French experience in management and research on the protection of building with respect to radon

Bernard Collignan

Radon Protection Conference, Dresden, 2nd and 3rd of December, 2013

Table

- Presentation of CSTB
- Radon management in France
- Information on building protection
- Examples of research studies
- Conclusion

Presentation of CSTB

Scientific and Technical Center for Building: independent French public institution dedicated to innovation in building, of around 900 employees

Public industrial and commercial establishment (known as an EPIC)

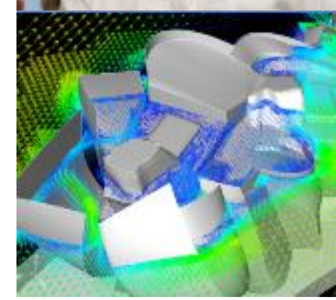
It is placed under the joint supervision of **Ministry of Housing** and **the Ministry of Ecology.**

Complementary areas:

- Research and innovative technology,
- Evaluation (tests and certification on construction products and processes)
- Knowledge dissemination towards professionals

Large range of disciplines in the field of construction:

acoustic, thermal engineering, lighting, environment, building structure, safety, health, economy, sociology, virtual reality,...

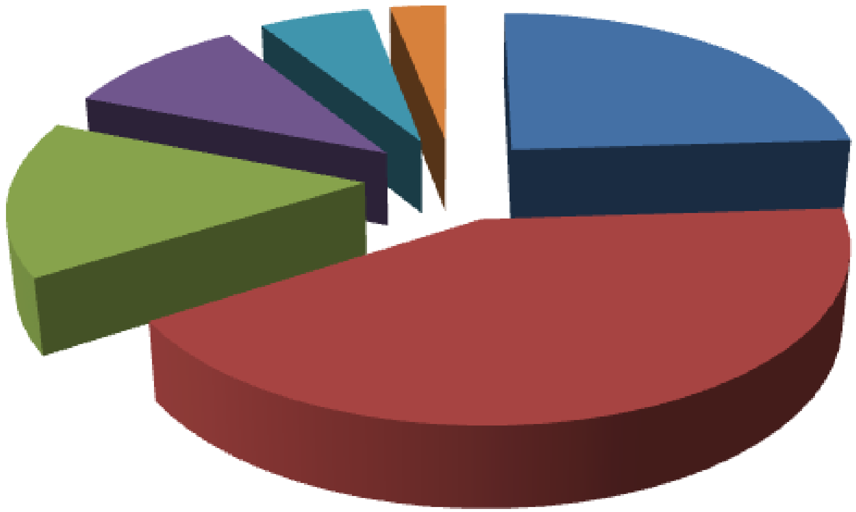


→ **contribution to the quality and safety of sustainable construction**

CSTB
le futur en construction

Radon Management in France

French exposure:



Source IRSN

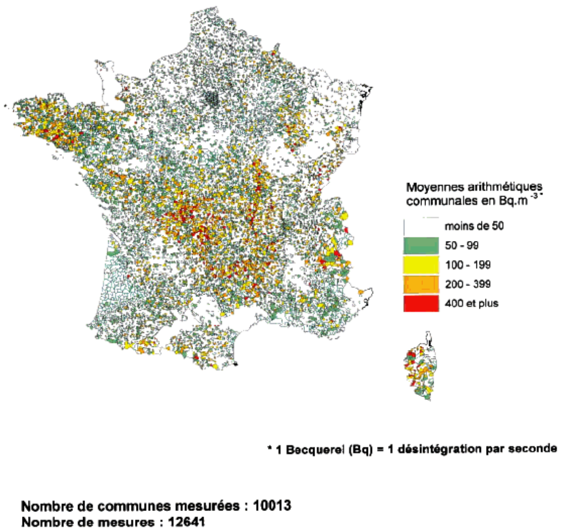
--> Total annual dose: 3,3 mSv

Risk assessment:

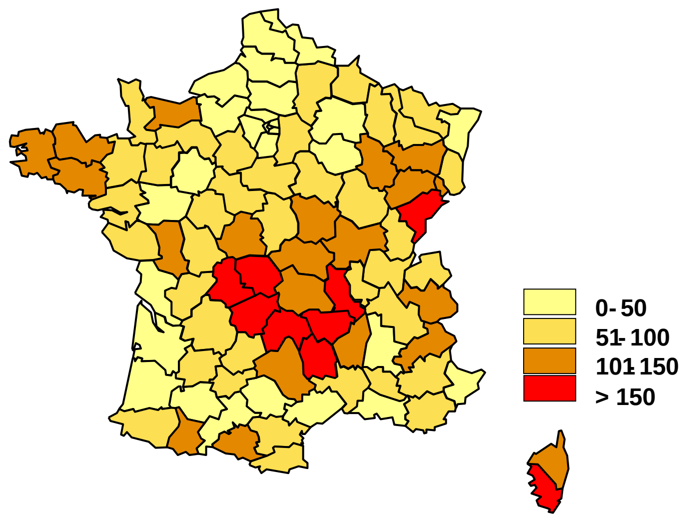
- excess risk of lung cancer
- 5-10% of lung cancers attributable to radon: between 1200 and 2900 deaths / year in France

  Aggravating factor: tobacco - *source InVS*
- Public health issue

Mapping



Measurement campaign in around 12 000 dwellings (DGS/IRSN)

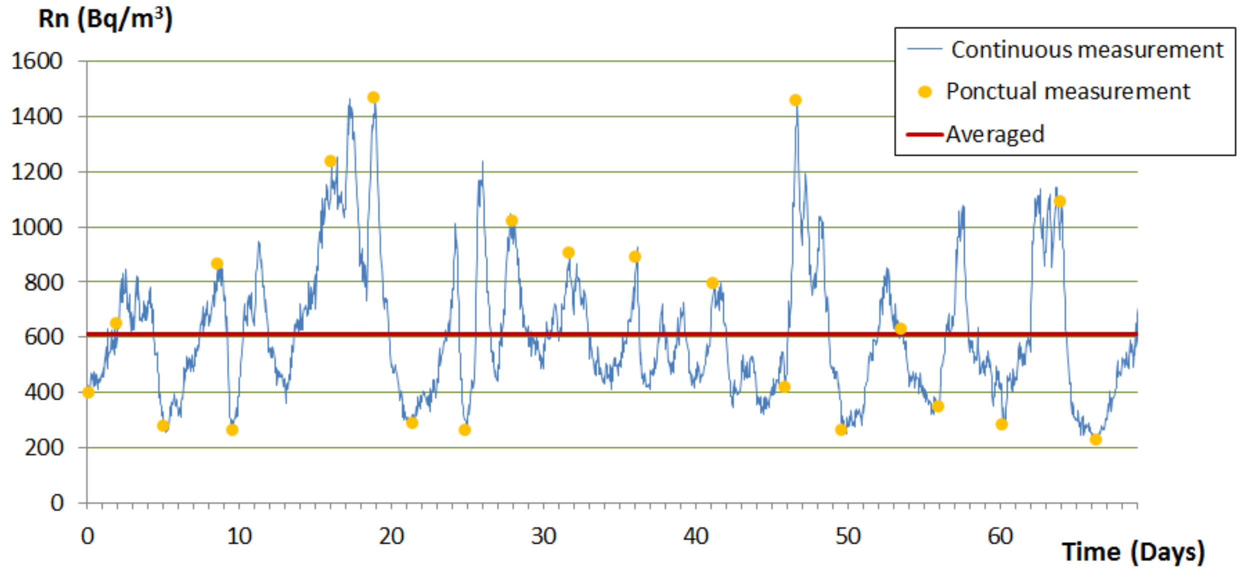


Definition of averaged departmental levels (Bq/m^3)

Definition of 31 priority departments for current regulation

Measurements

Example of Radon concentration evolution in a dwelling



Normalisation of screening methodology (NF ISO 11665-8)

- Two months measurement with passive dosimeter in living room during heating season to be representative of annual averaged measurement
- Used in current regulation for screening and control of efficiency of building protection

Current regulation

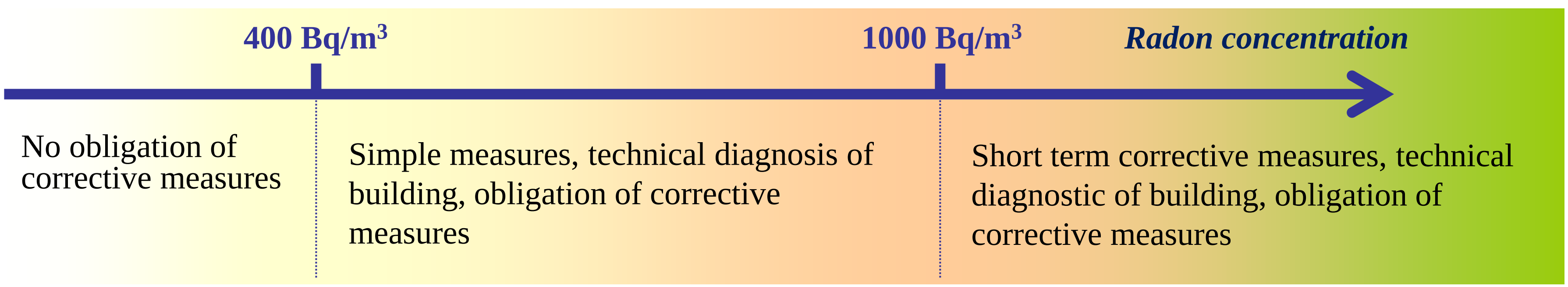
Existing Public buildings:

Decree of 22 July 2004: rules of risk management in some public buildings

Obligation of radon measurements:

- In the 31 priority departments
- Educational institutions, health and social institutions, jails and spas
- By agencies approved by Nuclear Safety Authority (ASN) (NF ISO 11665-8)

Obligation of implementation of corrective measures

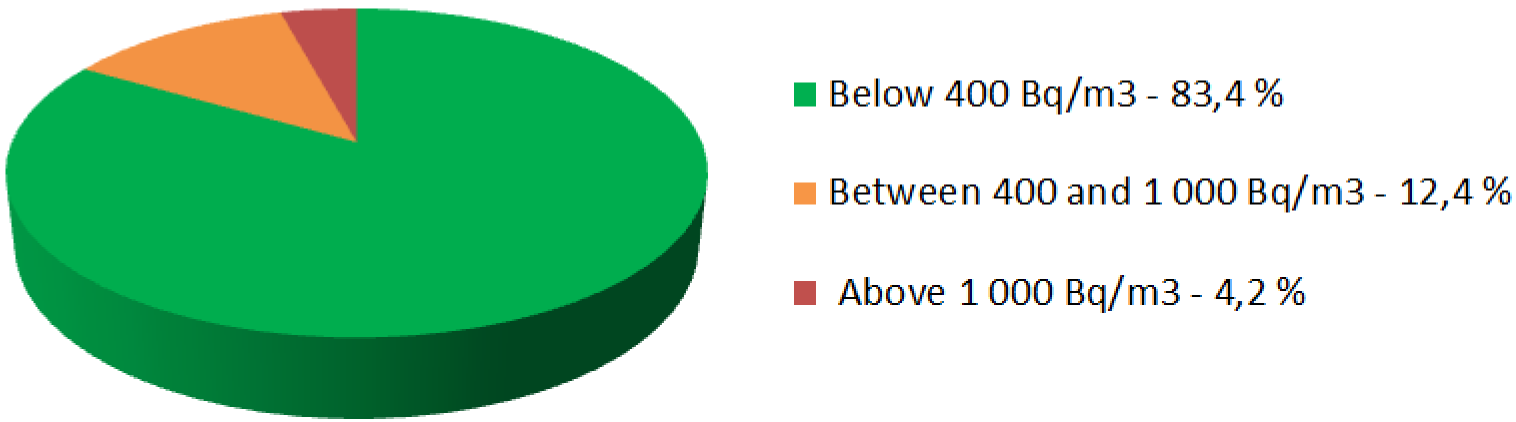


Current regulation

Feed back on measurements in existing Public buildings (2005-2011):

11 079 establishments screened including:

- 6 735 educational institutions,
- 4 301 health and social institutions,
- 20 spas,
- 23 jails.



Current regulation

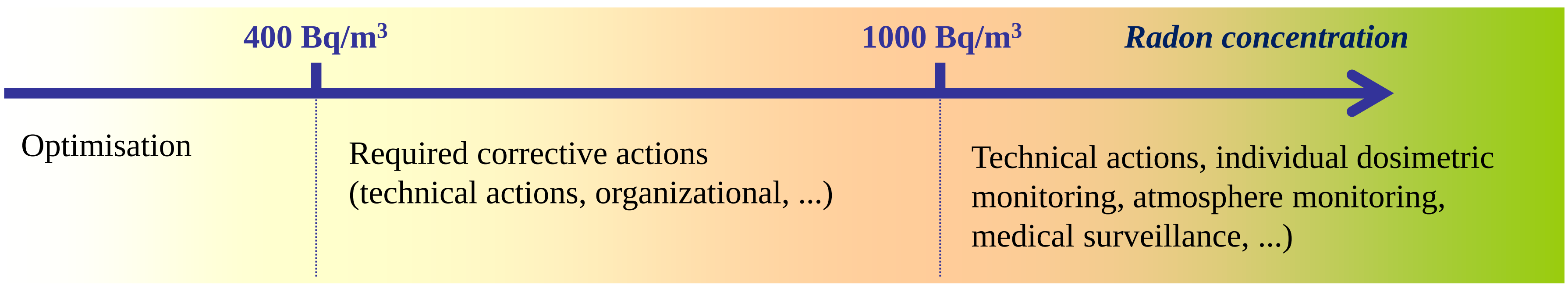
Underground workplaces:

Decree of 7 August 2008: rules of risk management in some underground workplaces

Obligation of radon measurements:

- In the 31 priority departments
- In the underground places for some professional activities, fixed by decree
- By agencies approved by Nuclear Safety Authority (ASN) (NF ISO 11665-8)

Obligation of action



Second National Action Plan (2011-2015)

Animated by The Nuclear Safety Authority (ASN)

In collaboration with the ministries involved:

- Department of Housing, Urbanism and Landscape (DHUP)
- General Direction of Health (DGS)
- General Direction of Labour (DGT)

And partner organizations:

- Institute for Radiological Protection and Nuclear Safety (IRSN)
- Scientific and Technical Centre for Building (CSTB)
- Health surveillance institute (InVS)

Regional relay:

- Regional Health Agencies (ARS)
- Local Technical centres (CETE)
- Local communities

Second National Action Plan (2011-2015)

Developped in continuity of previous plan (2005-2008) and within the logic of:

- The National Health and Environmental Plan (PNSE)
- The second Cancer Plan (2009-2013),
- The Health Work Plan (2010-2014)

Policy objectives:

- New mapping
- Exposure reduction in existing housing
- New rules of construction in new buildings
- Transposition of new Euratom Directive (action level: 300 Bq/m^3, impact of building material)

→ Ensure a low level of human exposure.

Success of the plan:

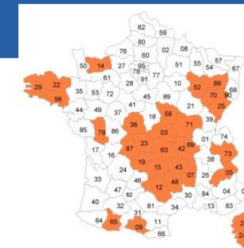
- Membership and collaboration of the various national and local actors,
- Regional initiatives, in the context of Regional Health and Environmental Plan:

→ To strengthen the skill of local actors

→ To make new partners emerge

→ To promote the sharing of expertise

New mapping

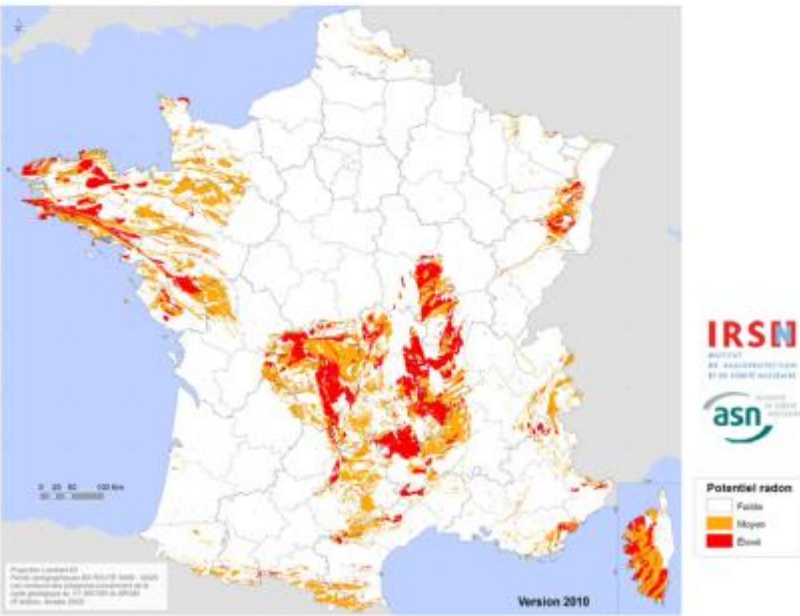


Existing mapping risk management:

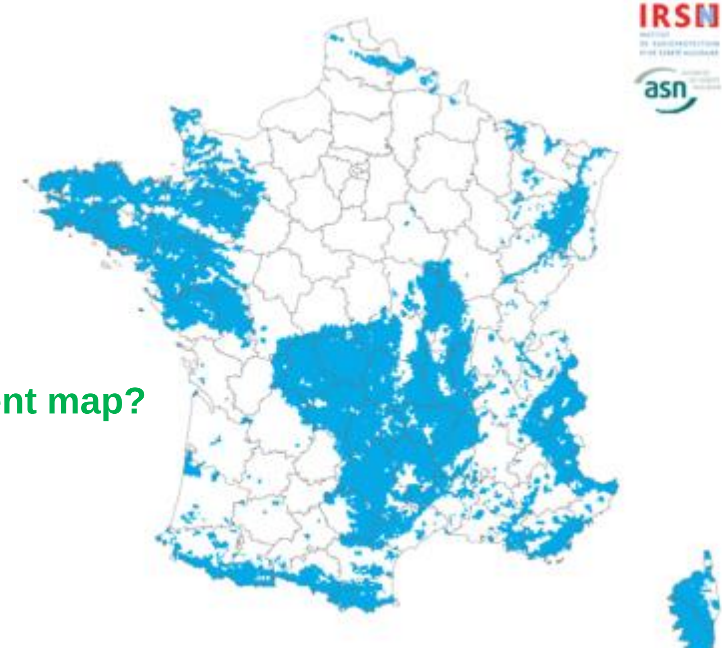
Definition of main radon areas but not enough precise for efficient management

IRSN built a new mapping for risk management linking:

Geological nature with cofactors facilitating the transport of radon in rocks and soils (faults, underground mine workings, hydrothermal sites)



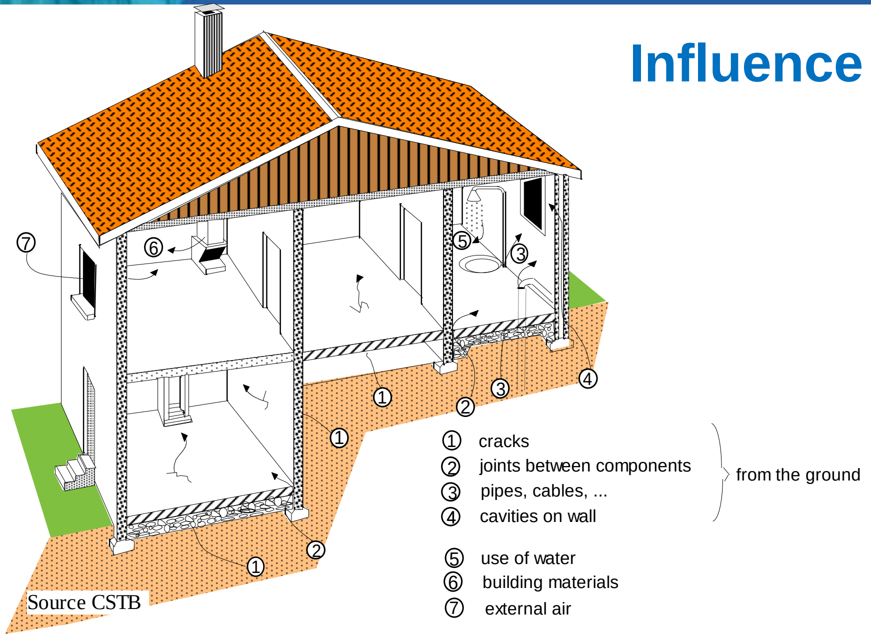
→ **Future Risk management map?**
Under discussions



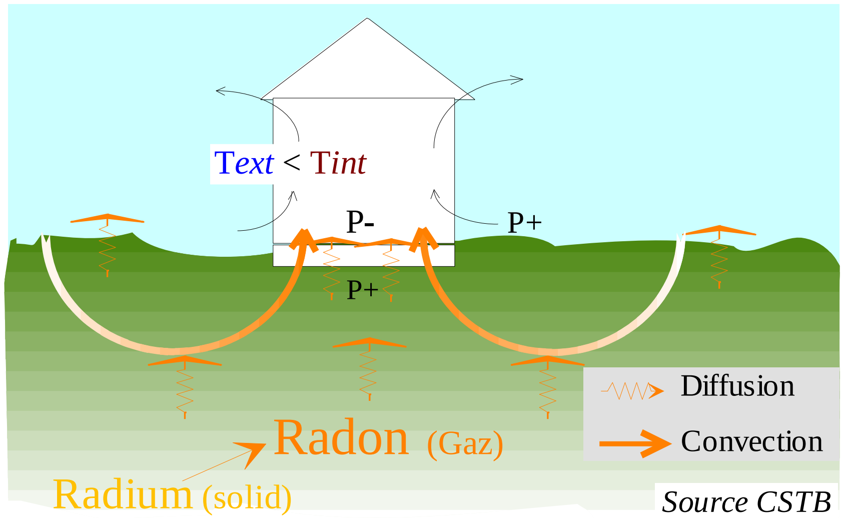
Radon potential map of geological formations

Map of municipalities affected by radon potential

Radon entry into building



Influence factors



Main process: convection generated by depression due to stack effect and wind

Indoor radon concentration:

- Underlying soil characteristics:

  Nature of the soil, air permeability, presence of cracks or fractures

- Specific building features:

  Nature and state of the basement, air permeability of the building, ventilation level, heating, number of floors of the building, etc..

- Behavior of the occupant.

  Airing (+), heating (-).

Building protection

Principles:

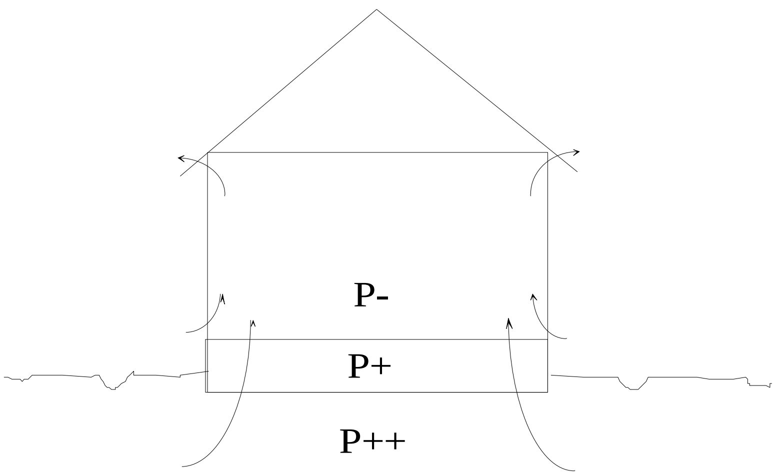
- Restrict the entry of radon
- Dilute the presence of radon in the building.

Solution Types:

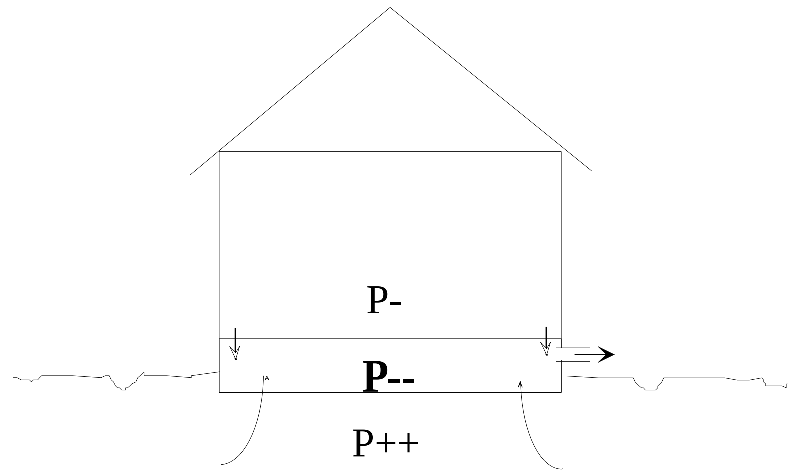
- Sealing the building interface with ground
- Building ventilation
- Treatment of the basement (ventilation, Soil Depressurization System)

Systematic approach using Soil Depressurization System (S.D.S.)

Principle of S.D.S.:



Initial state



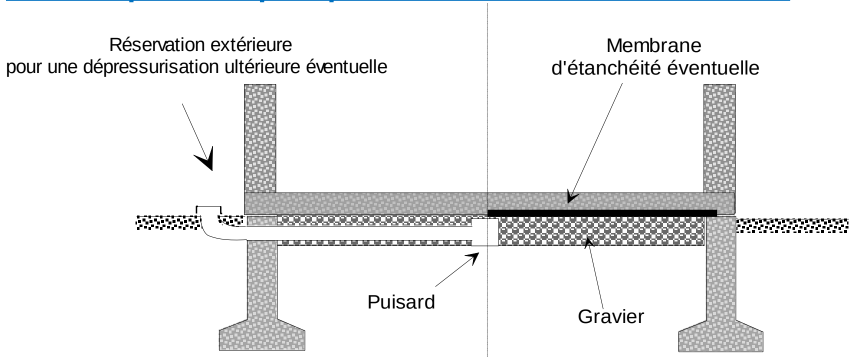
S.D.S.

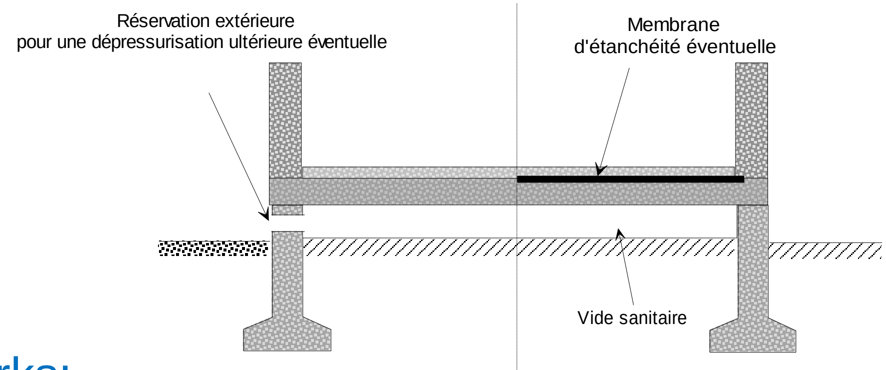
- To generate a slight depressurization of basement compared to indoor environment with low extract flow
- Associated with basement sealing

New building protection

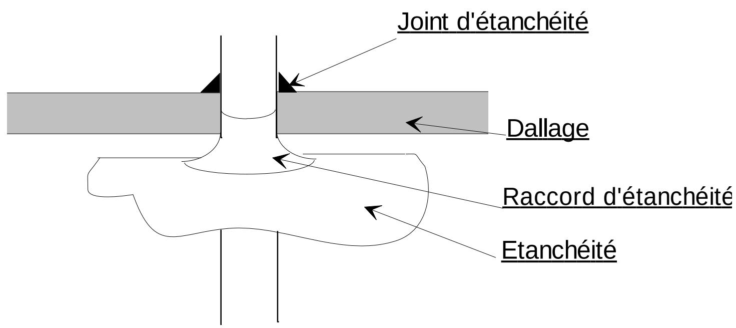
Systematic approach using Soil Depressurization System (S.D.S.)

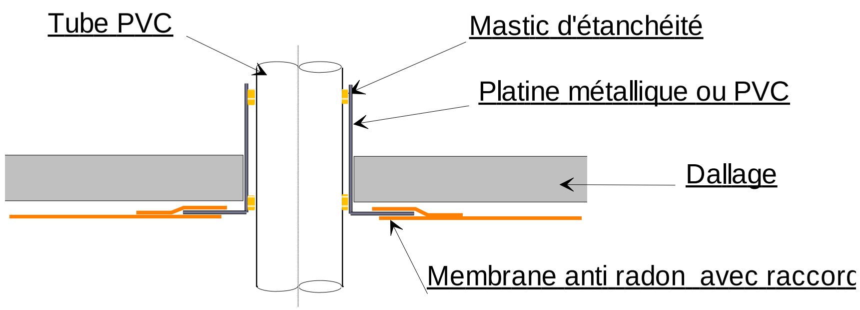
Principle of preparation of basement:





Examples of treatments for penetrations networks:





Easy to activate S.D.S. if necessary

Existing building protection

Disparity of situations

Solution protections to implement depend on:

- Level screening measures (NF ISO 11665-8)
- Building characteristics

solutions defined on a case by case basis, could be an iterative process

Appropriate combination:

- Sealing basement interface,
- Building ventilation,
- Treatment of basement

Importance of proper identification of the structure and building systems

Remediation efficiency in existing building

Feedback on the efficiency of solutions implemented in public buildings:

		Number of cases	%age
Control measurement	Below 400 Bq/m^3	49	40
	Above 400 Bq/m^3	73	60
	with:		
	Between 400 and 1 000 Bq/m^3	57	47
	Above 1 000 Bq/m^3	16	13

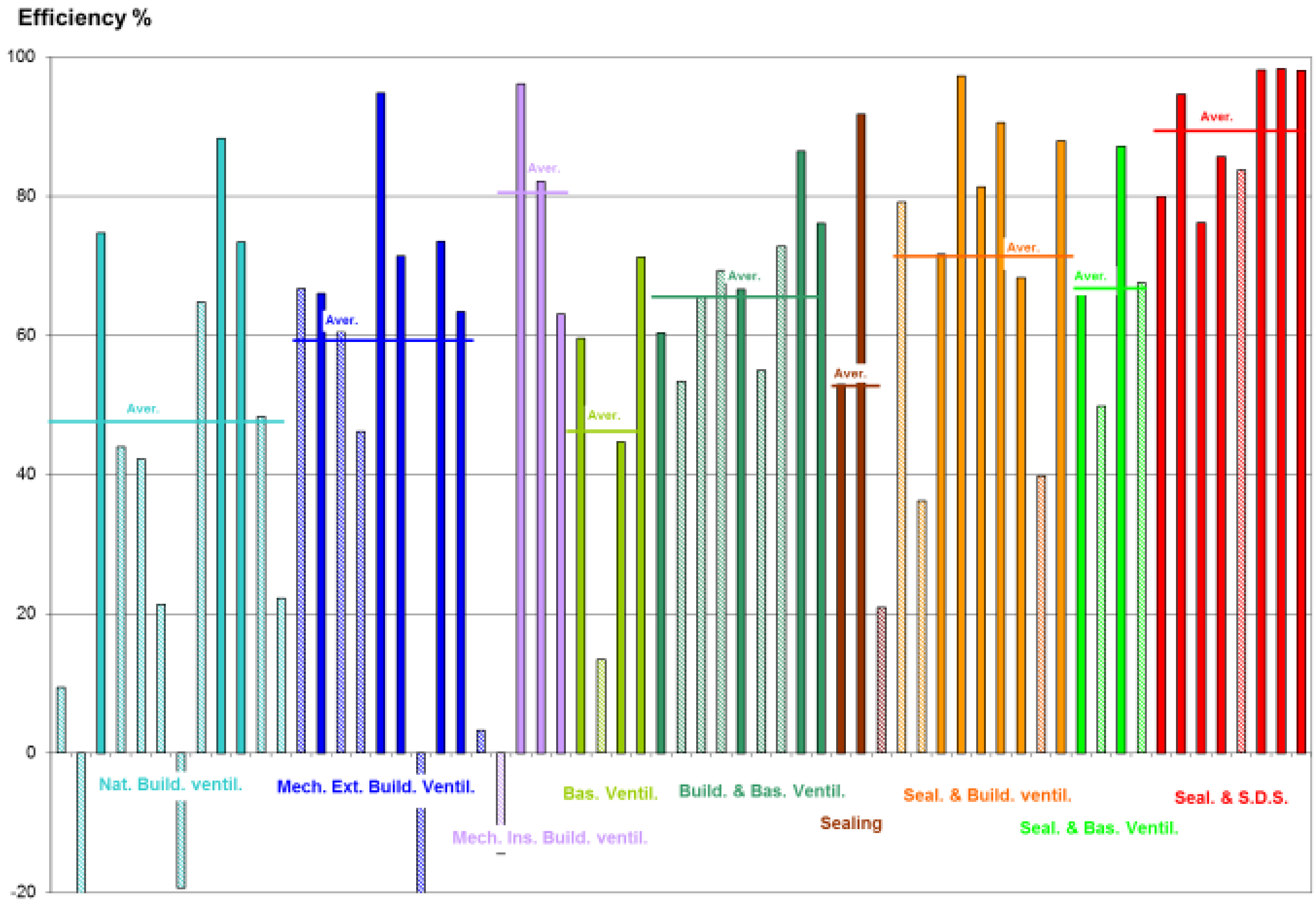
Levels of measurement controls obtained after remediation compared to the two action thresholds 400 Bq/m^3 and 1000 Bq/m^3
(122 cases, ASN data)

Remediation efficiency in existing building

Feedback on the efficiency of solutions implemented in public buildings:

Very variable and
not always satisfactory

- Radon pathways not always easy to identify.
- Building characterization should be undertaken in a relevant way
- Knowledge of actors not sufficient



Complementary tool for existing buildings

to support the management process of radon reduction in existing buildings

French experimental norm (February 2011):

Referential for technical diagnosis related to the presence of radon in buildings
Mission and methodology (NF X 46-040)

Objectives :

- to identify the causes of radon presence in the building
- to provide the necessary building description for the choice of remediation techniques best suited to the case encountered.

Technical content:

- Undertaken after screening measurement (NF ISO 11665-8),
- Qualitative analysis of building and basement structure, ventilation systems, occupant behaviour, …

Collect of information and building visit:

Geology, Site and building history, climatic conditions, building description, structure, basement, networks, materials, systems (ventilation, heating, …)

Could be completed with:

- Additional radon measurements (NF ISO 11665-8),
- Ventilation measurements

Applied research at CSTB

Aim of research:

- To ameliorate building protection
- To help authorities and building actors in risk management

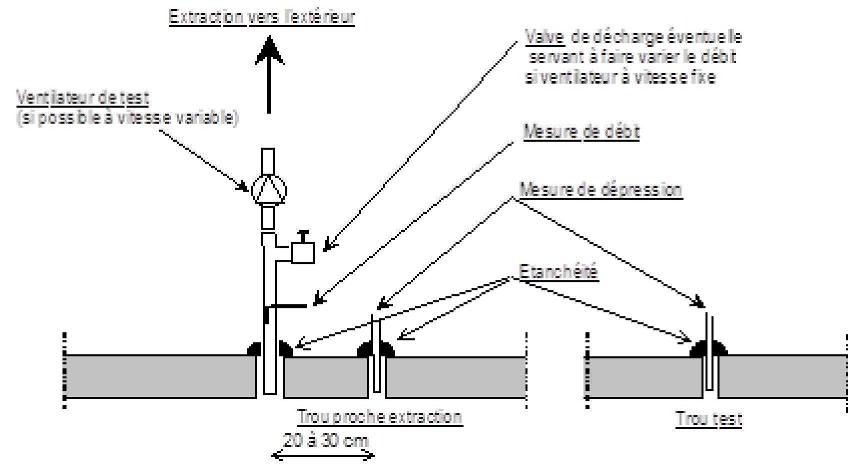
Some topics:

- Test of faisability for S.D.S. in existing building
- Use of existing mechanical ventilation system for S.D.S.
- Experimental study on passive S.D.S and modeling
- Efficiency of mechanical insufflating ventilation
- Building characterisation related to radon entry and exposure
- Impact of thermal rehabilitation on radon exposure

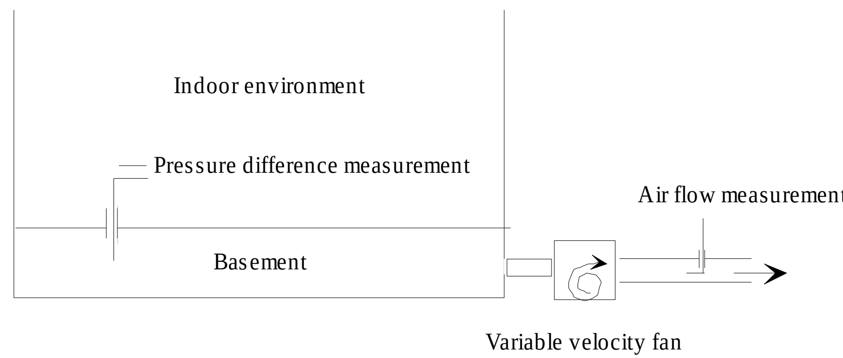
Test of faisability for S.D.S. in existing building

Principle:

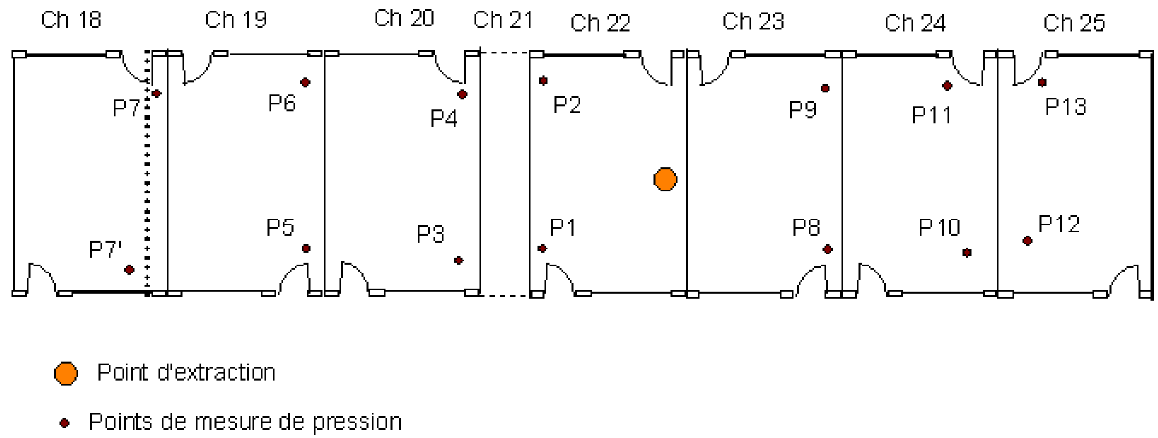
- To manage a hole on slab,
- To extract air flow from the ground,
- To measure the air flow,
- To measure pressure difference either side of the floor at different points



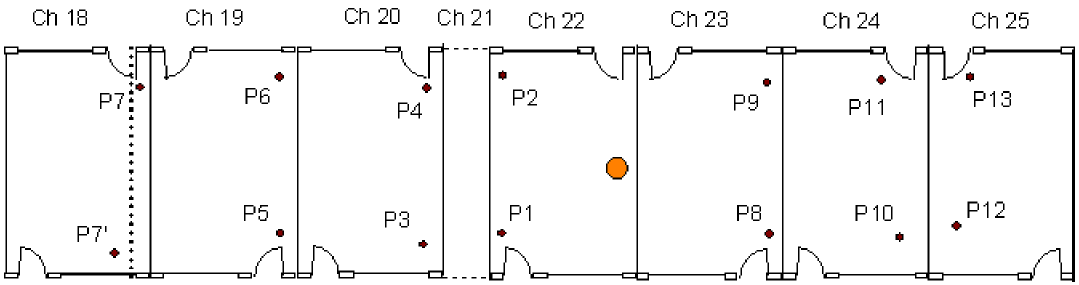
- ➢ Characterisation of air permeability of the ground below the floor
- ➢ Mechanical faisability of SDS
- ➢ Associated with continuous radon measurement: efficiency of SDS



Test of faisability for S.D.S. in existing building

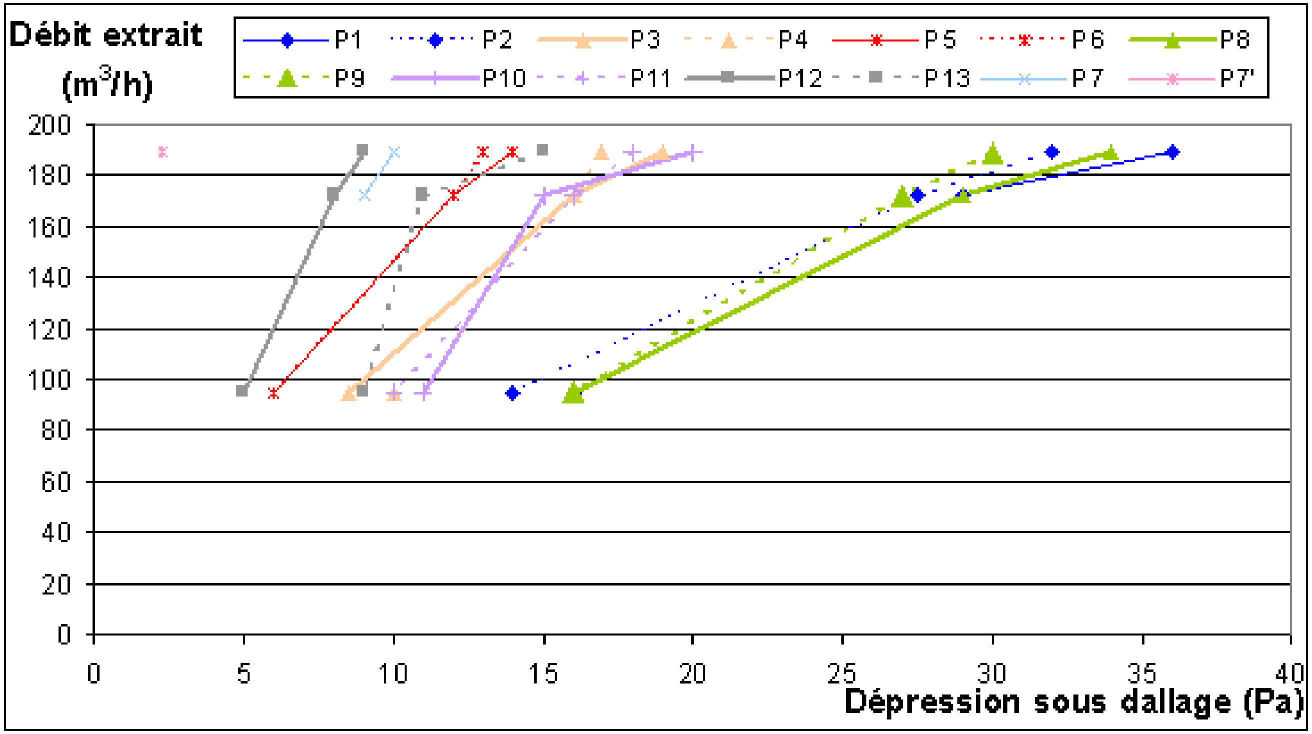


Test of faisability for S.D.S. in existing building

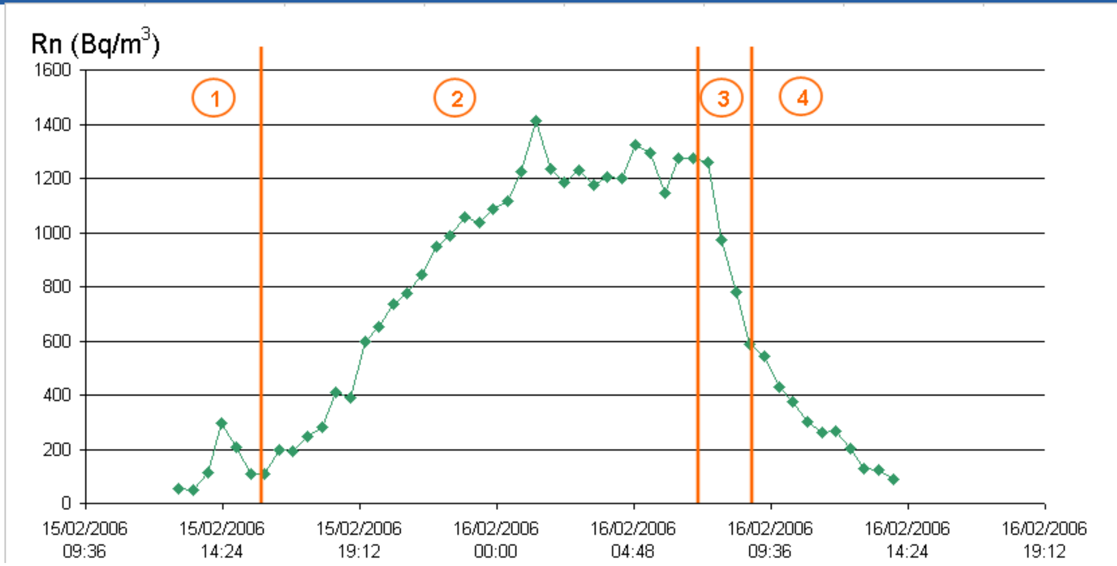


Point d'extraction

Points de mesure de pression



Test of faisability for S.D.S. in existing building



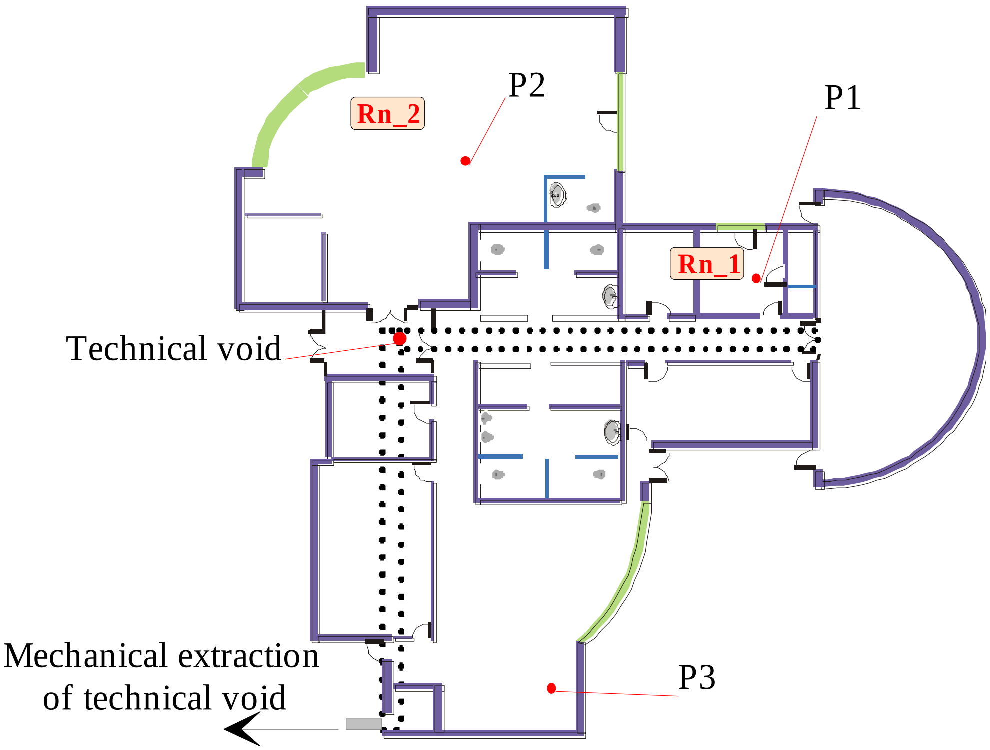
3: starting point of S.D.S. running

Installing real system:

Duct in a room

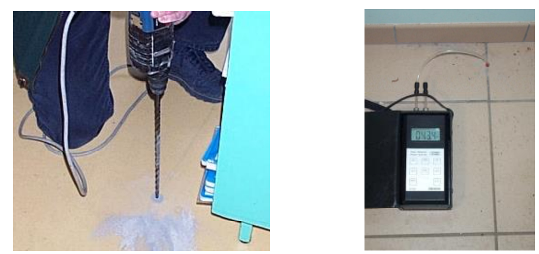
Fan below roof

Test of faisability for S.D.S. in existing building



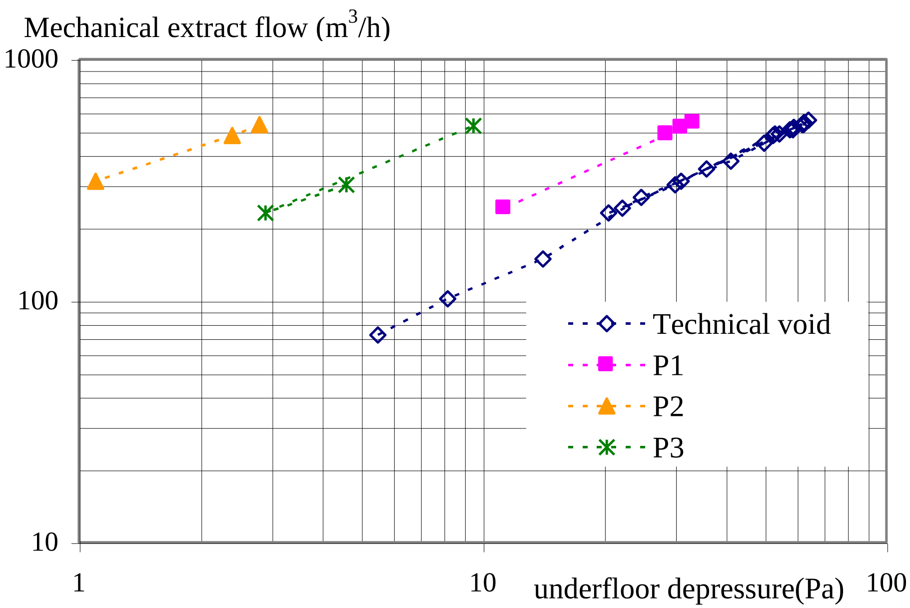
Technical void

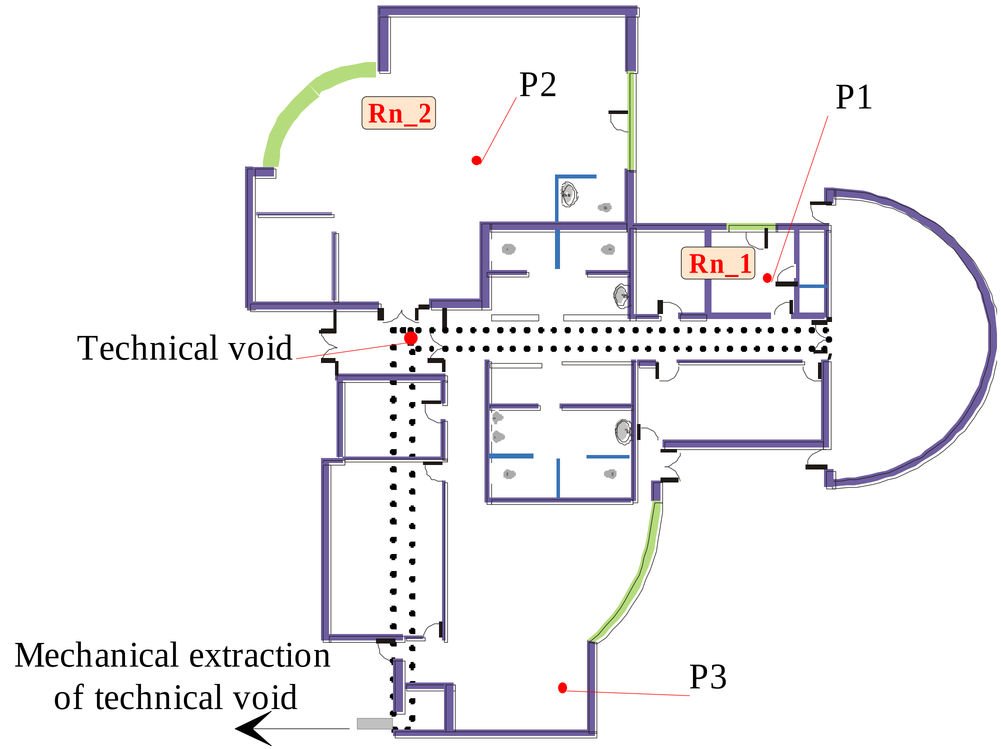
Mechanical extraction from technical void



Depression measurement below slab

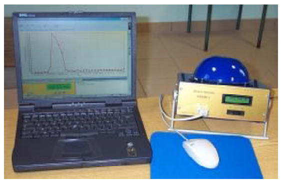
Test of faisability for S.D.S. in existing building



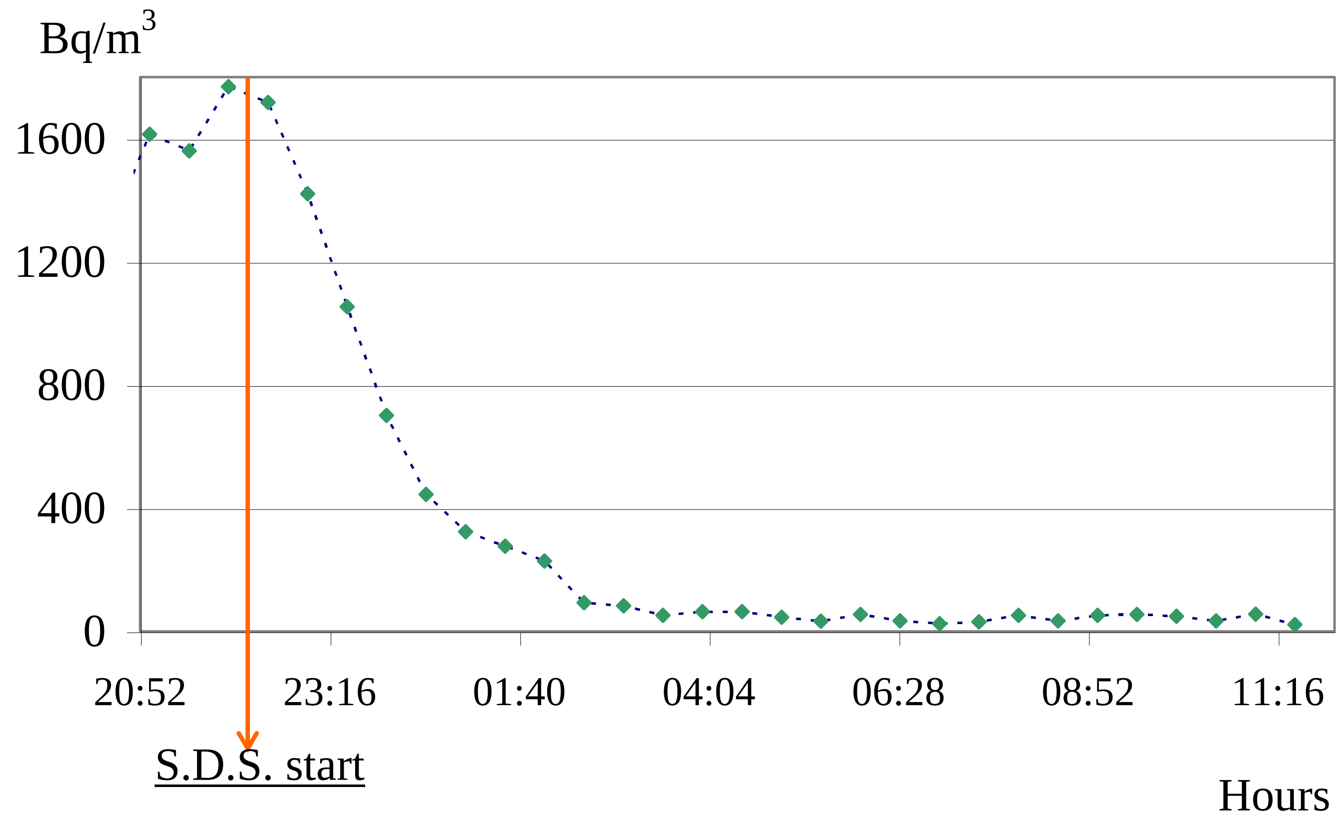


Test of faisability for S.D.S. in existing building

Impact of S.D.S. running on indoor radon concentration

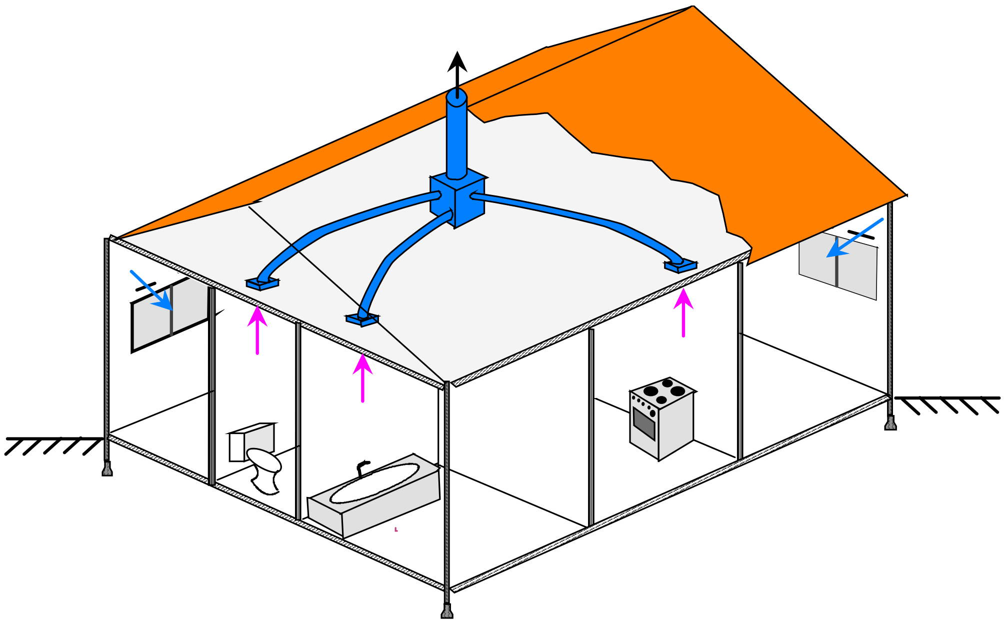


Radon measurement



Use of existing mechanical ventilation system for S.D.S.

Description of Mechanical Exhaust Ventilation Principle in a dwelling



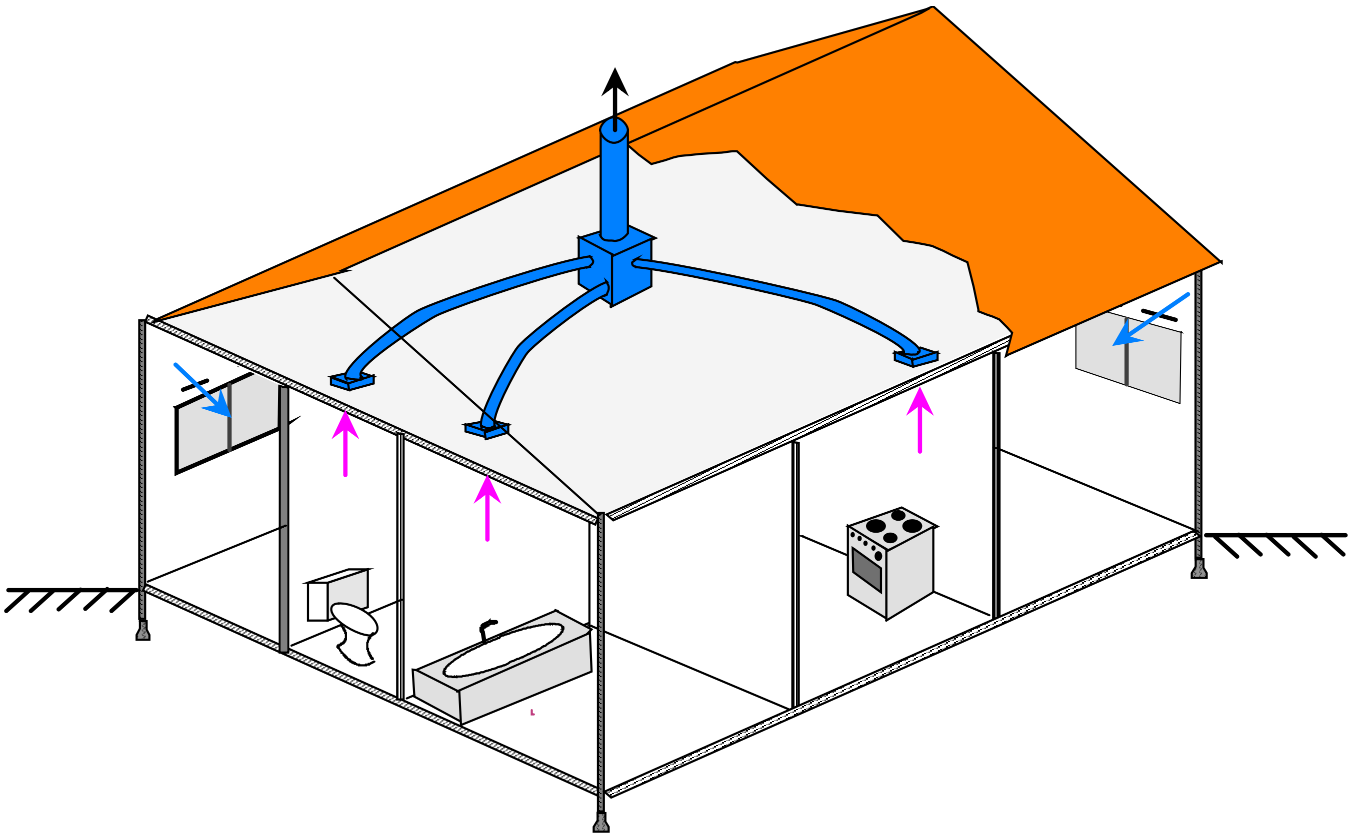
Kitchen	45 m^3/h
Kitchen, high flow, cooking activity	135 m^3/h
Bathroom	30 m^3/h
Toilet	30 m^3/h
Optional other bathroom	30 m^3/h
Optional other toilet	15 m^3/h

5 living room

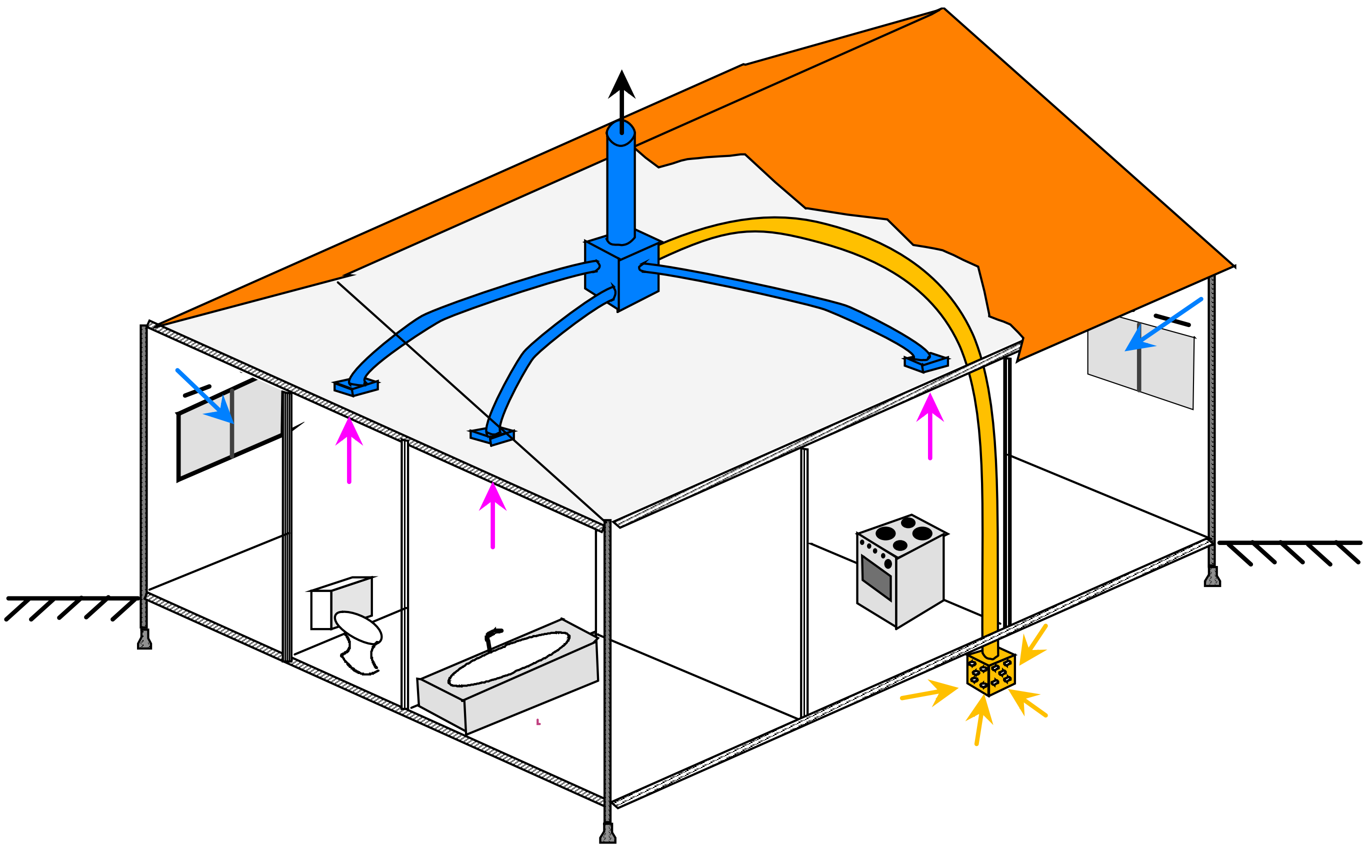
Self regulated registers to obtain required exhaust flow

Use of existing mechanical ventilation system for S.D.S.

S.D.S. connexion to the exhaust unit



S.D.S. connexion to the exhaust unit



Use of existing mechanical ventilation system for S.D.S.

Results

		Dwelling ventilation			S.D.S.	
		Kitchen exhaust flow (m^3/h)	Bathroom exhaust flow (m^3/h)	Toilet exhaust flow (m^3/h)	basement exhaust flow (m^3/h)	***Basement depressurization (Pa)***
Only mechanical ventilation	Low velocity	55	35	34		
	High velocity	149	30	30		
Sump with 15 m^3/h theoretical register	Low velocity	52	34	33	20	***5.8***
	High velocity	131	29	28	17	***4.8***
Sump with 30 m^3/h theoretical register	Low velocity	52	35	33	32	***12***
	High velocity	140	31	30	28	***9.9***
Sump connexion with no register	Low velocity	49	32	31	45	***18.9***
	High velocity	123	29	29	40	***14.9***

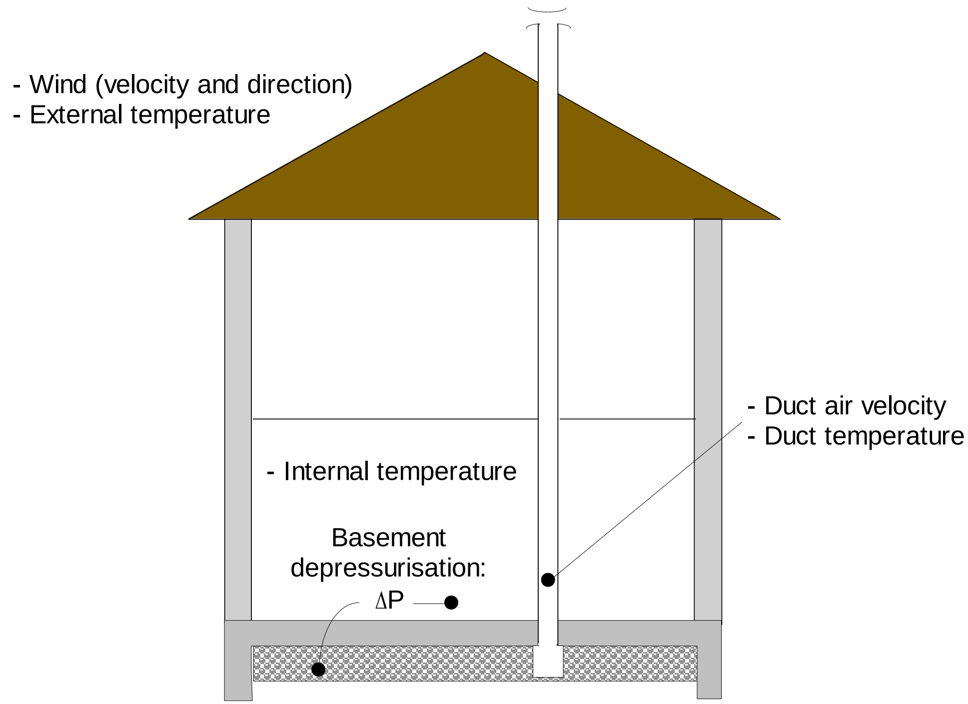
Kitchen, bathroom and toilet connexion configuration

Experimental study on passive S.D.S and modeling

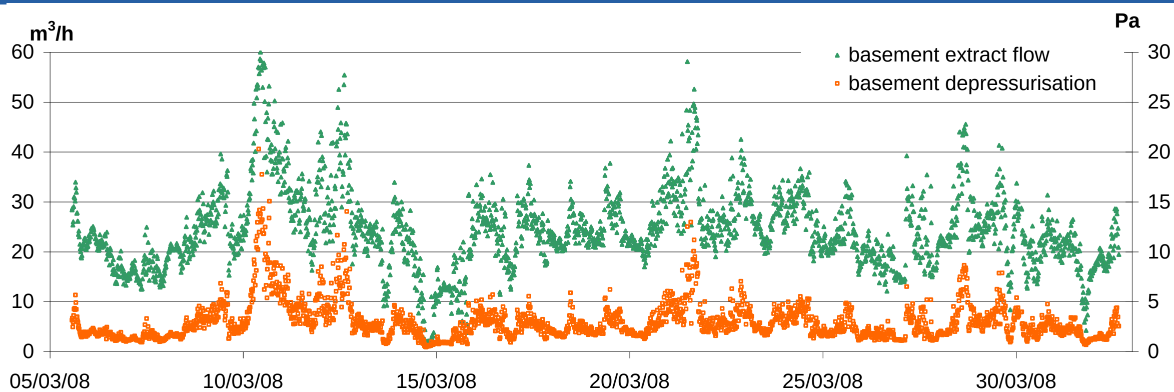
One year follow up to assess mechanical efficiency of passive SDS

In situ experimental dwelling

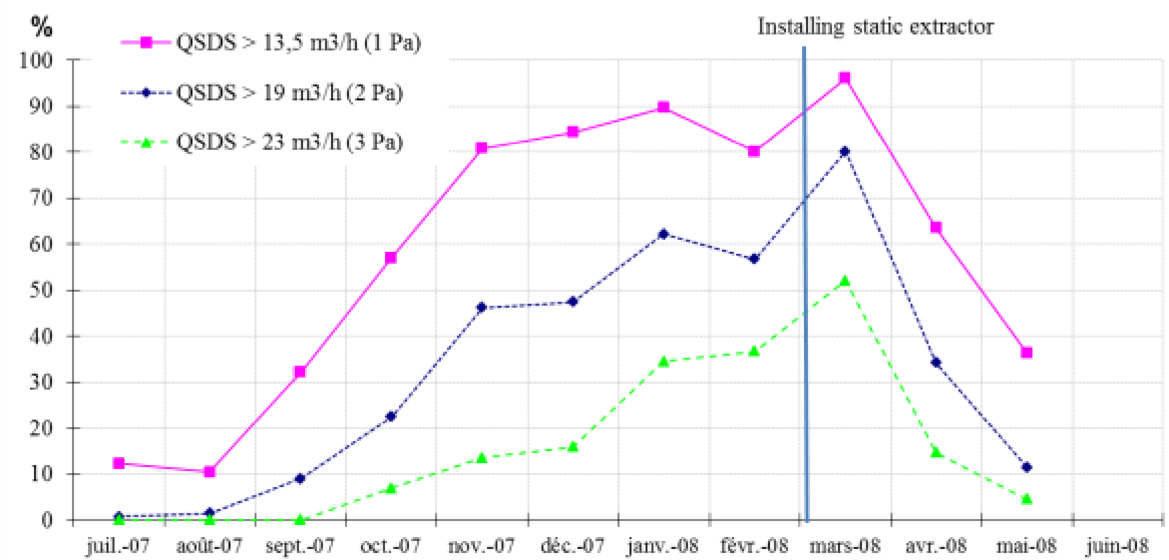
Adaptation of initial sump



Experimental study on passive S.D.S and modeling



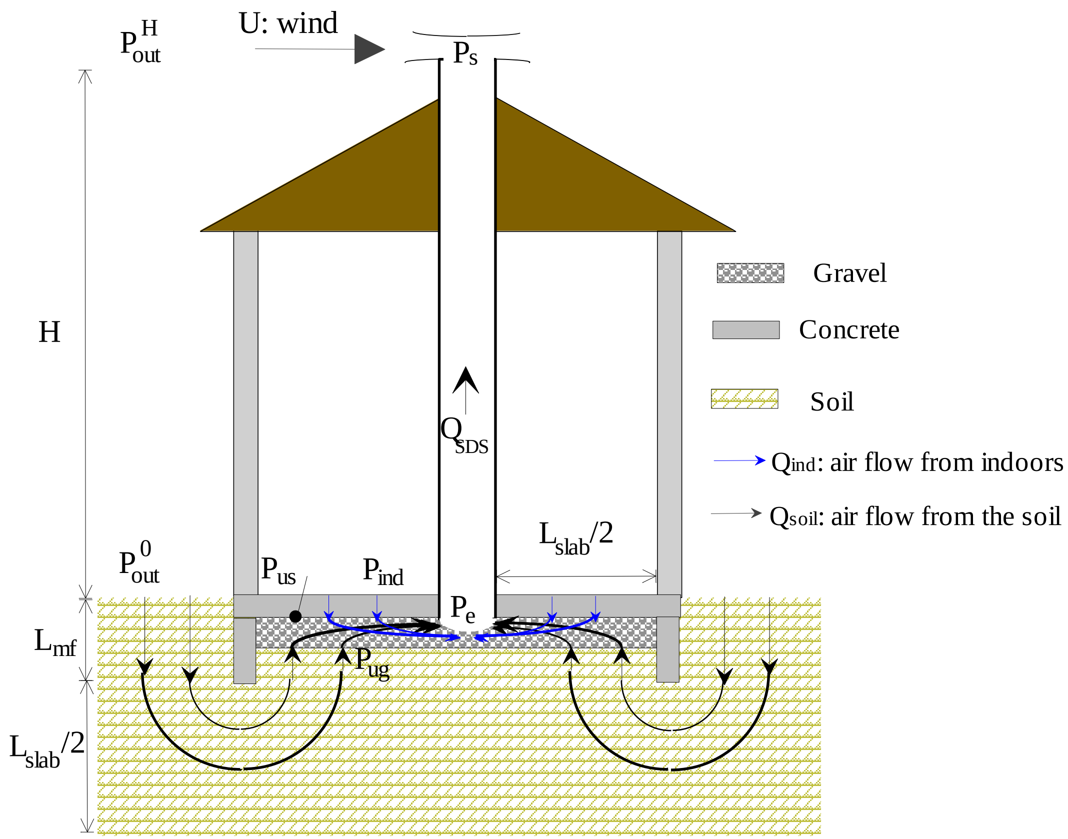
Evolution of basement extract flow (Q_{SDS}) and basement depressurisation



Monthly percentage of running time of SDS above three thresholds

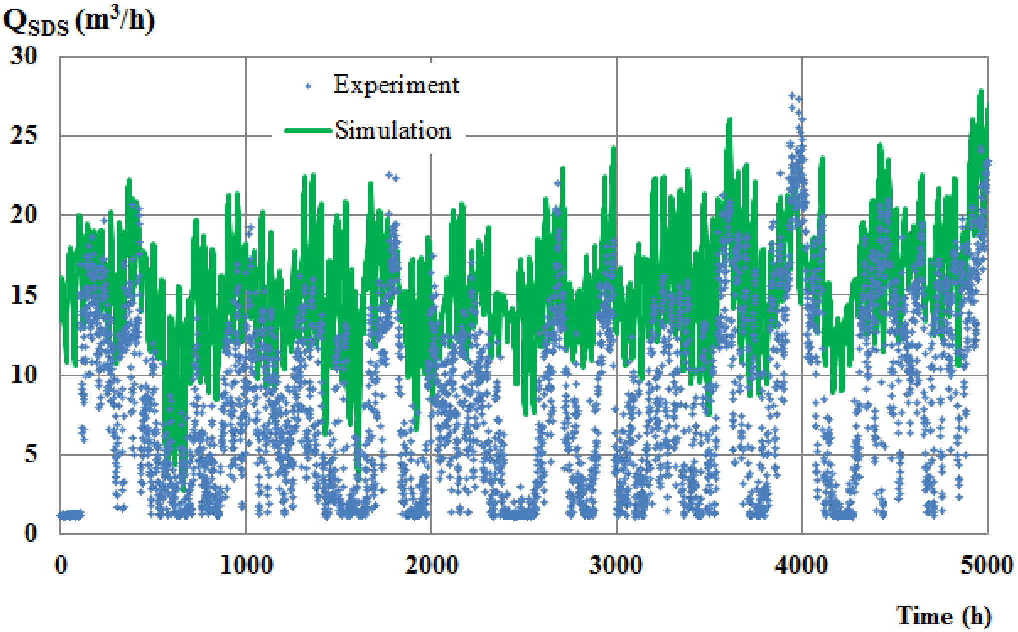
Modeling:

to develop an analytical model to determine the mechanical running characteristics of a passive SDS (Q_{SDS} and P_e) as a function of building characteristics and meteorological conditions

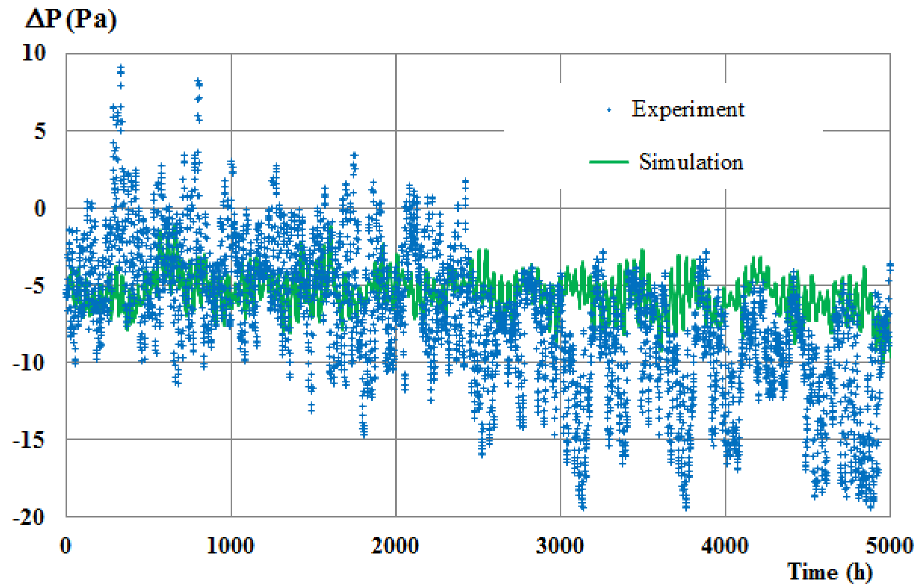


$$Q_{SDS} = Q_{ind} + Q_{soil}$$

Modeling: controntation with experimental data



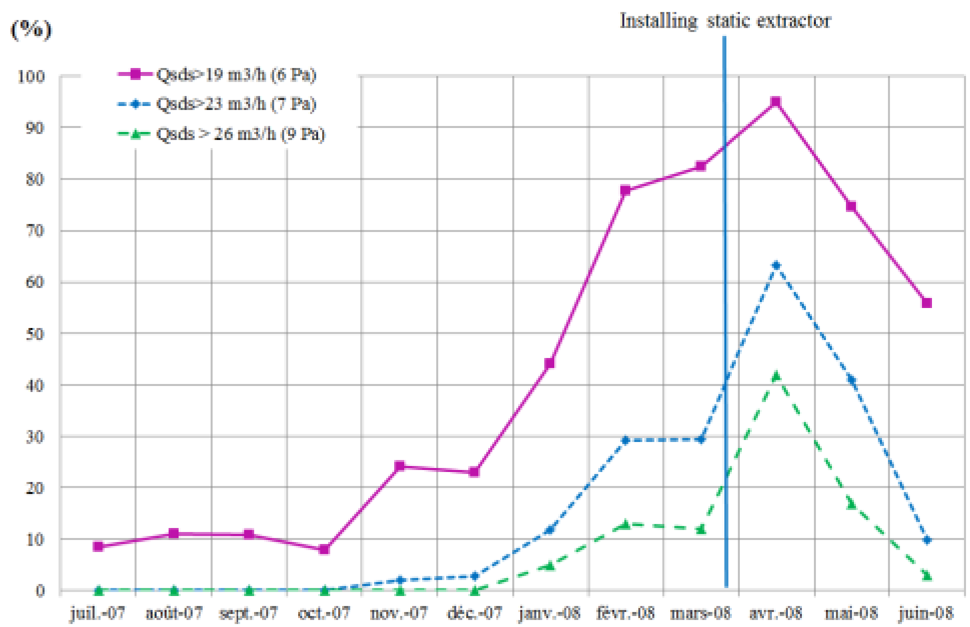
Airflow trough SDS duct



Gravel depressurization

Experimental study on passive S.D.S and modeling

Modeling: sensitivity studies



Monthly percentage of running time of SDS above three thresholds

→ **To test and to dimension passive SDS in a given configuration: Building, climate**

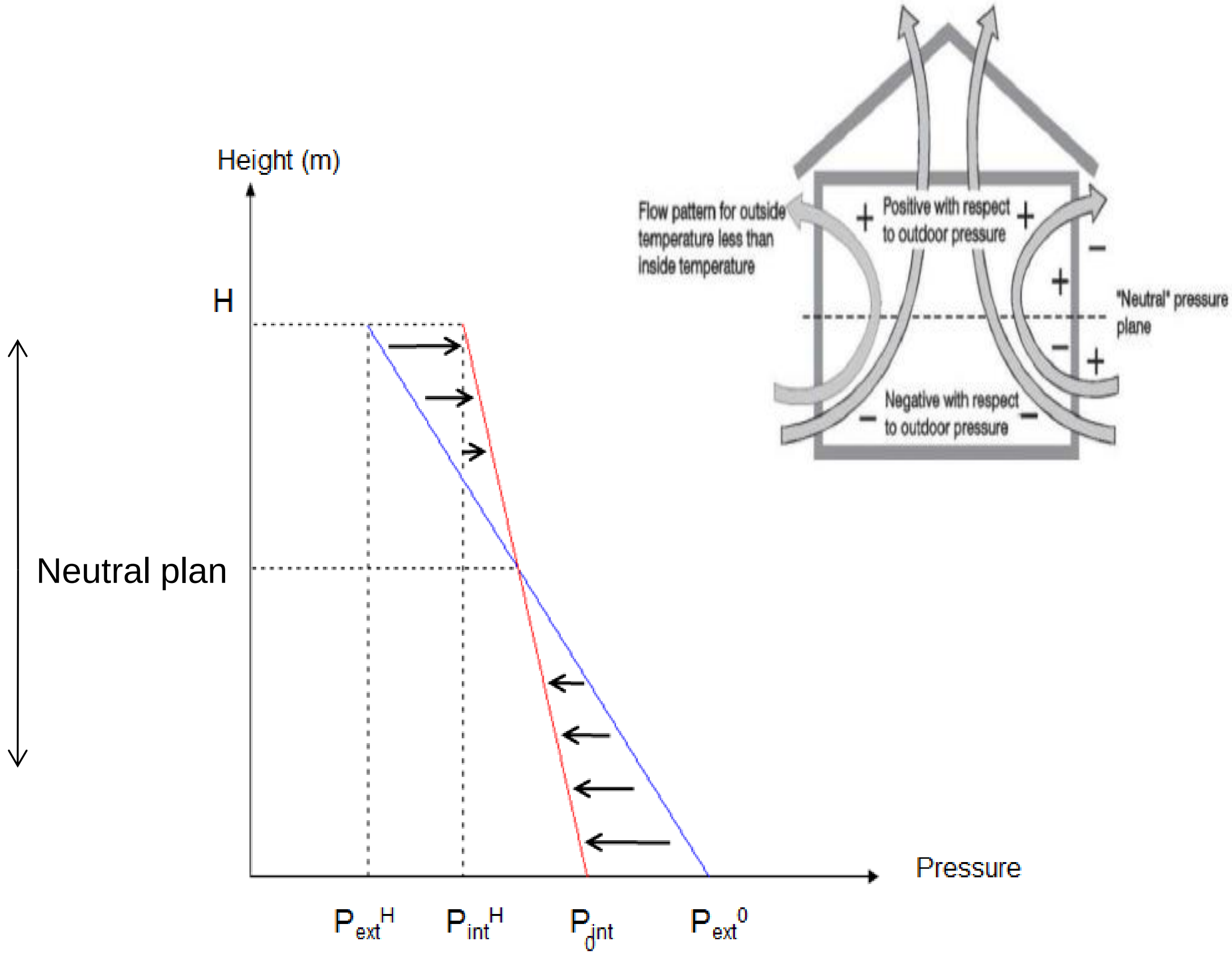
Efficiency of mechanical insufflating ventilation

Use of mechanical **extraction** for ventilation: enhance depressurisation at floor level

Use of mechanical **insufflation** for ventilation: diminish depressurisation at floor level

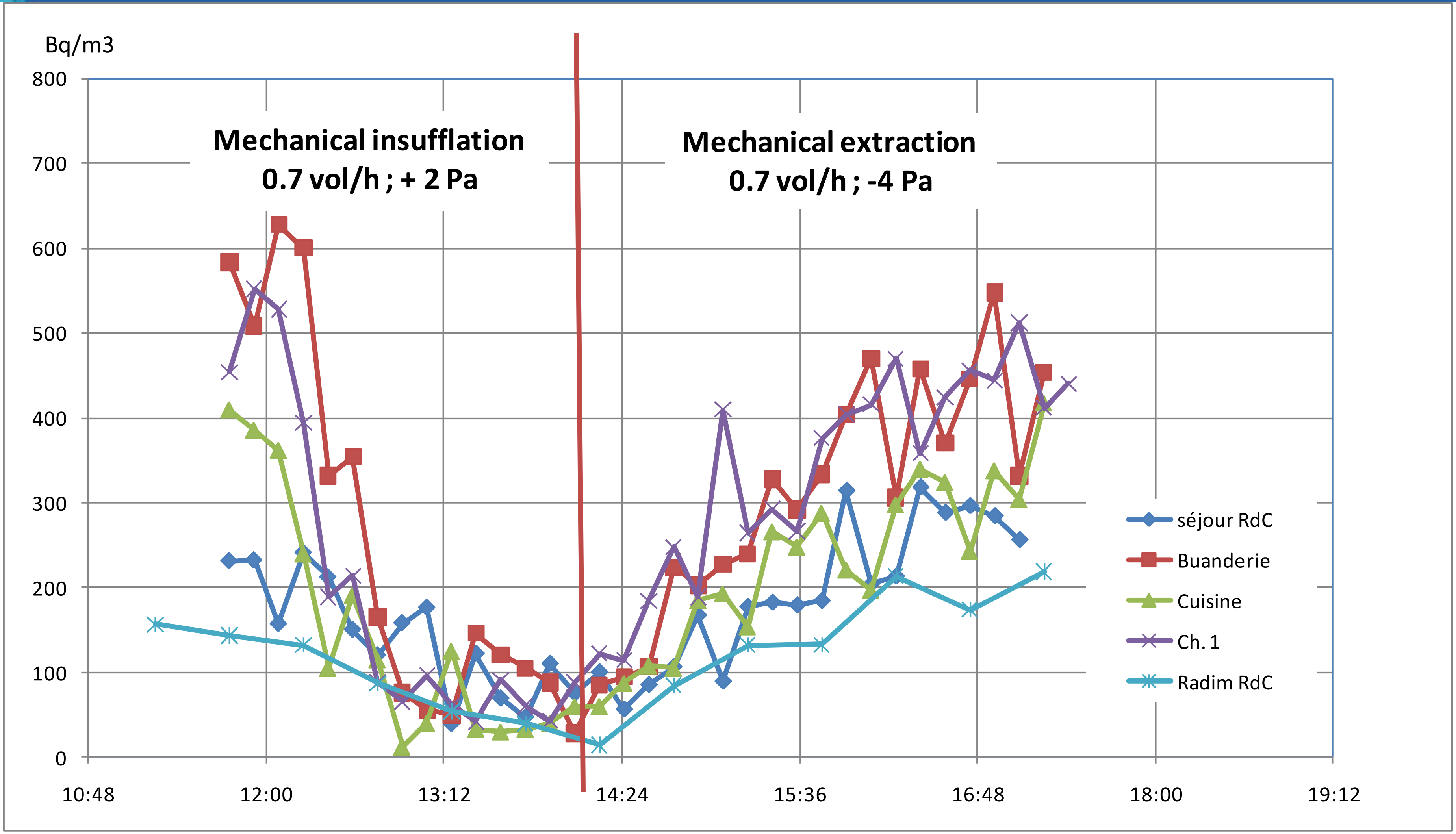
$$P_{\text{int}}{}^{H} = P_{\text{int}}{}^{0} - \rho_{\text{int}} \cdot g \cdot H$$

$$P_{ext}{}^{H} = P_{ext}{}^{0} - \rho_{ext} \cdot g \cdot H$$

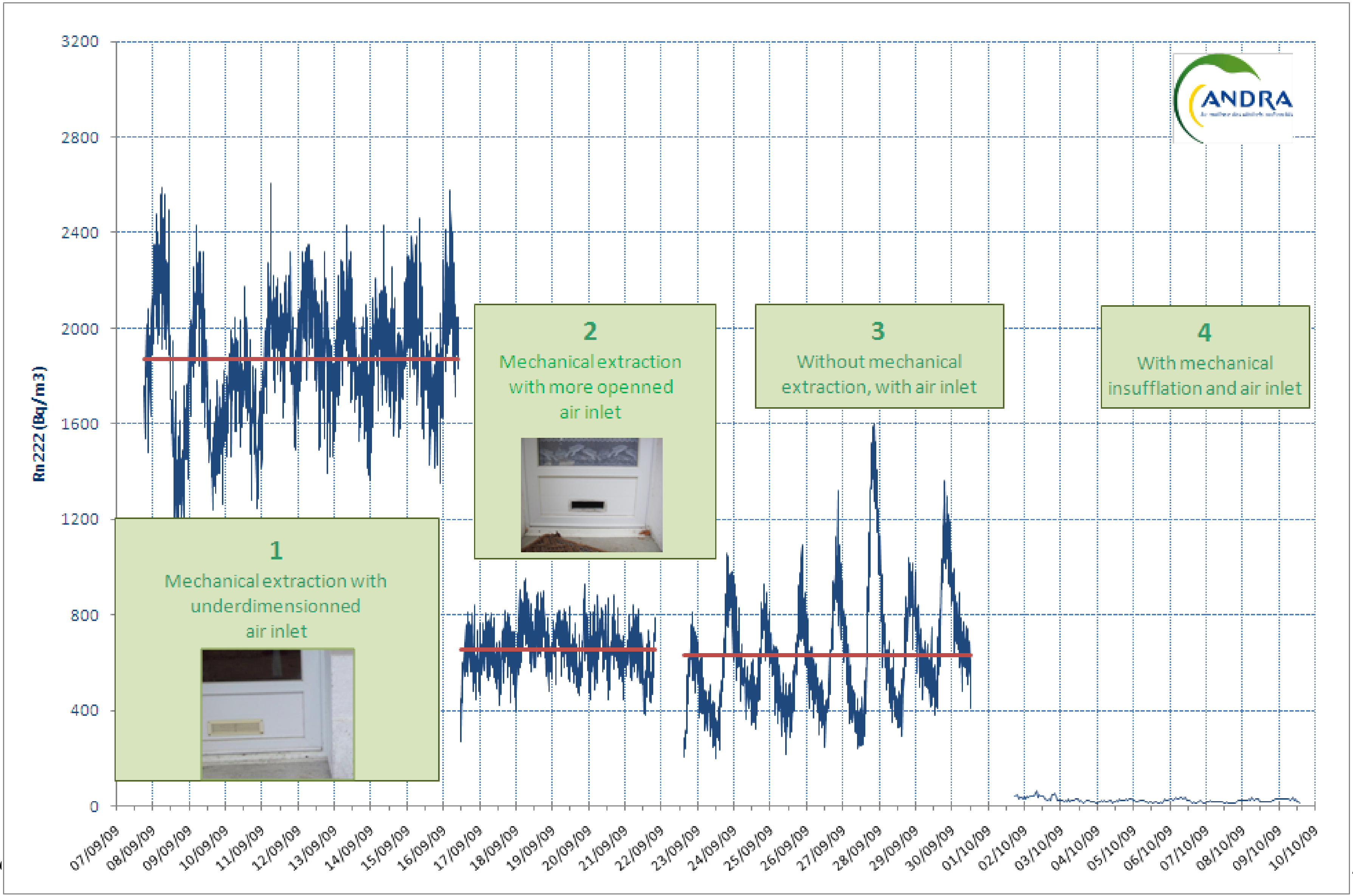


Indoor and outdoor hydrostatic pressures depending on heigh of building

Efficiency of mechanical insufflating ventilation



Efficiency of mechanical insufflating ventilation



Efficiency of mechanical insufflating ventilation

- **Very good efficiency against radon entry**

- **Cost-effective solution**

Potential condensation risk accentuation in walls depending on:

- water vapour production in building,
- meteorological conditions and
- building characteristics.

Building characterisation related to radon entry and exposure

Context:

- High variability of indoor radon concentration along time.
- In France in current regulation, radon screening normalised: 2 months measurement during heating period to assess annual averaged indoor radon concentration
- Difficult to use this protocol in existing dwelling (real estate transaction, occupant behaviour, ...)

Objective:

To find an alternative or complementary technique to assess radon potential of a dwelling

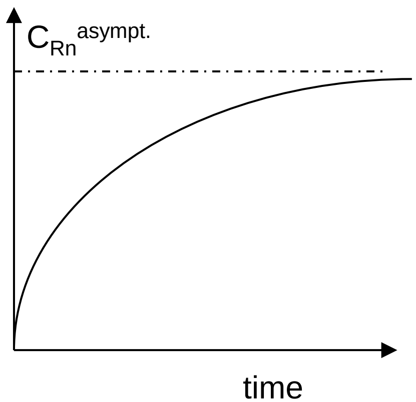
Building characterisation related to radon entry and exposure

Protocol:

> Depressurisation of dwelling using blower door

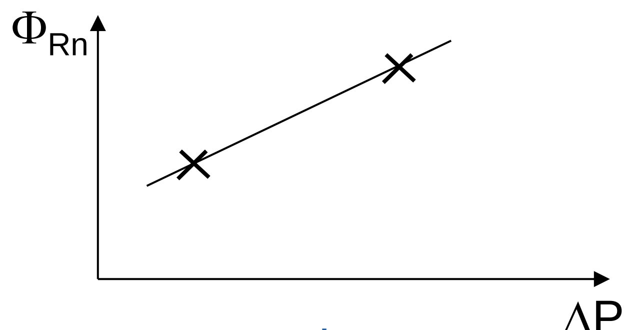
Principle:

- For a given depressurisation and mechanical exhaust air (AR) flow of dwelling, analysis of Indoor Rn concentration (measured at the exhaust)



- Test at different depressurisation levels

  → convective flux of radon from ground:



→ $\Phi_{Rn} = C_{Rn}^{asympt.} \times AR$ for a given ΔP

$\Phi_{Rn} = k \times \Delta P^n$

Building characterisation related to radon entry and exposure

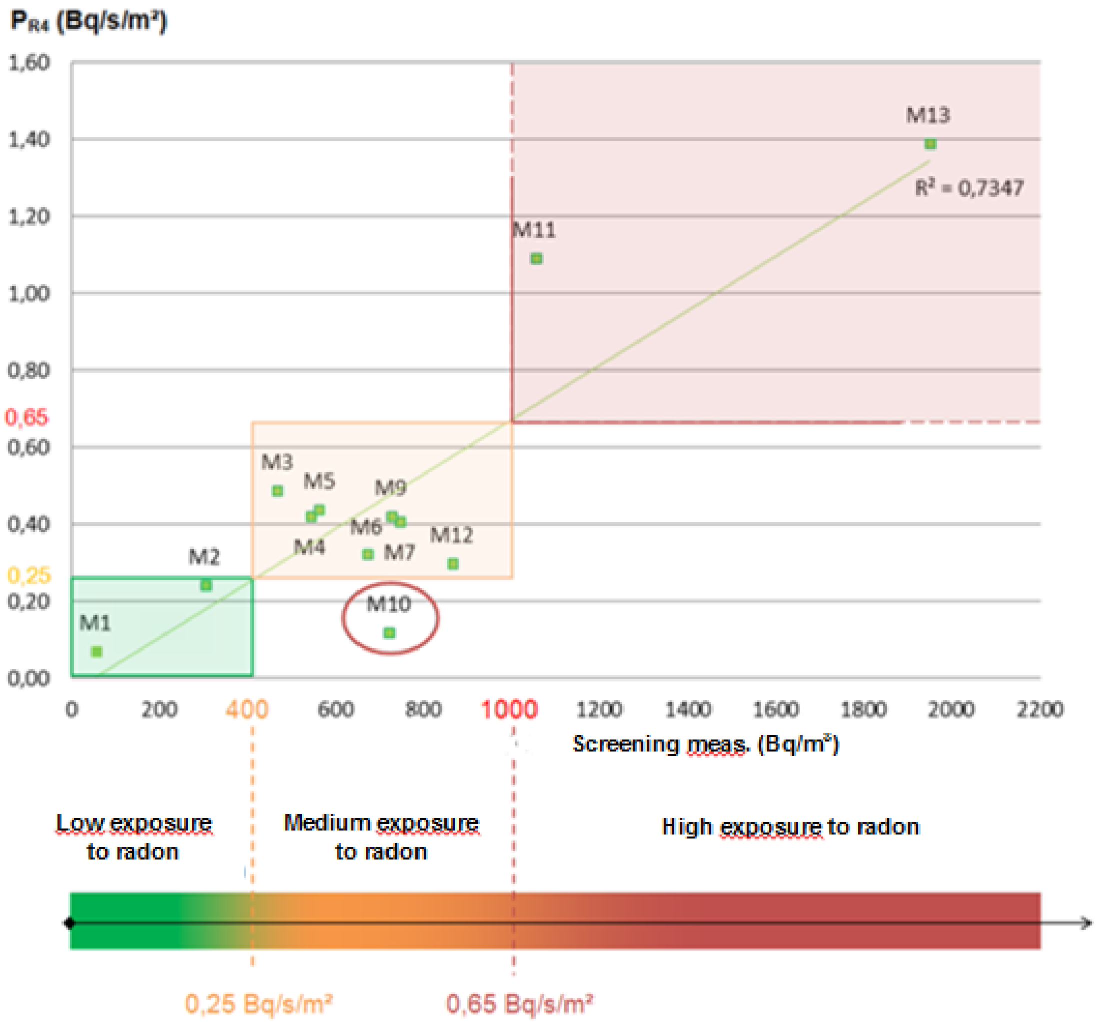
Potential for entry of radon building:

P_{Rn4}: Convective flux of radon under 4 Pa depressurization per square meter of floor (Bq/s/m²)

Protocol tested on 14 dwellings where classical screening had also been realized

Building characterisation related to radon entry and exposure

Tentative of classification:



$P_{Rn4} < 0,25\ Bq/s/m^2$

→ **low exposure to radon**

$0,25 < P_{Rn4} < 0,65\ Bq/s/m^2$

→ **Medium exposure to radon**

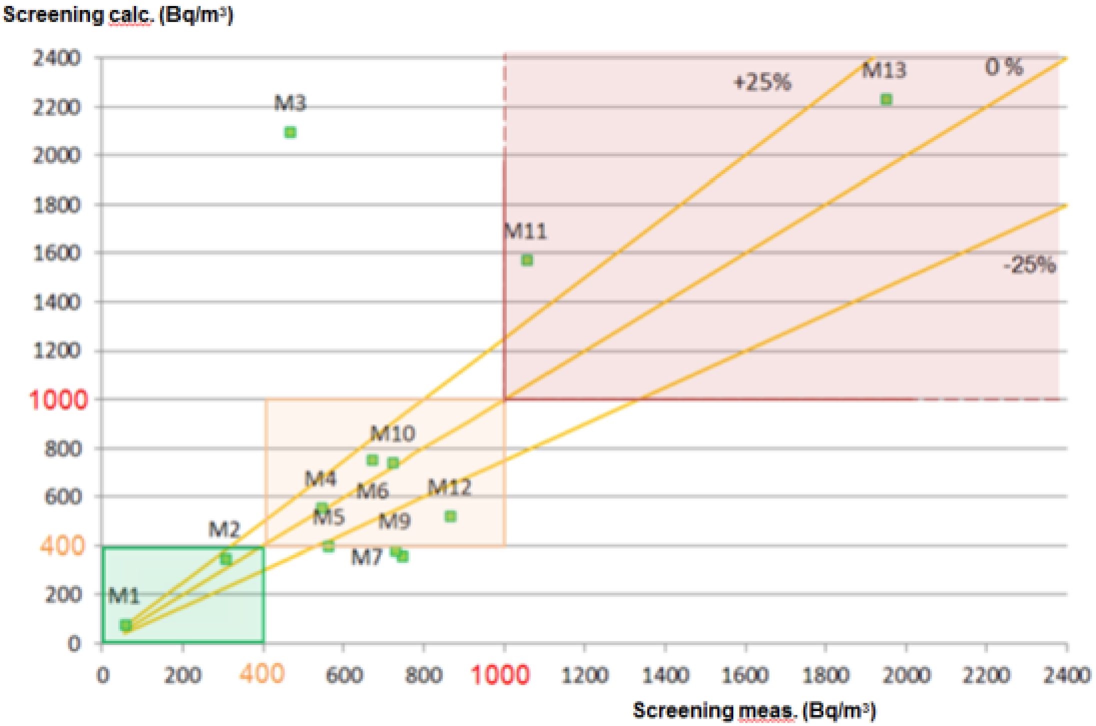
$P_{Rn4} > 0,65\ Bq/s/m^2$

→ **High exposure to radon**

Classification globaly in accordance with measurements

Building characterisation related to radon entry and exposure

Numerical assessment of averaged radon concentration:



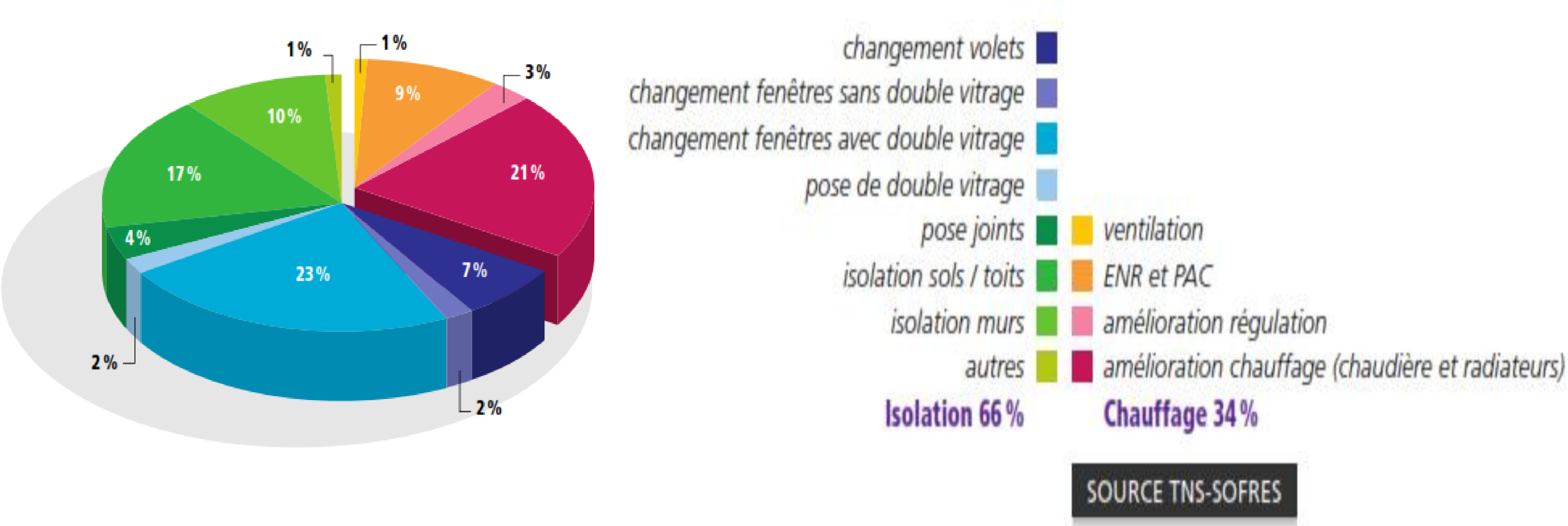
- Annual calculation using ventilation model and Rn emission law characterised experimentally
- To rebuild annual averaged Rn concentration

Conclusion:

Promising methodology, need to be tested in a larger number of building to be reinforced could be considered as a complementary tool for radon management

Impact of thermal remediation on radon exposure

Data on thermal rehabilitation In France

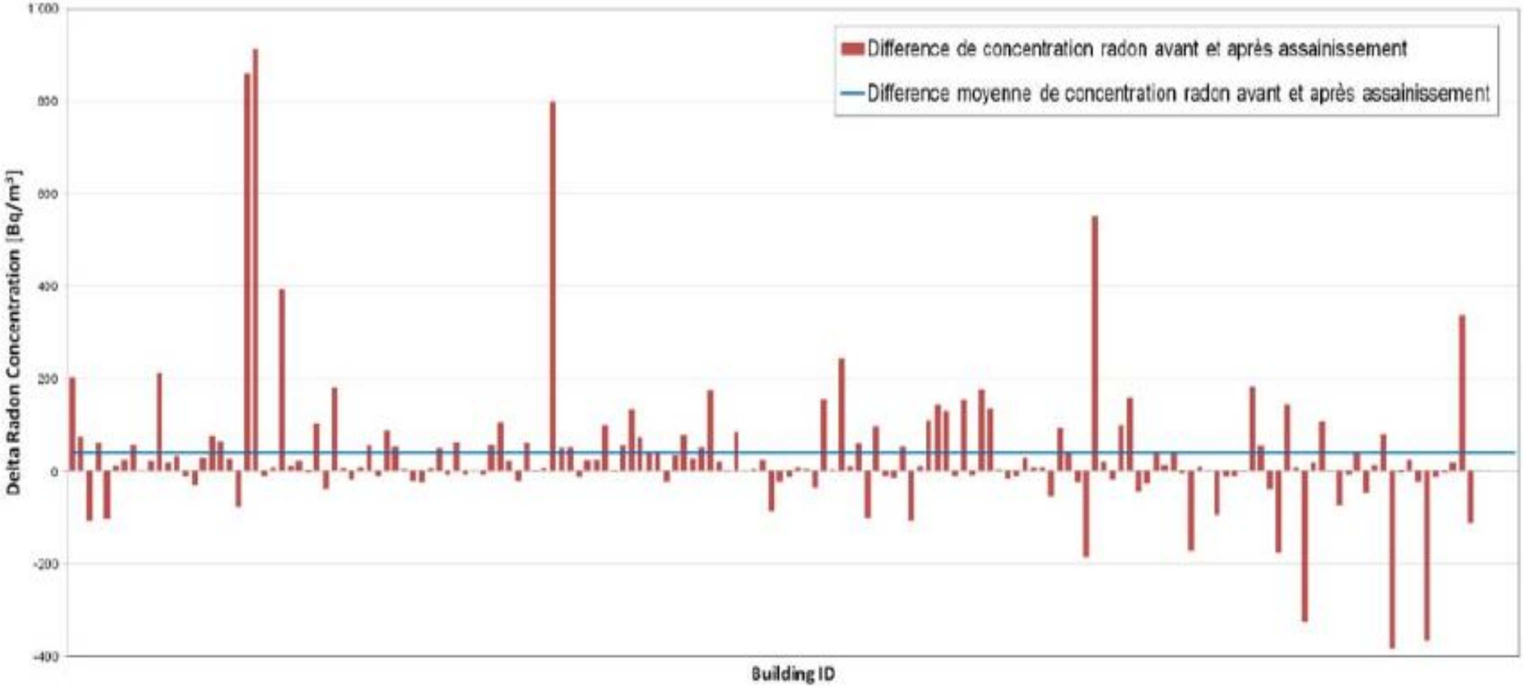


Source Ademe

Often iterative process

Impact of thermal remediation on radon exposure

Data from Switzerland:



Difference in concentration of radon after retrofitting (undifferentiated) for 163 dwellings

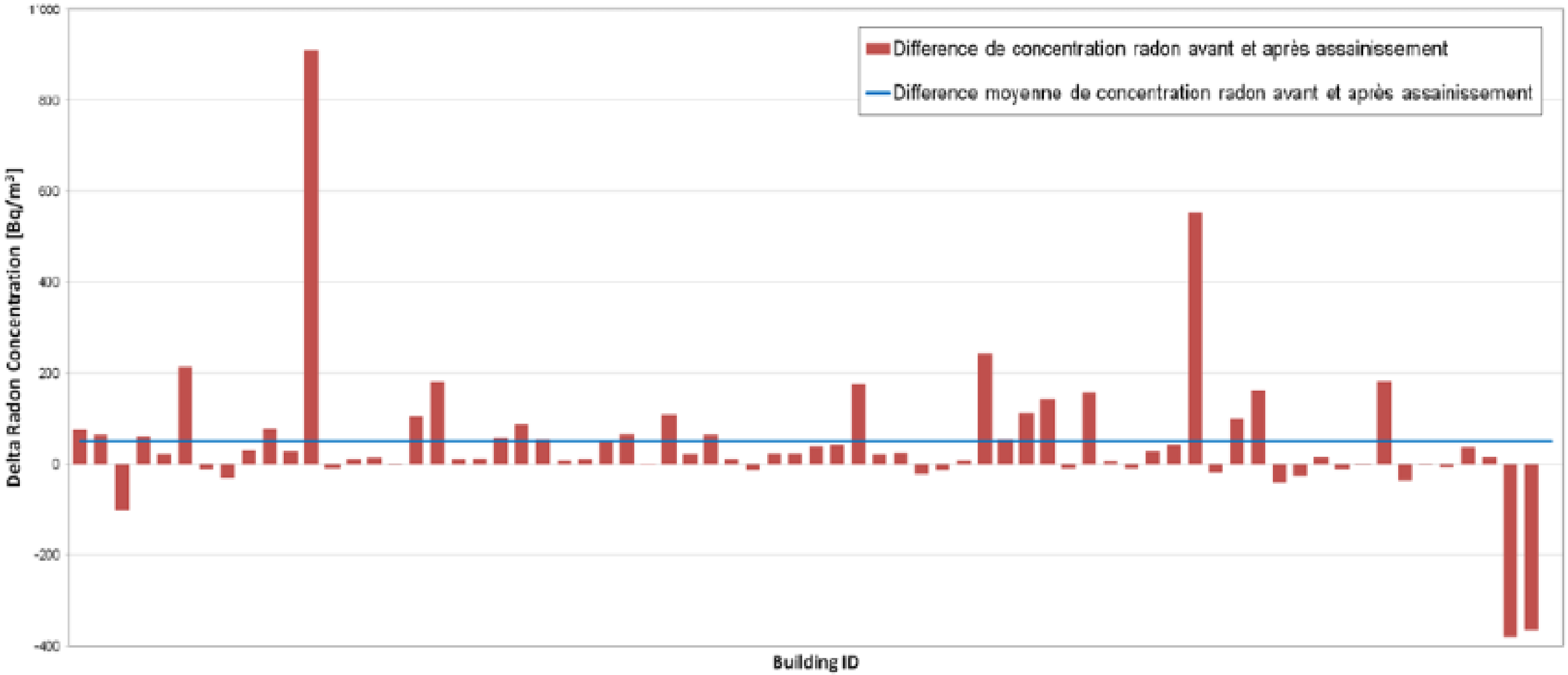
Averaged before retrofitting : 153 Bq/m^3

Averaged after retrofitting : 193 Bq/m^3

Increase of 40 Bq/m^3 (26 %)

Impact of thermal remediation on radon exposure

Data from Switzerland:



Difference in concentration of radon after retrofitting (changing windows) for 70 dwellings

Averaged before retrofitting : 141 Bq/m^3

Averaged after retrofitting : 191 Bq/m^3

Increase of 50 Bq/m^3 (35 %)

Numerical study on impact of thermal remediation on radon exposure

Sensitivity study using ventilation model and convective law for radon entry:

	Airtightness of dwelling			
				
	I_4 = 1,6 m³/h/m²	**I_4 = 1,2 m³/h/m²** Changing windows	**I_4 = 1 m³/h/m²** + internal insulation	**I_4 = 0,8 m³/h/m²** + external insulation
No ventilation system	X	X	X	X
Natural ventilation system	Reference case	X	X	X
Exhaust Mechanical ventilation	X	X	X	X
Double flux	X	X	X	X

Numerical study on impact of thermal remediation on radon exposure

Sensitivity study using ventilation model and convective law for radon entry:

Airtightness of dwelling

	I_4 = 1,6 m³/h/m²	I_4 = 1,2 m³/h/m² Changing windows	I_4 = 1 m³/h/m² + internal insulation	I_4 = 0,8 m³/h/m² + external insulation
No ventilation system	313	418	503	628
Natural ventilation system	176	220	253	301
Exhaust Mechanical ventilation	153	169	178	191
Double flux	99	110	117	127

Radon annual averaged concentration (Bq/m³)

Conclusion

- **Future Challenges :**

  - Development of professional practices for existing and new building to ameliorate protection efficiency

  - Existing building:
    Thermal remediation of building and radon exposure

  - New buildings:
    Efficiency of ventilation systems and good maintenance along time

Thank you for your attention !

Examples of radon free buildings