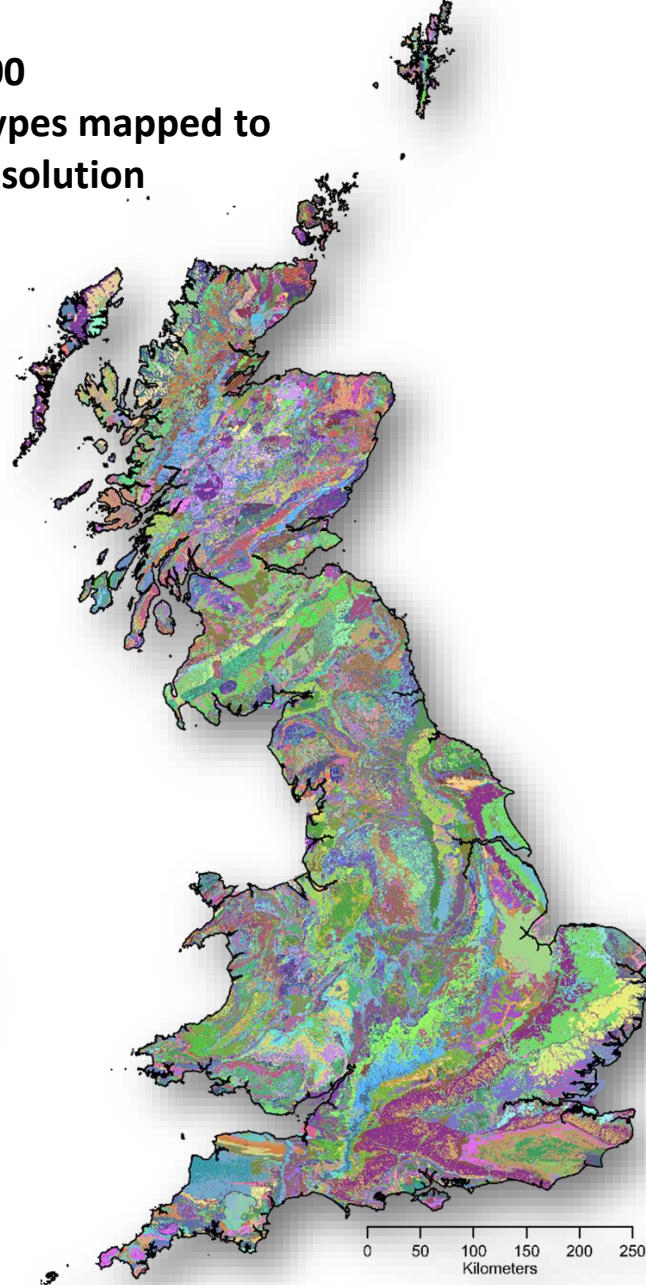
> 560 000  
indoor radon  
measurements

> 10 000  
Rock types mapped to  
50m resolution

Statistical model to  
combine source,  
pathway and receptor



+



=



# What changed between the previous and new versions?

|  | Previous edition (2007)  | New edition (2022)  |
|--|--|---|
| <b>Measurements</b>                                      | 479000   | 560740 (80000+)   |
| <b>Geology map</b>                                       | Version <b>3.14</b>  | Version <b>8.25</b>   |
| <b>Method: combining geology datasets</b>                | <b>one layer</b> of 'simplified' geology combinations ( <b>COM</b> )   | <b>four layers</b> of 'simplified' geology ( <b>BS, BED, Lex, RCS</b> ), with a hierarchical structure between them and decreasing geological complexity  |
| <b>Method: number of simplified geology combinations</b> | <b>COM: <u>2232</u></b> combinations (798 for Scotland + 1434 for England & Wales)   | Layer 1 ( <b>BS</b> ): <b>9323</b> combinations<br>Layer 2 ( <b>BED</b> ): 1674 combinations<br>Layer 3 ( <b>Lex</b> ): 348 combinations<br>Layer 4 ( <b>RCS</b> ): 45 combinations <span style="font-size: 2em; vertical-align: middle;">}</span> Across GB    |
| <b>Method: other modifications</b>                       | UKHSA gridding: <b>100 +</b> samples per COM;<br>BGS gridding: - 100 samples per COM ( <b>4 gridding methods</b> according to No. samples per COM: <b>10 + samples NOT ensured</b> )<br>Wider use of expert judgement to 'fill' gaps | UKHSA gridding: <b>30 +</b> samples per BS;<br>BGS gridding: - 30 samples per BS ( <b>1 gridding method applied to 4 layers</b> , according to No. samples per Layer #: <b>10 + samples ensured</b> )<br>Much reduced use of expert judgement ( <b>0.006%</b> ) |



# Geology Map Changes

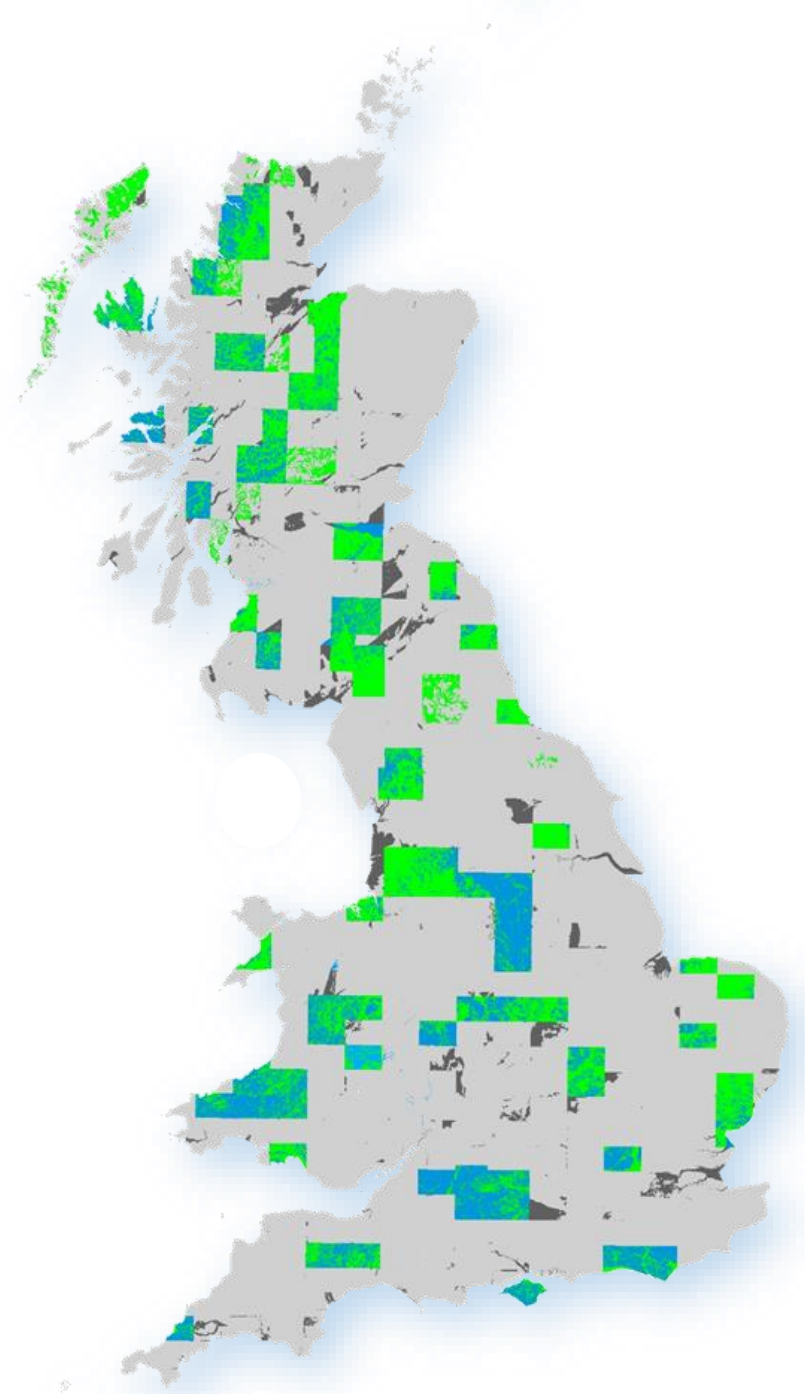
Geology doesn't change very much in Great Britain.

However, how we map it, and our understanding about it, is evolving all the time.

In the last 15 years the vast majority of our geology map has had some form of update, or resurvey, and it is that improvement of data that impacts how much we understand how rocks and soils behave.

Only the dark grey areas in the map shown here are completely unchanged since 2007. The green and blue areas are completely new maps, and many are in areas where Radon can pose a risk. Pale grey areas are where minor changes in nomenclature have been made.

Better maps (and faster computers) allow us to do more than we could in 2007. So revisiting how we 'combine' areas of geology to use together with the UKHSA measurements, is a logical next step in improving the mapping of Radon.



# 4 Levels of Simplified Geology Detail (preference from left to right):

**BS** (N=9323)

>

**BED** (N=1674)

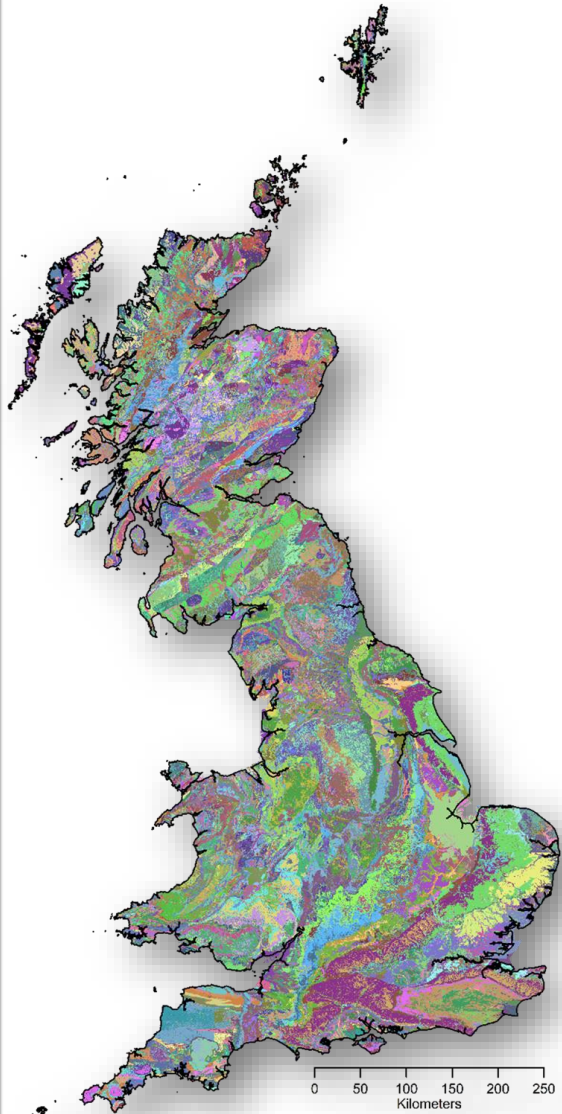
>

**Lex** (N=348)

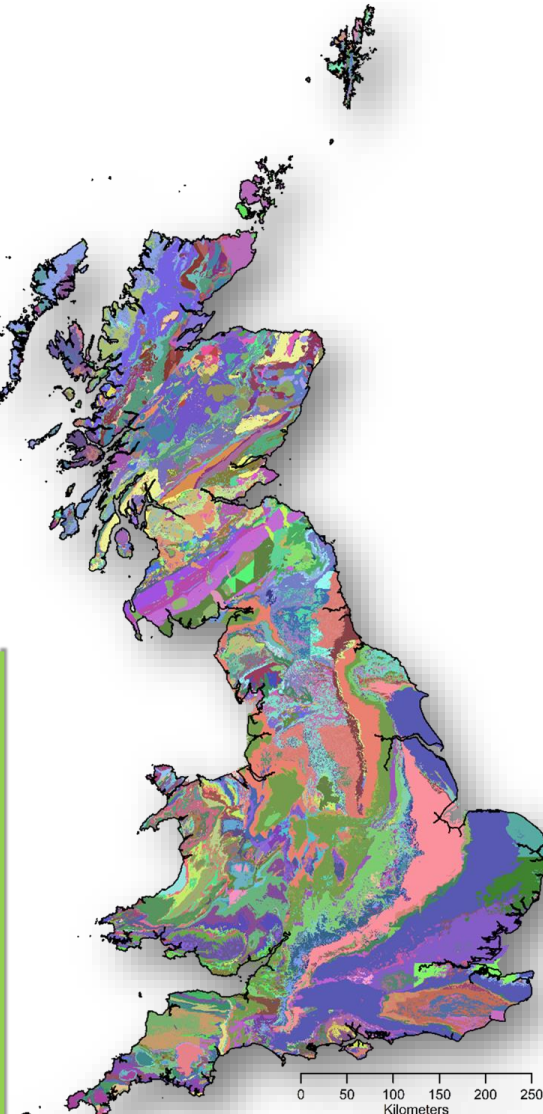
>

**RCS** (N=45)

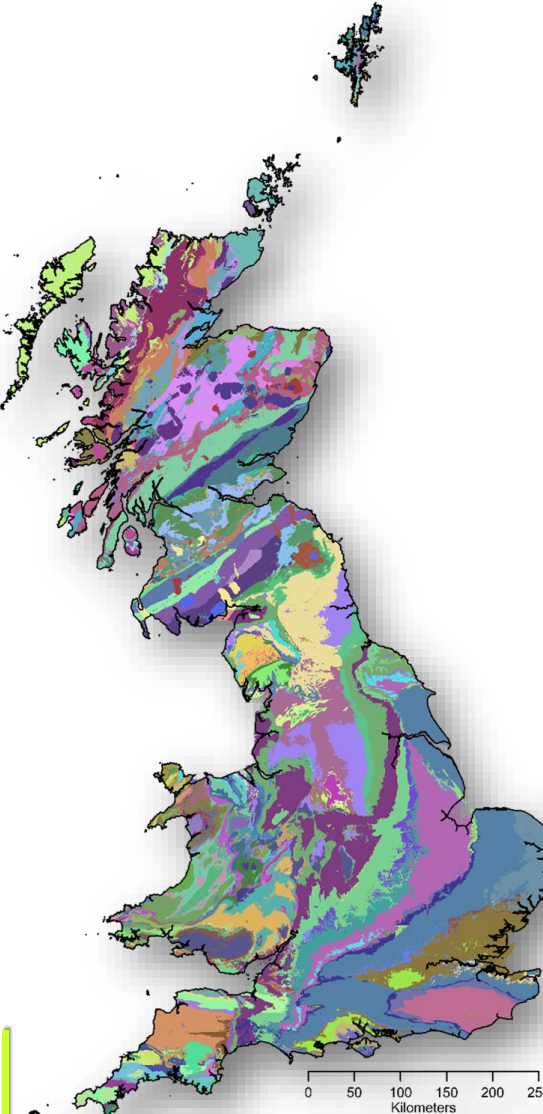
**AGE + LITHOLOGY + SUPERFICIAL DEPOSITS**



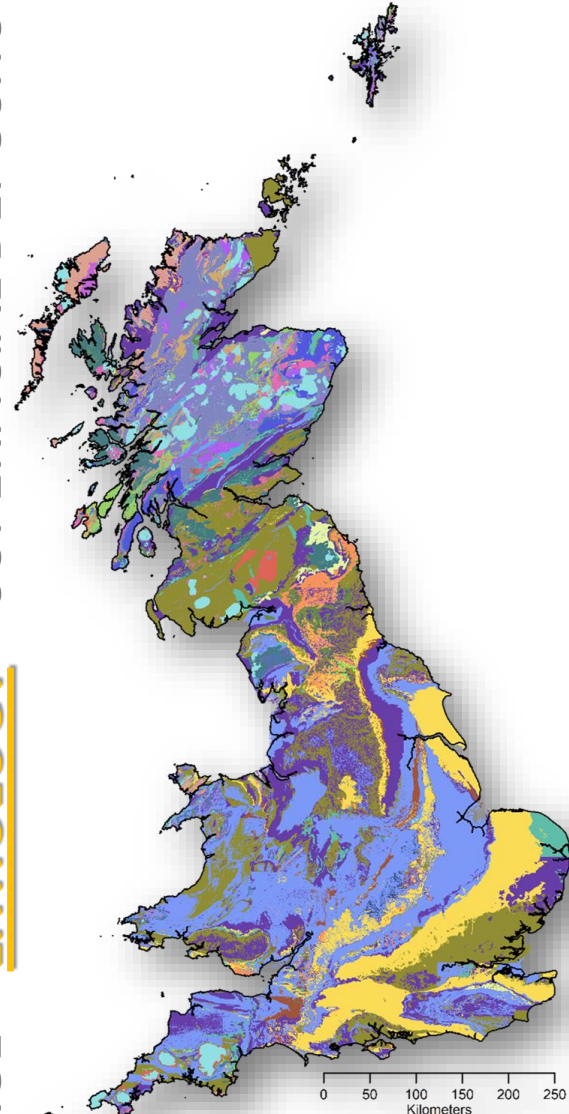
**AGE + LITHOLOGY + SUPERFICIAL DEPOSITS**



**AGE + LITHOLOGY + SUPERFICIAL DEPOSITS**



**AGE + LITHOLOGY + SUPERFICIAL DEPOSITS**





Radon Class estimated using BS  
computed by UKHSA



## Radon Class estimates

are based on  
GM, GSD and RnP statistics  
of the nearest 30  
measurements

for

BS simplified geologies with  
NRnM  $\geq 30$

**75.7% of GB covered**  
(area in green)

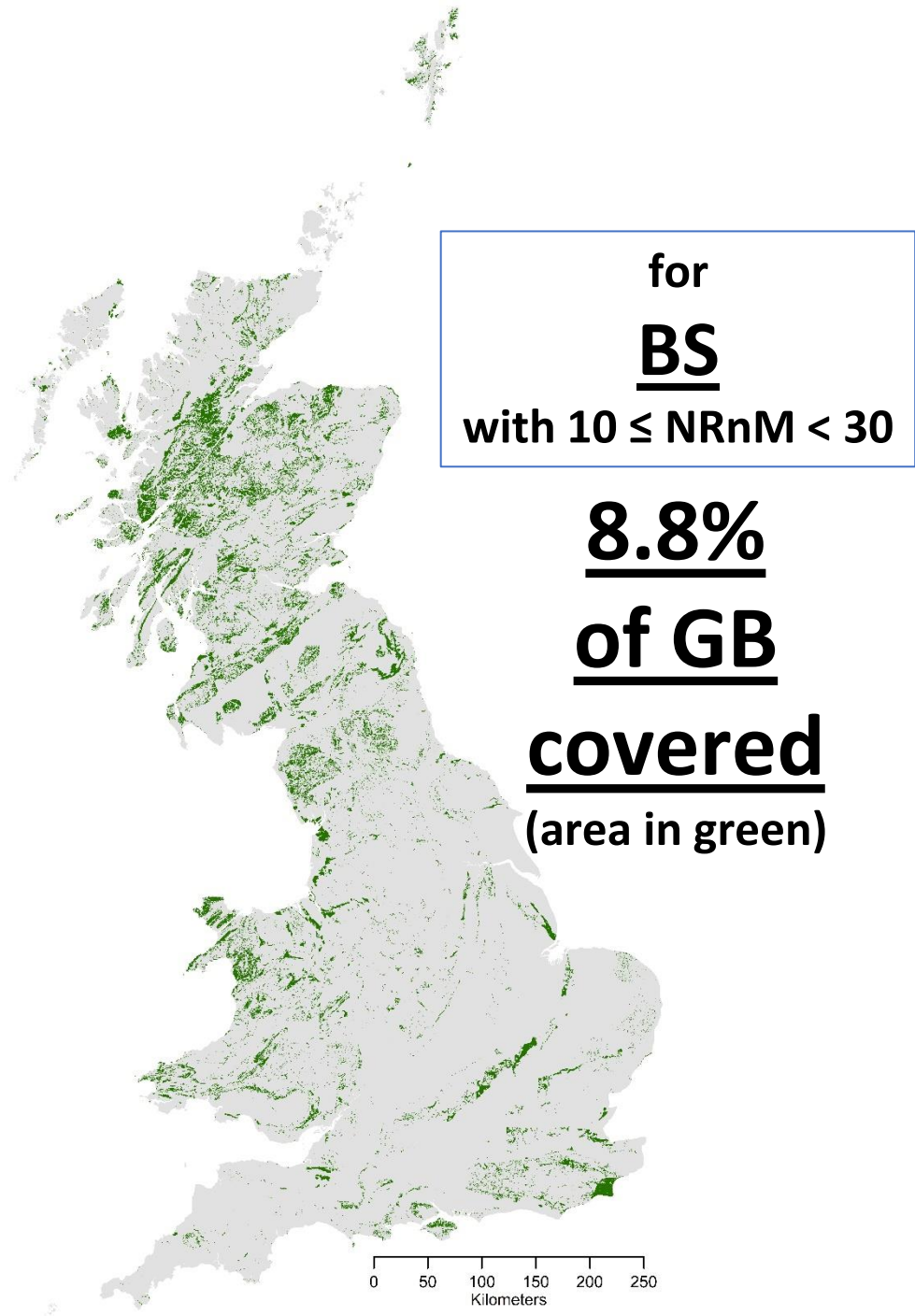
BS: detailed simplified geology

GM: geometric mean

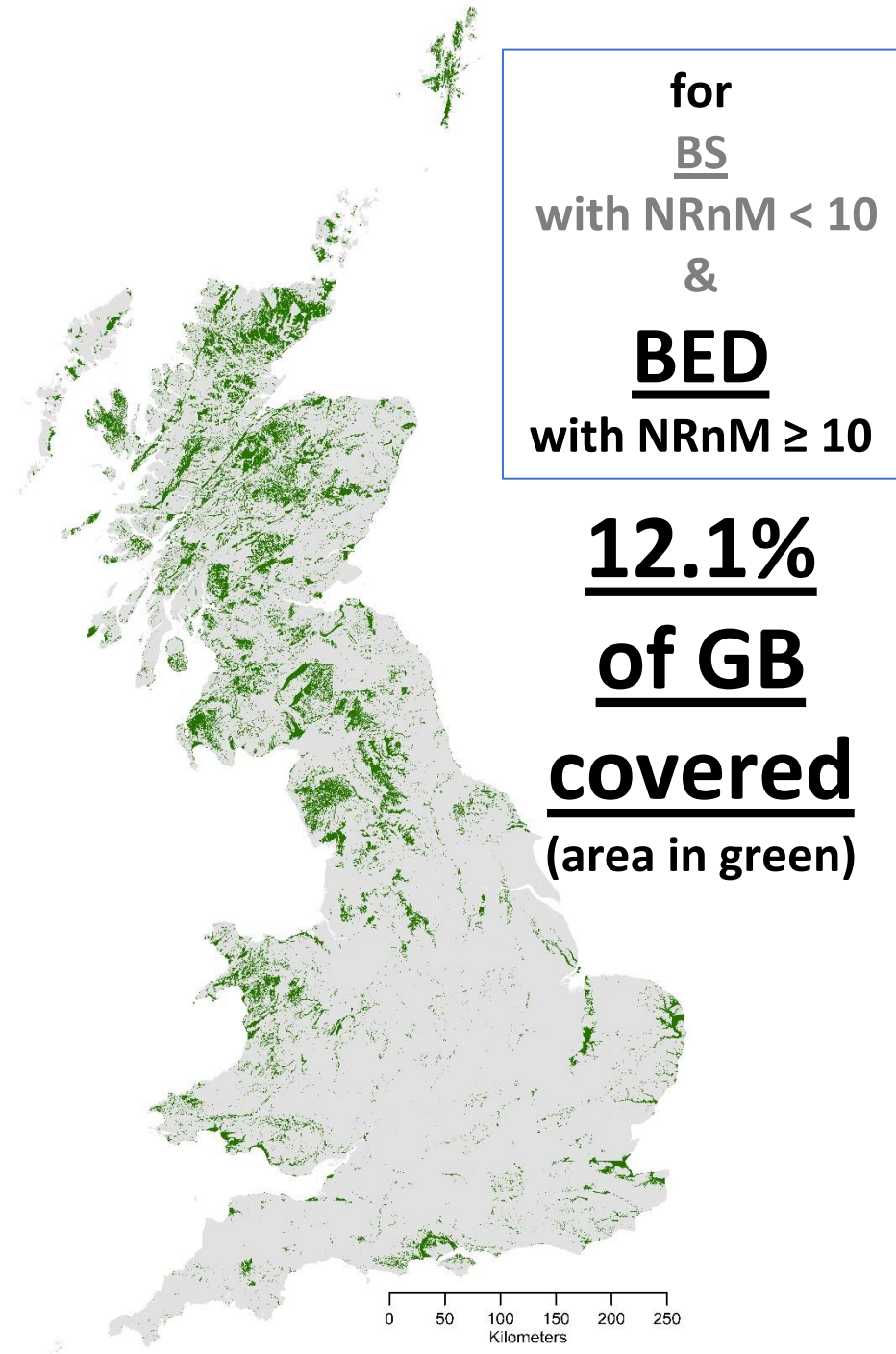
GSD: geometric standard deviation

NRnM: Number of Radon Measurements

Radon Classes estimated using BS  
computed by BGS

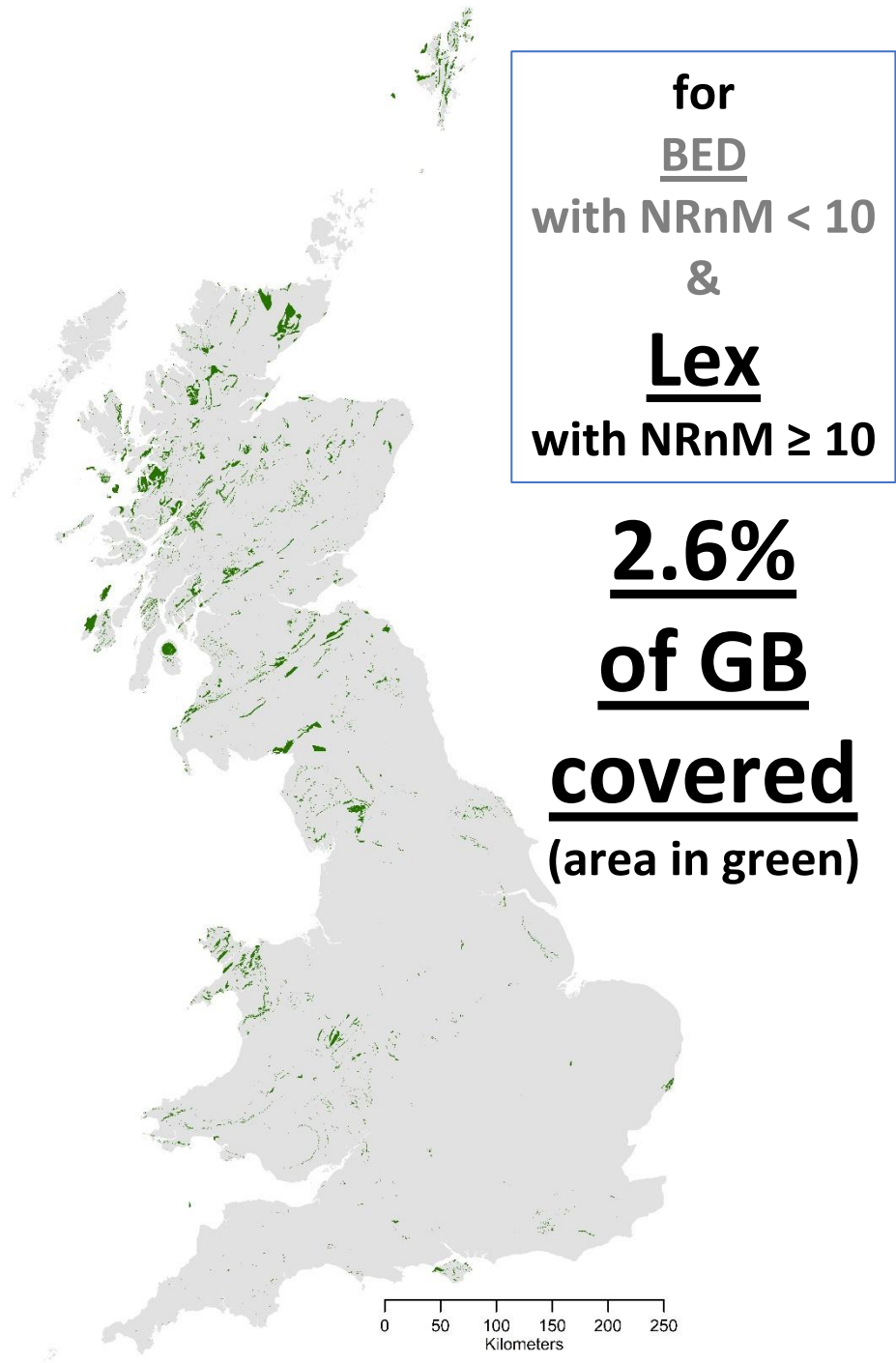


Radon Classes estimated using BED  
computed by BGS

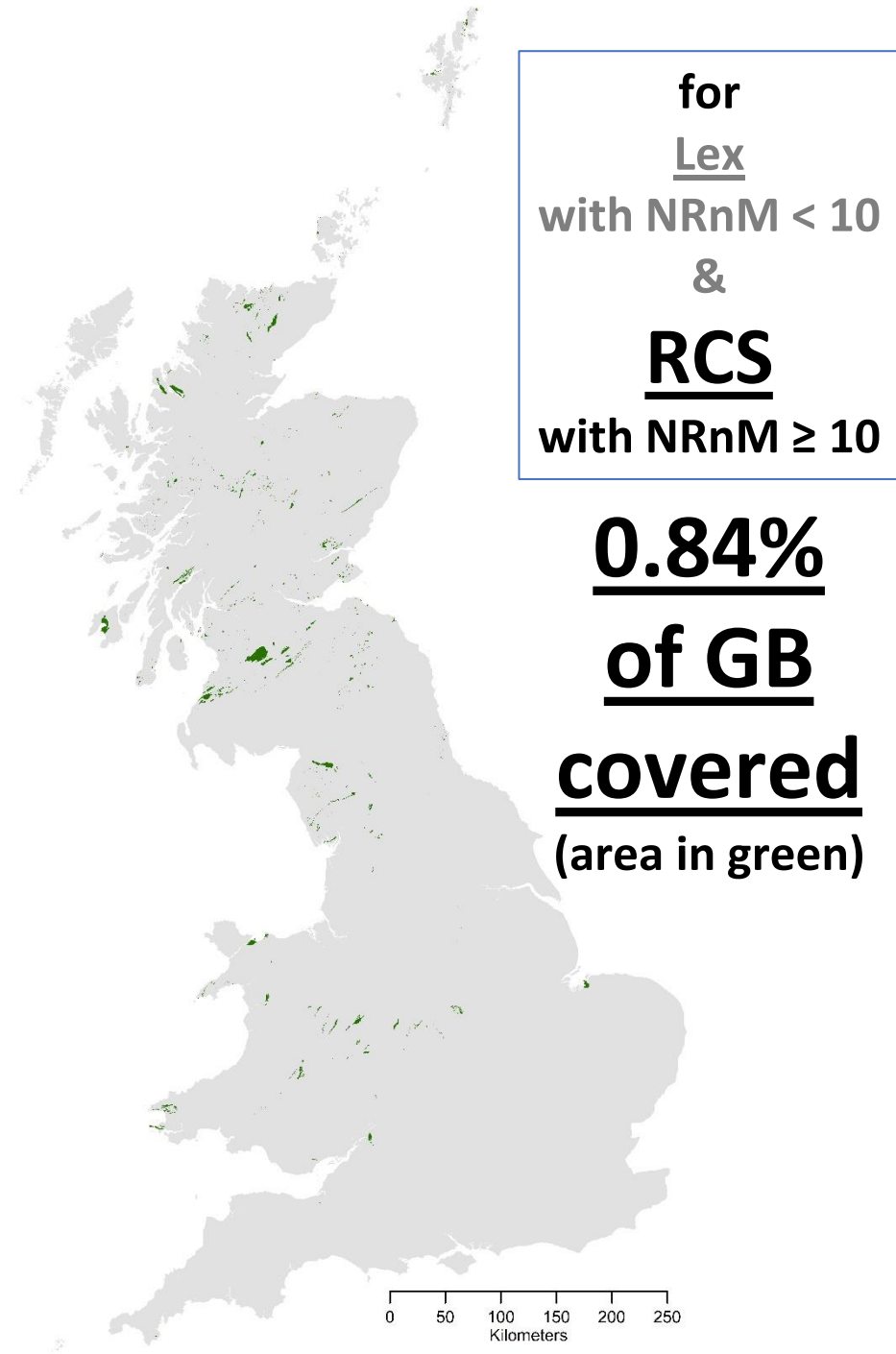




Radon Class estimated using Lex  
computed by BGS

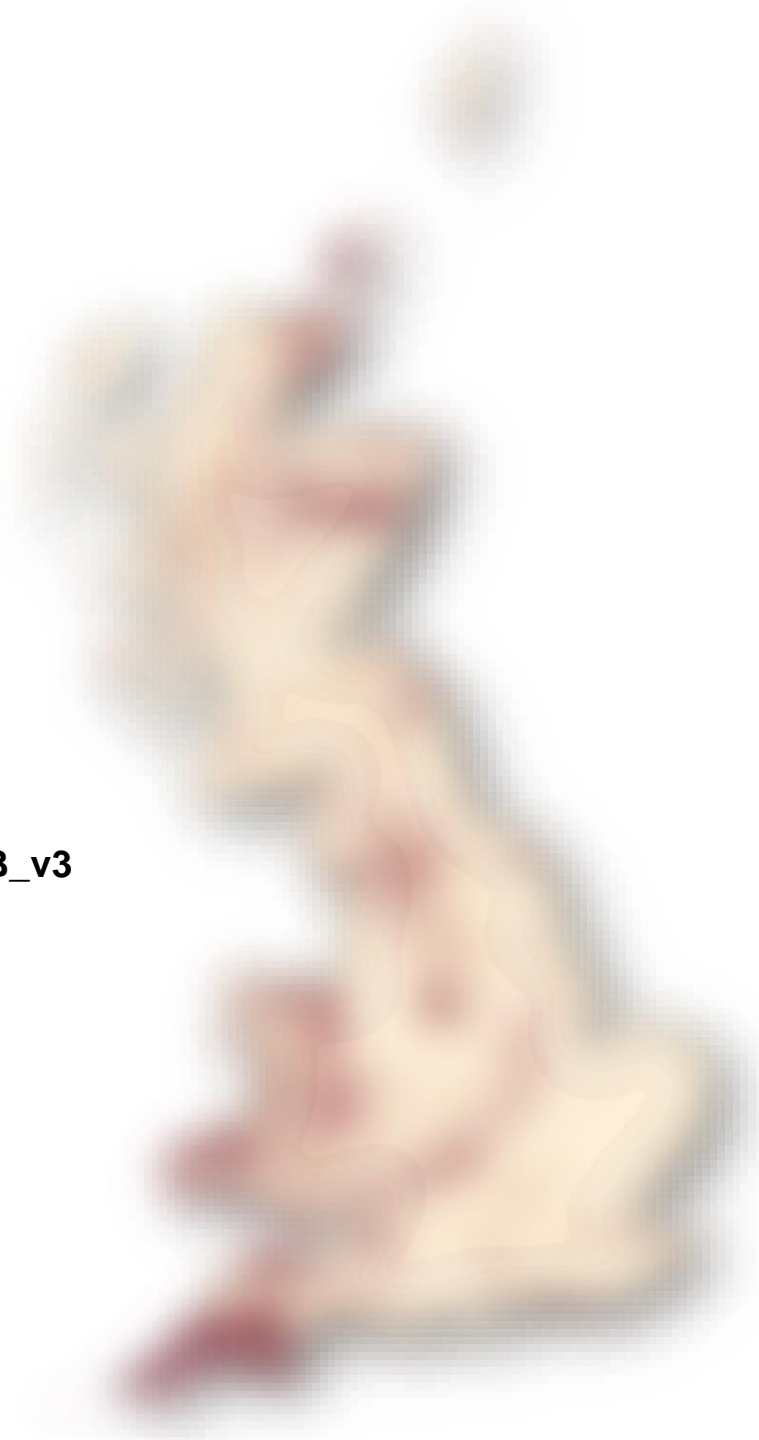
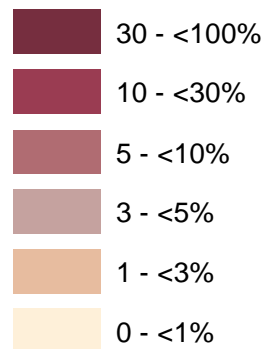


Radon Class estimated using RCS  
computed by BGS



# 6 Radon Classes for GB

Radon\_Potential\_GB\_v3



**Radon Classes (RnC)**

**for GB (100% coverage)**

**after ALL frames**

**(UKHSA, BS, BED, Lex,  
RCS)**

**computed by**

**UKHSA and BGS**



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# Reducing Radon in Homes

Radon mitigation measures:

| Floor type                            | Solid                              |            | Suspended   |   |
|---------------------------------------|------------------------------------|------------|---|---|
|                                       | Under 500                          | Over 500   | Under 500   | Over 500  |
| Radon level*<br>(Bq m <sup>-3</sup> ) |                                    |            |   |   |
| Recommended solutions, best first     | Radon sump or Positive ventilation | Radon sump | Natural under-floor ventilation or Positive ventilation | Mechanical under-floor ventilation or Natural under-floor ventilation |

Radon levels in **EXISTENT** homes can be **REDUCED** by applying one or more of 4 options according to **FLOOR TYPE** and **Rn LEVEL**

For houses with mixed floor types, a combination of the above can be used.

\*The level of 500 Bq m<sup>-3</sup> is an approximate guide.

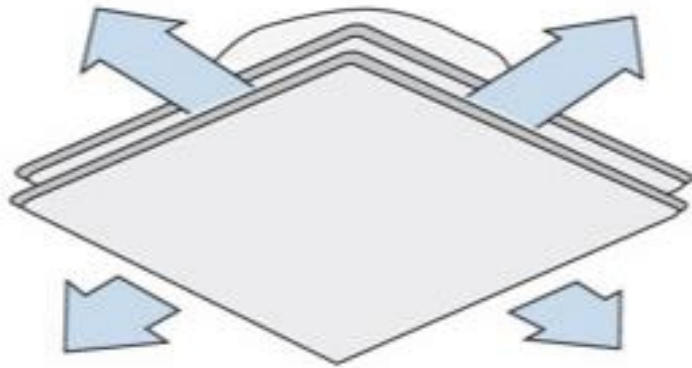
<http://www.ukradon.org.uk/>

| Remedy                          | Typical cost | Normal range |
|---------------------------------|--------------|--------------|
| Active Sump (with fan)          | £800         | Up to £2,000 |
| Active Sump (DIY)               | £300         | Up to £700   |
| Passive Sump (without fan)      | £450         | Up to £1,000 |
| Natural Under-floor Ventilation | £200         | Up to £600   |
| Active Under-floor Ventilation  | £700         | Up to £1,500 |
| Positive Ventilation            | £550         | Up to £1,000 |

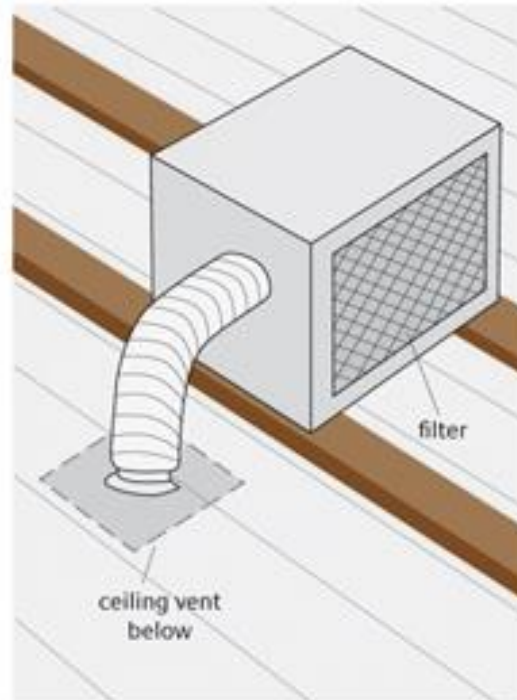


# Radon Mitigation measures

Ceiling vent



Positive ventilation unit

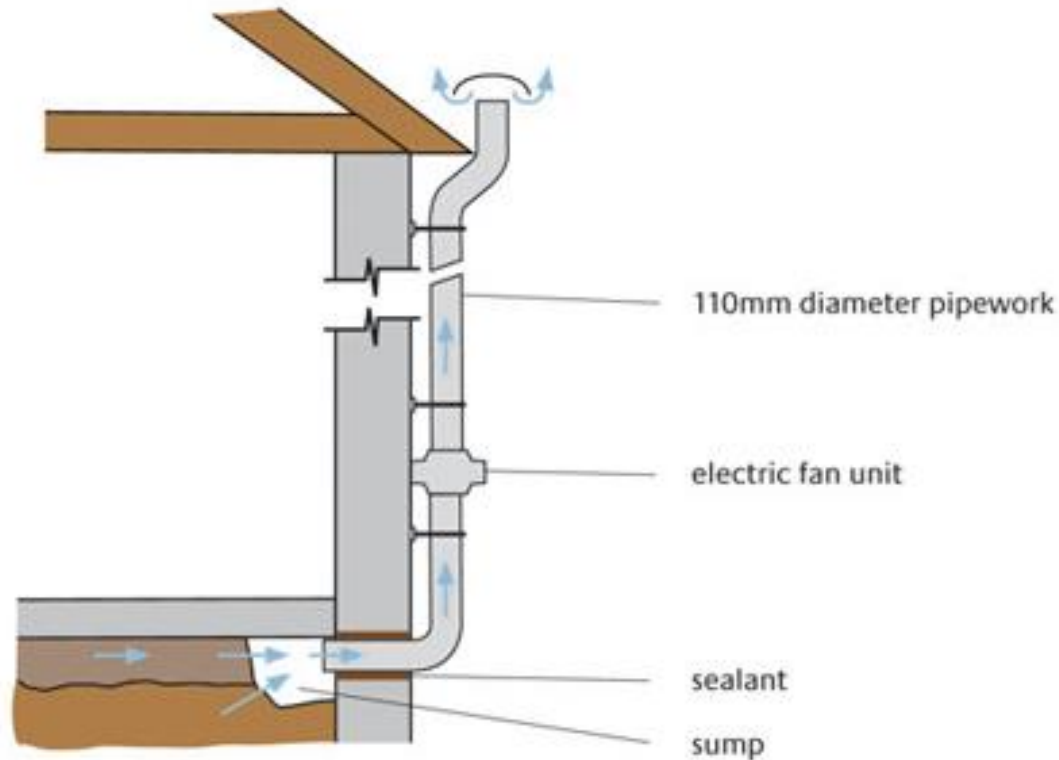


the **POSITIVE VENTILATION**

for  
 **$R_n < 500 \text{ bq/m}^3$**

Positive ventilation brings fresh air into a home, and dilutes the radon. The flow of air and radon from the ground may also be reduced. A positive ventilation system can be effective in homes with radon levels up to and around  $500 \text{ Bq m}^{-3}$ . A small fan blows air, usually from the roof space, into the home.

# Radon Mitigation measures

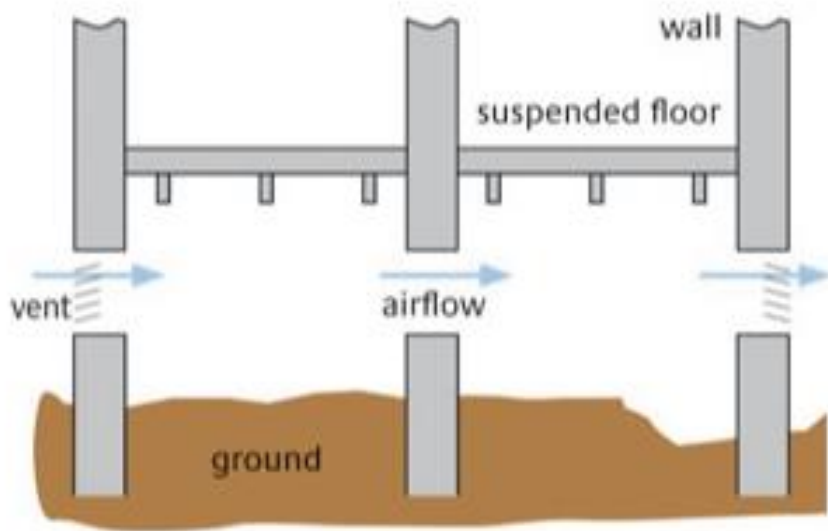


## the ACTIVE RADON SUMP for SOLID Floor

An active radon sump, fitted with a fan, is the best way to reduce indoor radon levels. Sumps work effectively under solid floors, and under suspended floors if the ground is covered with concrete or a membrane. Occasionally, passive sumps without a fan may reduce radon levels.



# Radon Mitigation measures

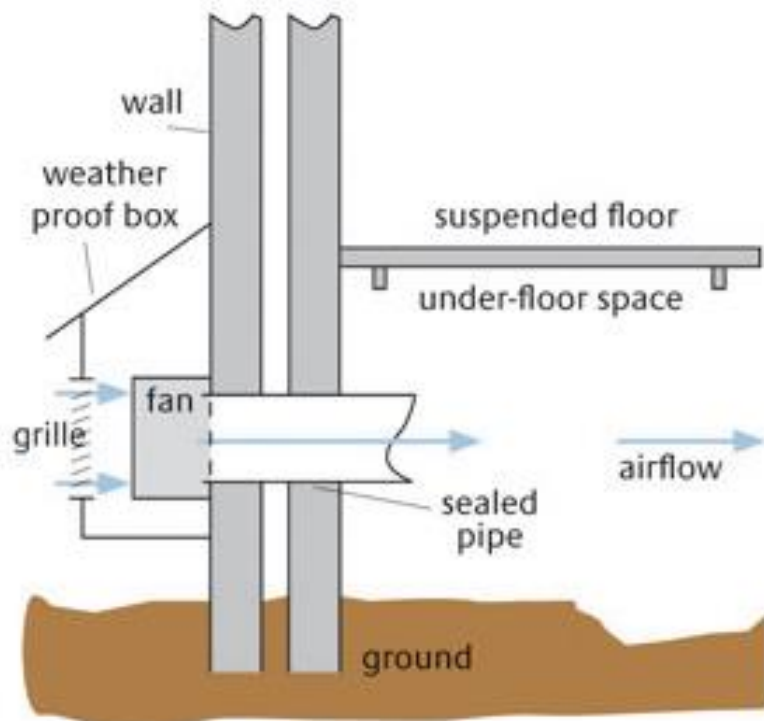


**the NATURAL  
under-floor VENTILATION  
for  
SUSPENDED Floor**

Many homes have a suspended ground floor with a space underneath. Good ventilation of this space can reduce indoor radon concentrations.

# Radon Mitigation measures

Under floor fan

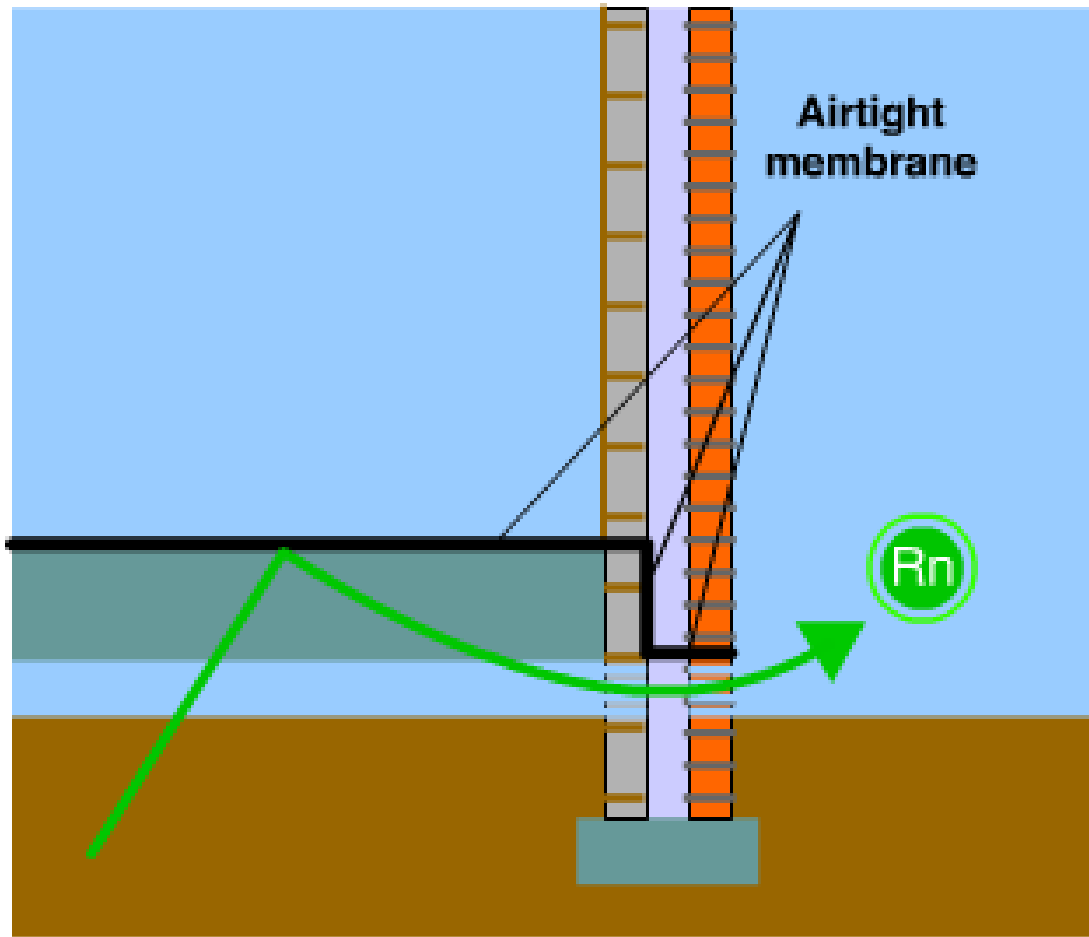


When natural ventilation under a suspended floor is inadequate to reduce the radon level, active under-floor ventilation can be installed. A fan is used to either continuously blow air into or extract air from the under-floor space. Both ways can be successful.

the **MECHANICAL**  
under-floor **VENTILATION**

for  
**SUSPENDED Floor**  
and  $R_n > 500 \text{ bq/m}^3$

# Radon Preventive measures



## the AIRTIGHT MEMBRANE

can be applied in  
**NEW** homes  
to **PREVENT**  
Rn seeping  
from underneath

For new houses, simple measures can be taken cheaply during construction to prevent high radon levels. This diagram shows an airtight membrane across the floor and through the walls.



# Radon Protection Levels for Buildings

Radon Potential, Radon Class, and Protection levels  
(based on BR211 guidance)

| Radon Potential or Probability (RnP) | Radon Class (RnC) | Level of Protection   |                 |
|--------------------------------------|-------------------|-----------------------|-----------------|
|                                      |                   | Scotland / N. Ireland | England & Wales |
| RnP < 1                              | 1                 | None / None           | None            |
| 1 <= RnP < 3                         | 2                 | Basic / Zone 1        | None            |
| 3 <= RnP < 5                         | 3                 | Basic / Zone 1        | Basic           |
| 5 <= RnP < 10                        | 4                 | Basic / Zone 1        | Basic           |
| 10 <= RnP < 30                       | 5                 | Full / Zone 2         | Full            |
| RnP >= 30                            | 6                 | Full / Zone 2         | Full            |

A minimum of Rn protection measures (**Basic, Full**) may apply to new buildings according to

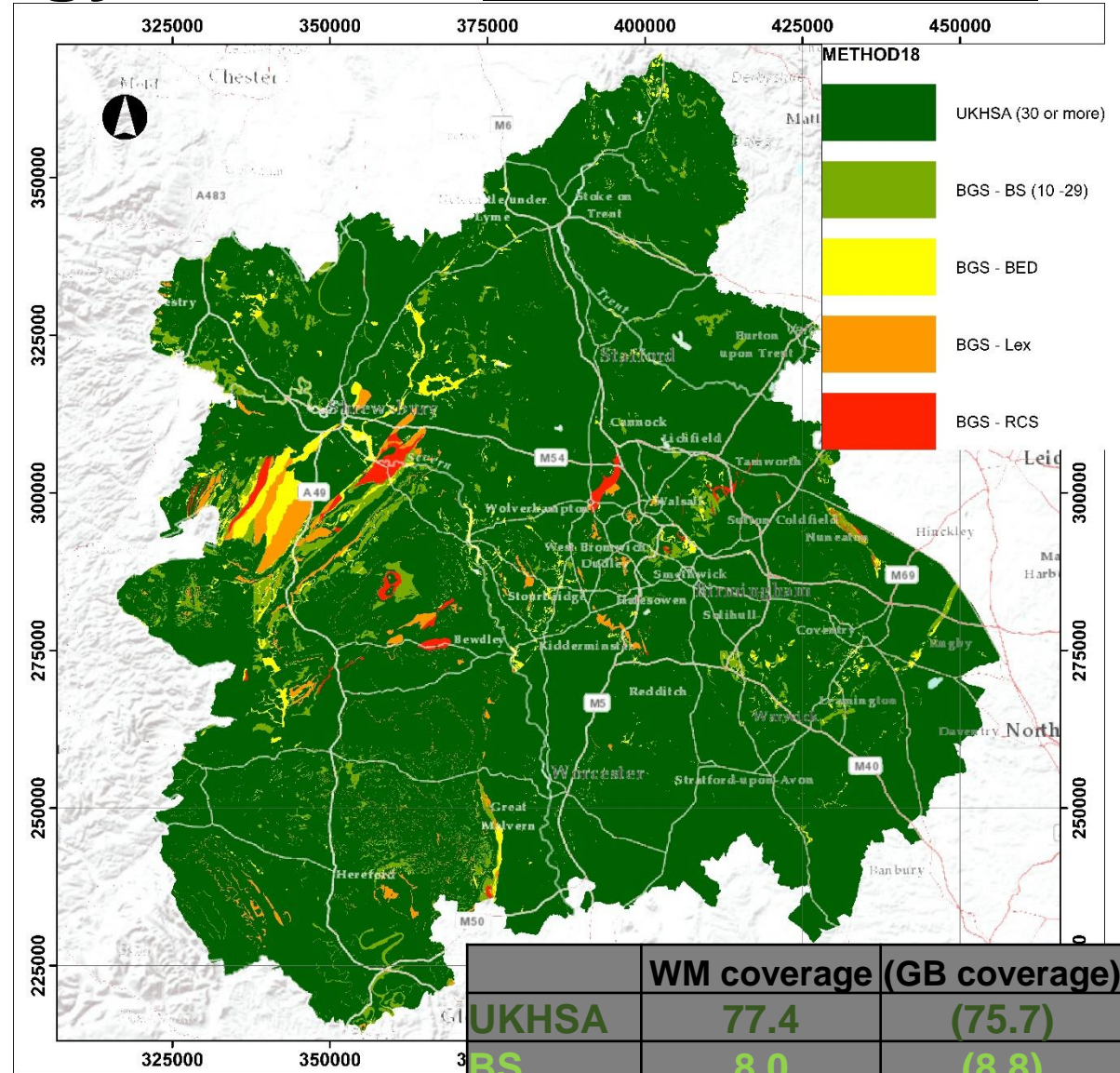
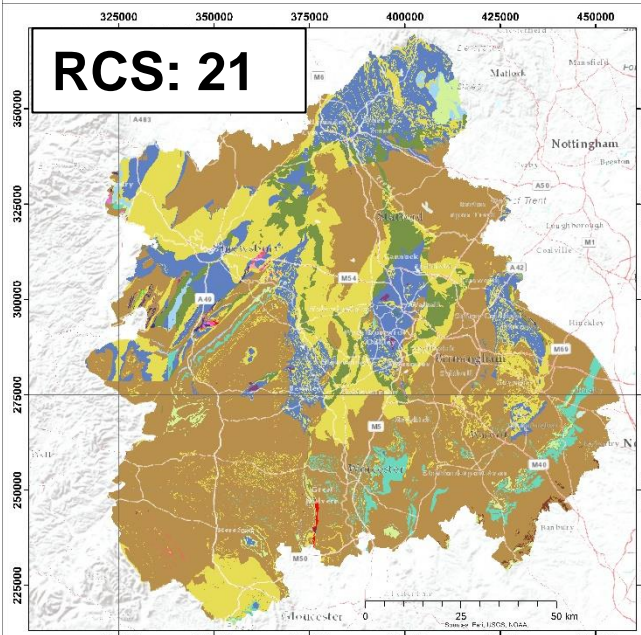
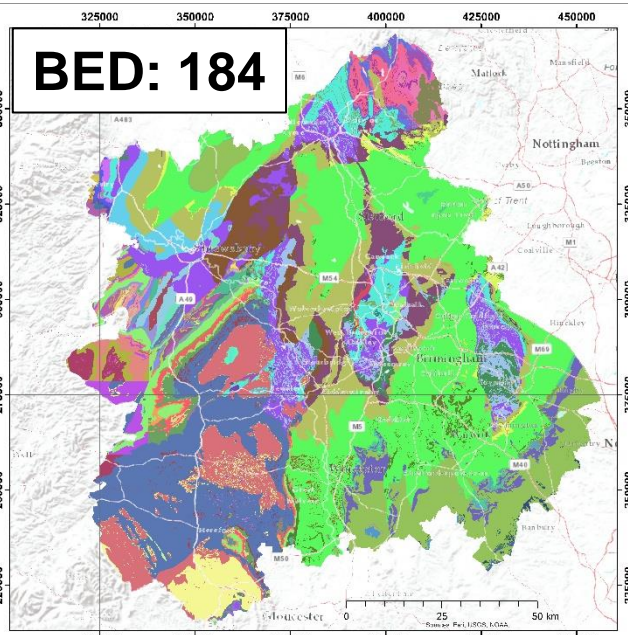
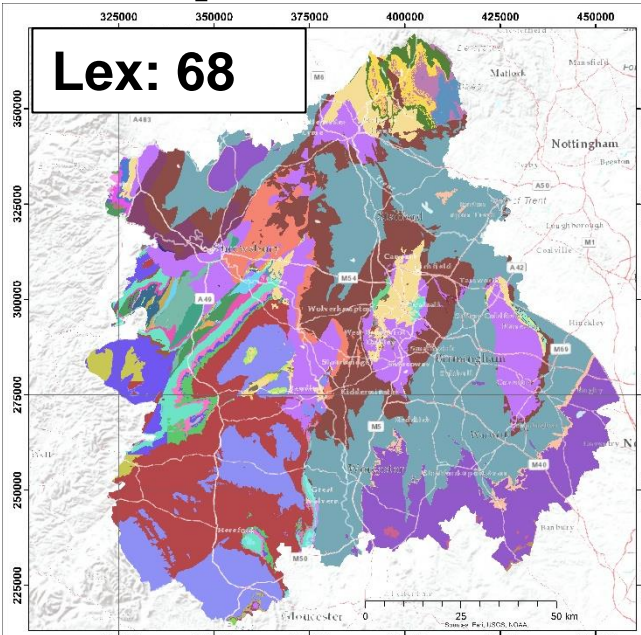
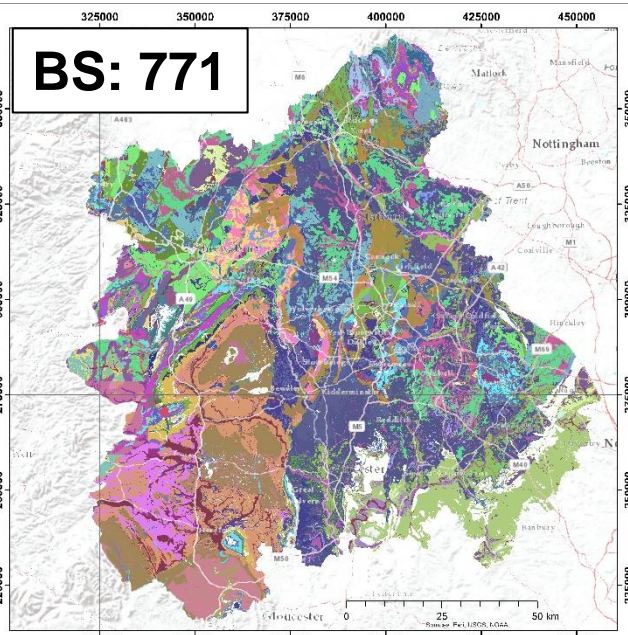
- the **Radon potential of the area** and
- as **defined by the Building Regulations** in place for each one of the 4 UK countries.

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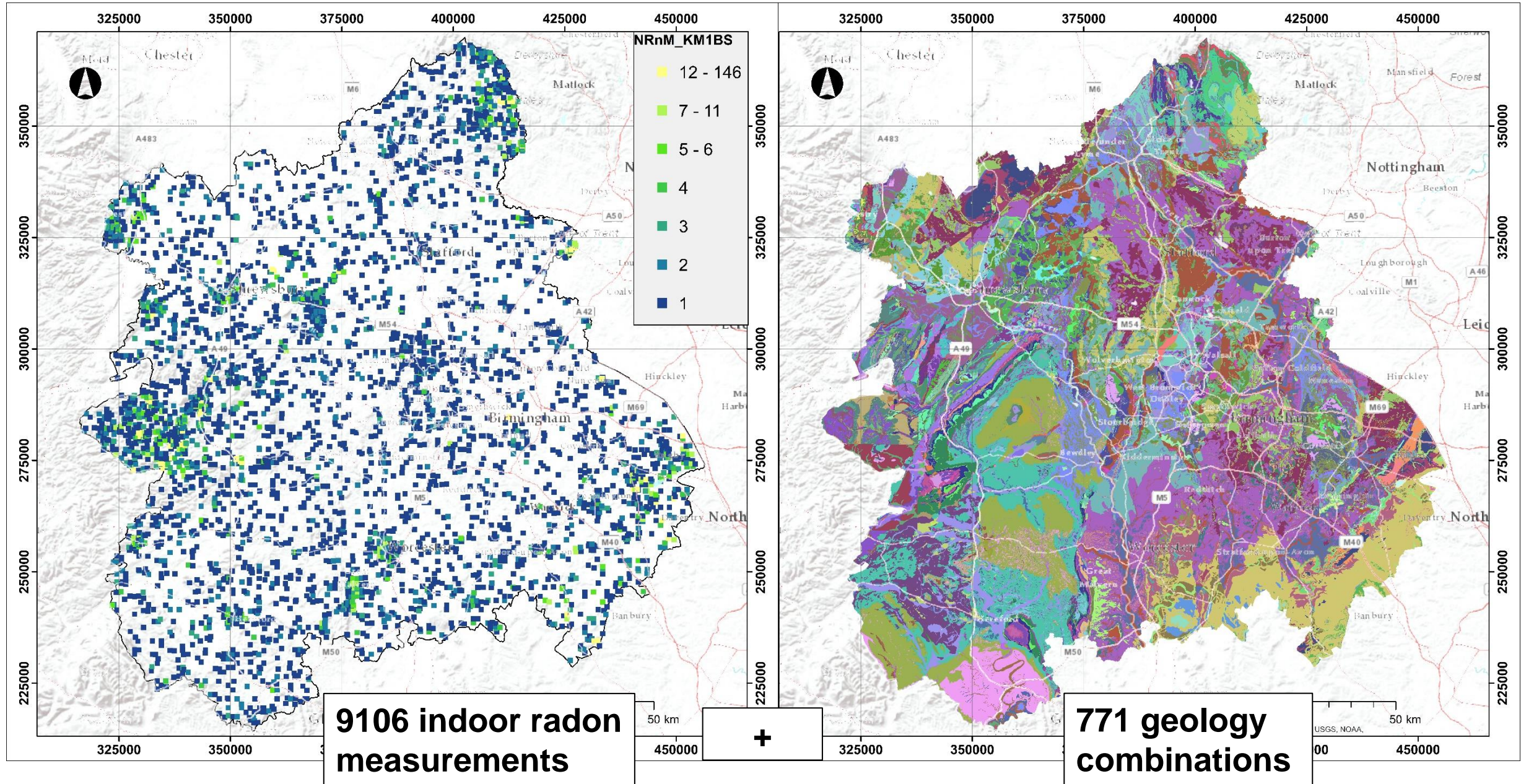
# The 4 Levels of Simplified Geology Detail in West Midlands:



|              | WM coverage | (GB coverage) |
|--------------|-------------|---------------|
| <b>UKHSA</b> | <b>77.4</b> | <b>(75.7)</b> |
| <b>BS</b>    | <b>8.0</b>  | <b>(8.8)</b>  |
| <b>BED</b>   | <b>7.8</b>  | <b>(12.1)</b> |
| <b>Lex</b>   | <b>5.7</b>  | <b>(2.6)</b>  |
| <b>RCS</b>   | <b>1.1</b>  | <b>(0.84)</b> |

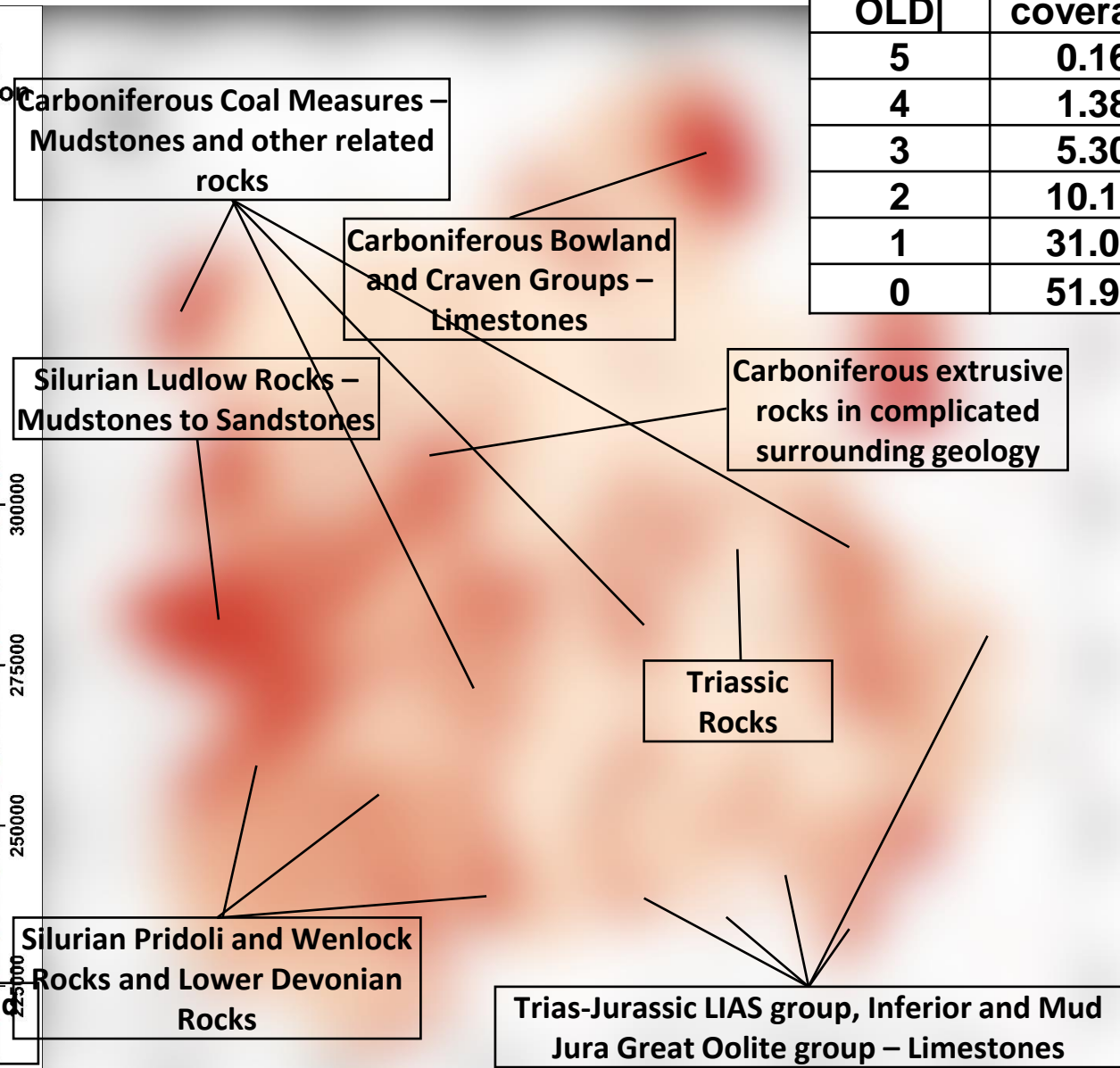
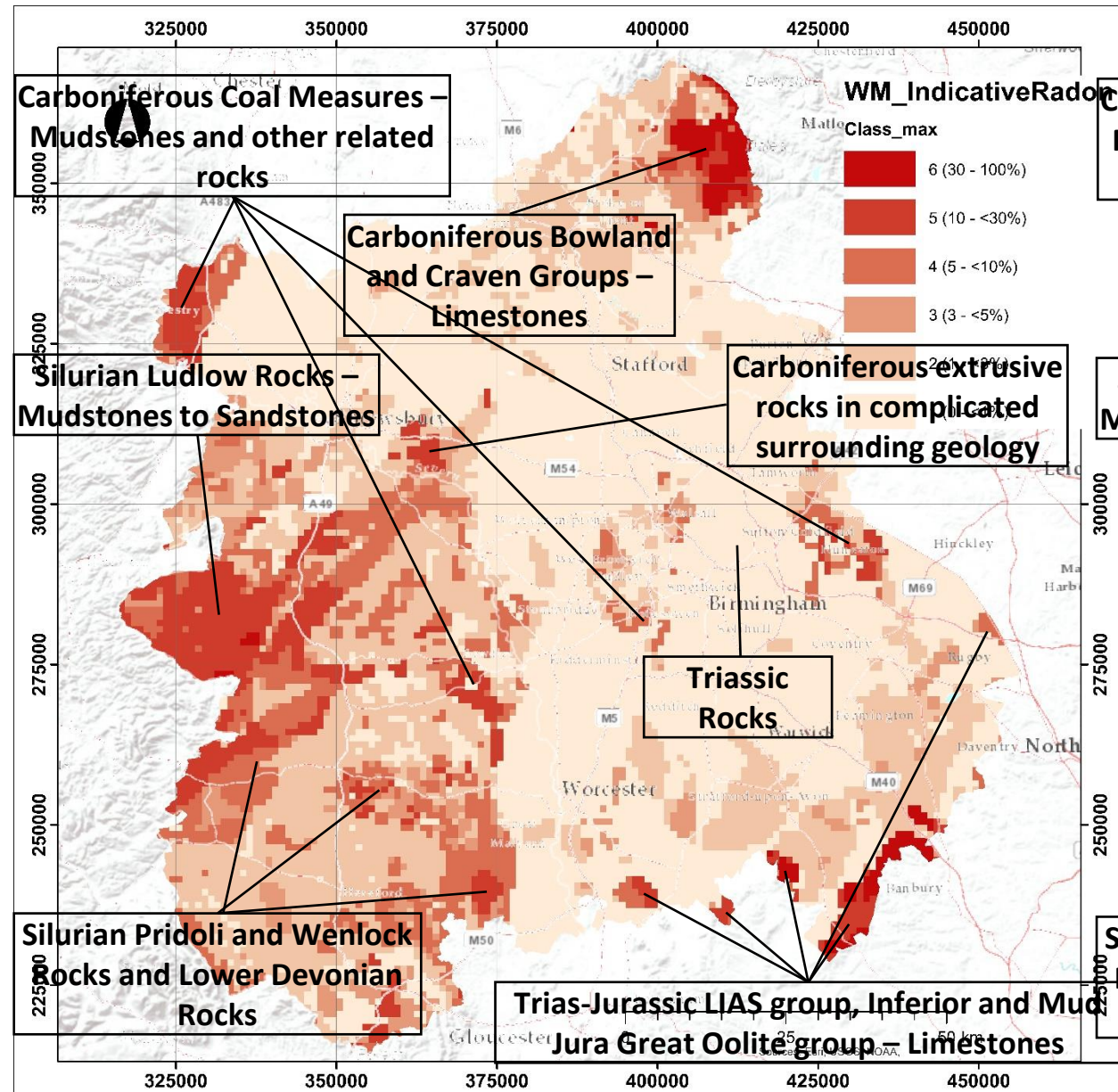


# Indoor Radon measurements + Geology in West Midlands





# Indicative Rn Map: OLD and NEW (West Midlands)



| NEW-OLD | % coverage |
|---------|------------|
| 5       | 0.16       |
| 4       | 1.38       |
| 3       | 5.30       |
| 2       | 10.13      |
| 1       | 31.08      |
| 0       | 51.95      |

THANK YOU!

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