Radon Rn Control in Buildings
A Building Science/Systems (BS^2) Approach

BS^2

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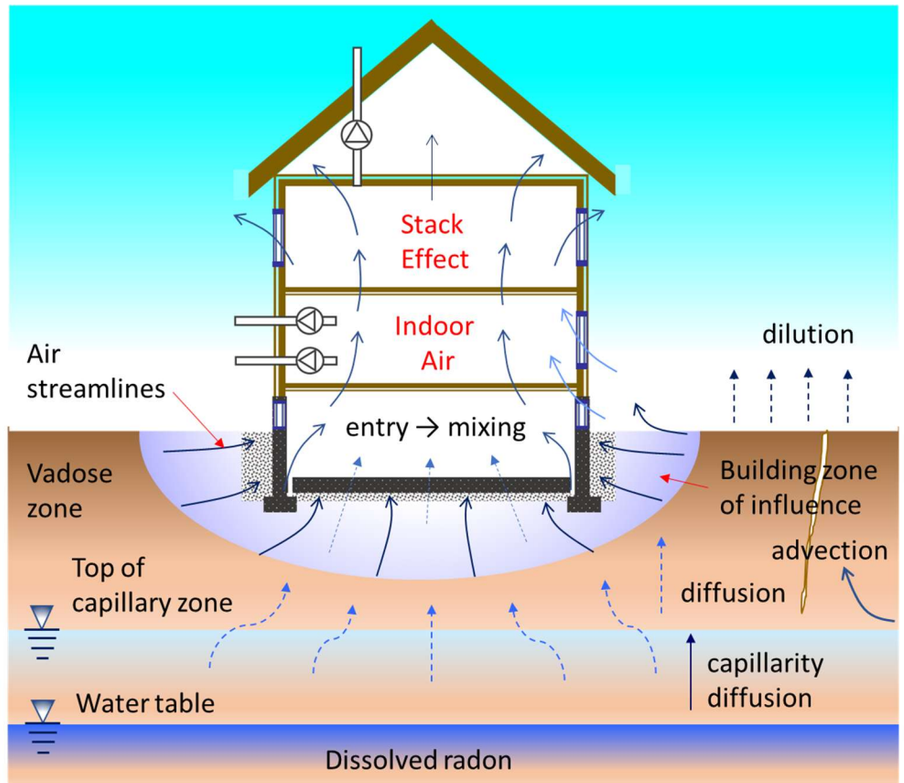
A seminar presentation to:

ARCHITECTURAL INSTITUTE OF BRITISH COLUMBIA

Radon Gas: Origin and Health

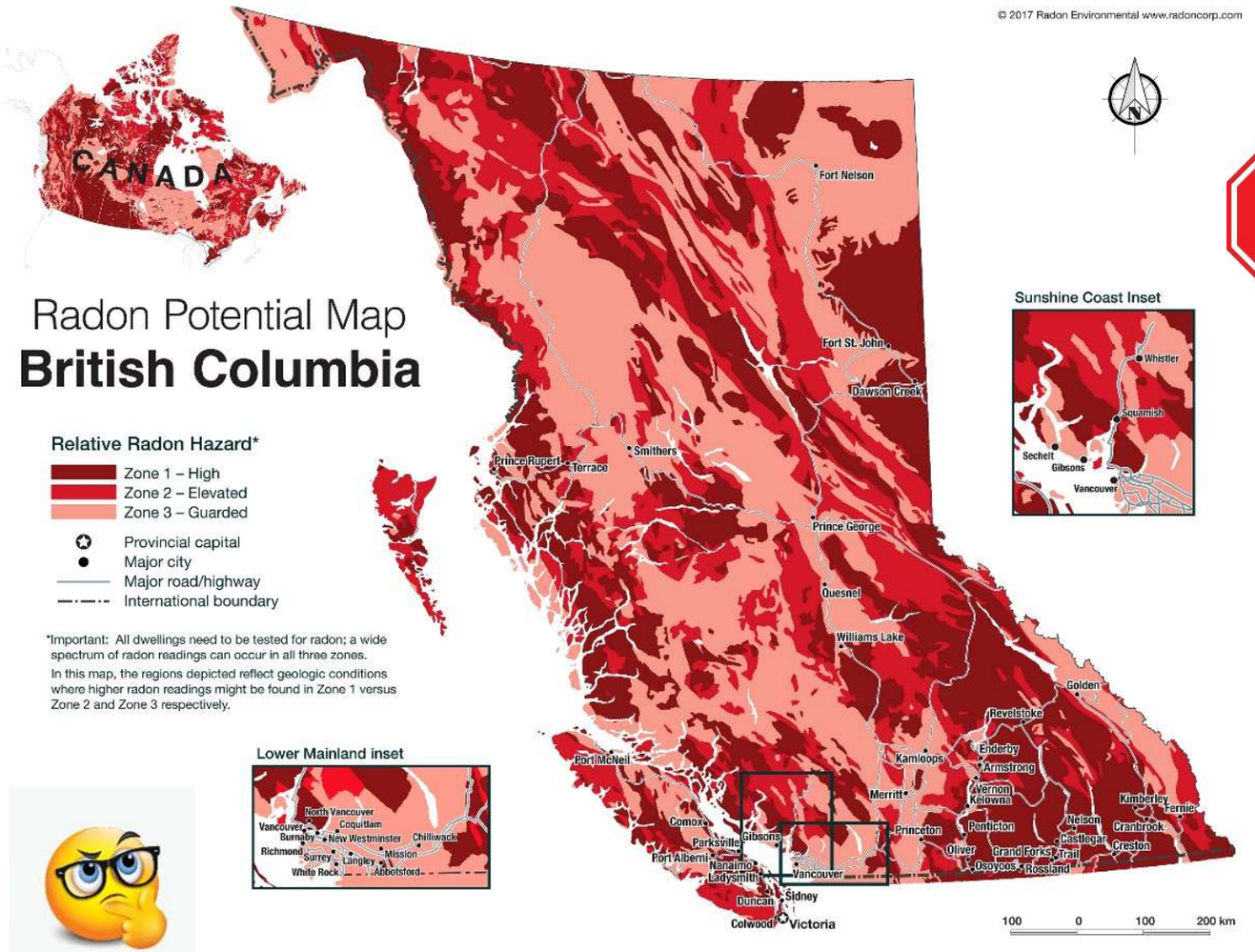
- Radon is a radioactive gas
- Originates from the breakdown of uranium
- Migrates from the ground to the surface
  - ~ Naturally diluted in the atmosphere
  - ~ Can accumulate in buildings
- Enters the building through the foundation
- Route of exposure: inhalation



- Health Canada: leading cause of lung cancer in non-smokers
- Health Canada: 3,000+ deaths a year in Canada radon-induced lung cancer

Radon Hazard

Geologic Radon Potential/Risk Map of BC



- **Based on Regional: geology**

Reality: radon levels and risk can vary from house to house even in the same block!

Map inaccuracies due to:

→ Local: geologic heterogeneities close to the surface

→ Site: increased soil porosity, urban heterogeneities, hard surfaces

→ Surrounding building: loose soil, granular material, cavities

Why Radon? Why Now?

1. 3,000+ deaths a year in Canada radon-induced lung cancer (Health Canada)
2. Results from relatively recent campaigns on indoor air radon testing: (mainly in homes)
   - ~ Geologic radon maps: accurate mostly in high-risk regions (⚠ region → ⚠ indoor)
   - ~ But high radon levels also found in houses in lower risk regions
3. Recent studies in Canada[1]:
   - ~ High energy efficiency → high indoor radon (why?) 🤔
   - ~ Particularly critical in existing buildings after energy-retrofits
4. Increased awareness on potential higher risk for vulnerable populations:
   - ~ Schools and childcare centres

[1]BC Lung (2023). Radon and energy efficiency, internet website: https://bclung.ca/radon-and-energy-efficiency

Why Radon? Why Now?

Engineers and Geoscientists BC – Code of Ethics:

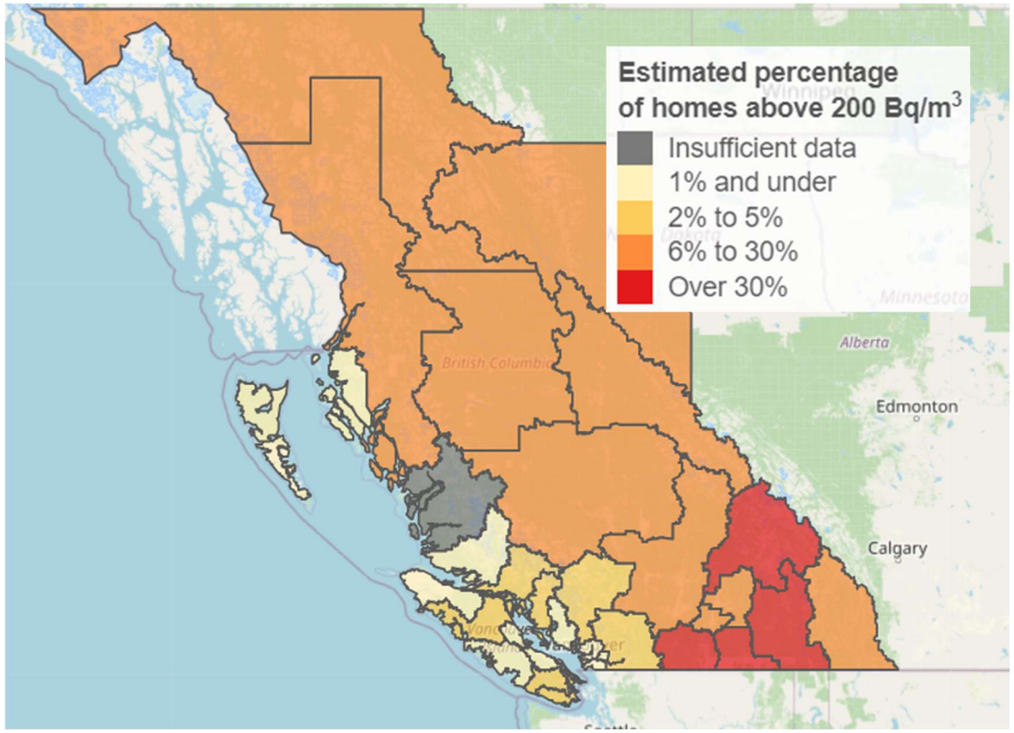
"*Registrants must hold paramount the safety, health, and welfare of the public, including the protection of the environment, and take into consideration the key linkages between climate change and public safety. Further, A registrant's obligation to protect the environment includes consideration for climate change, which means that registrants are expected to consider any impact of their work on the climate (and the impact of climate on their work).*"

Radon Hazard

More accurate maps based on databases on **Indoor Air Testing**

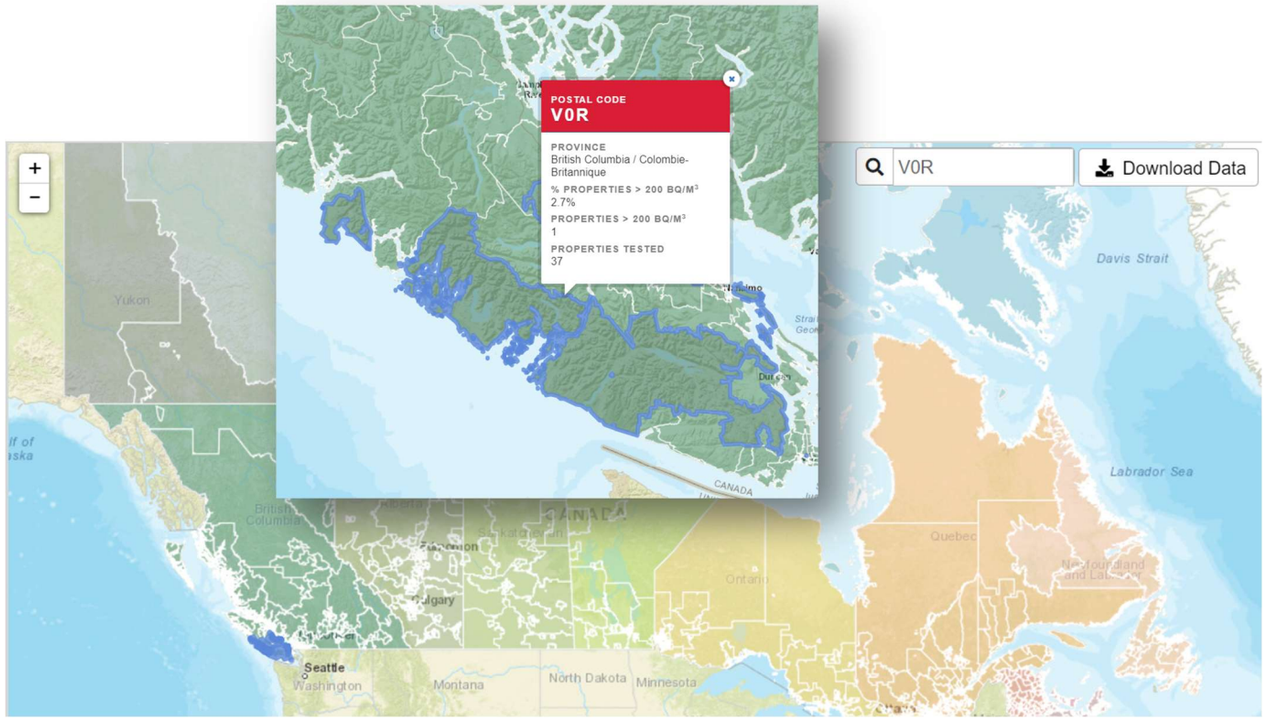
BC CDC Radon Map
Radon Testing Data Repository

https://bccdc.shinyapps.io/bcradonmap/



Canadian – National Radon Proficiency Program (C-NRPP)

https://c-nrpp.ca/radon-map/?center%5B%5D=58.81374171570782&center%5B%5D=-94.482421875&zoom=4



Radon Entry and Exposure

Accumulation?
(Bq/m^3)

↑

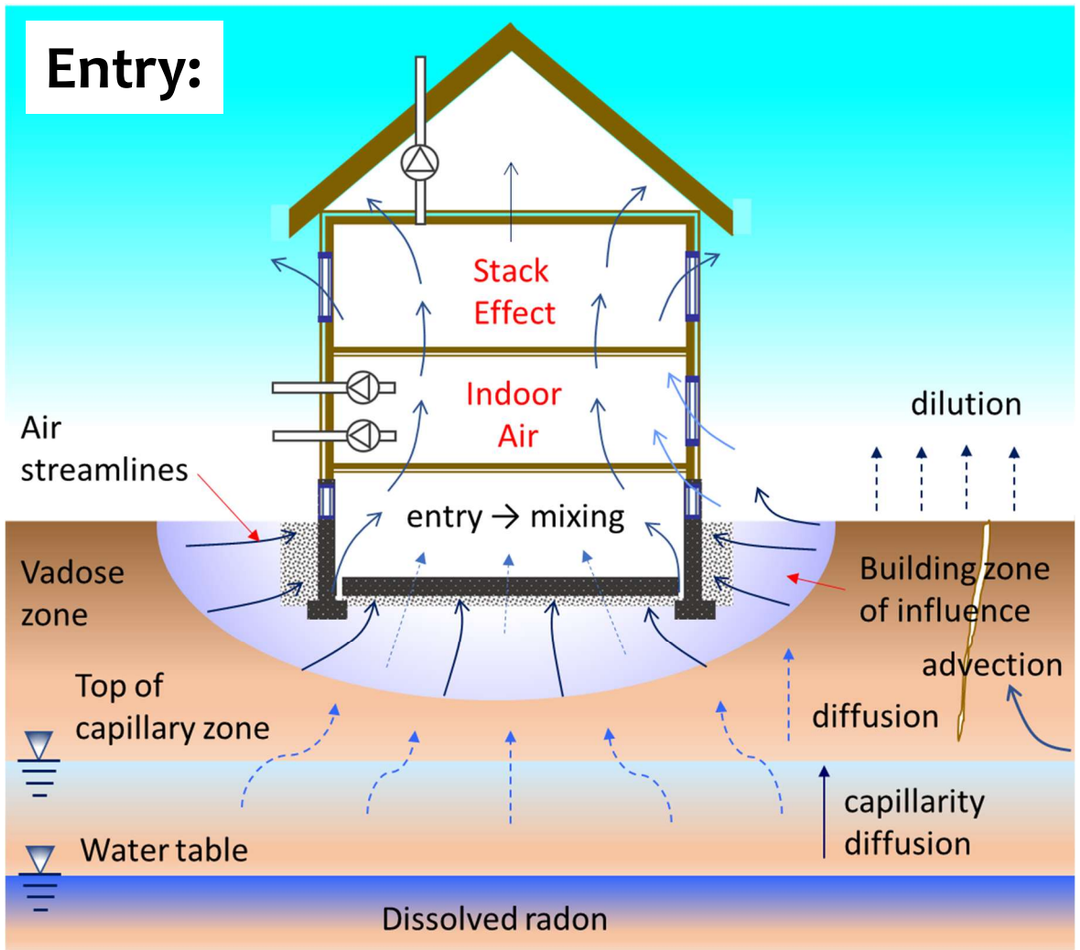
Driving Forces

↑

Crack/gaps

↑

Source



Exposure:

ALARA

$$E_i = \sum_{j=1}^{n} (C_j \cdot t_{ij})$$

- E_i total exposure of individual i
- C_j air concentration of radon at location j,
- $t_{i.j}$ proportion of day spent by individual i in location j.

Canada Guideline: 200 Bq/m^3

As **L**ow **A**s **R**easonably **A**chievable

Priority: Air tighten the below-grade enclosure

Human Exposure & Radon Limits Indoors

- Canada Guideline: $200\ Bq/m^3$: action required when exceeded annually on average
  - ~ At places where we spend more than 4 hours per day
- The United States: $148\ Bq/m^3$
- World Health Organization (WHO): $100\ Bq/m^3$
- ALARA : as low as reasonably achievable
- There is no safe level for radon!
- Vast majority of cancers: exposure to persistent low levels
- Only way of knowing is by testing
- Health Canada suggests that there is radon in all homes
- In theory, all buildings should be tested (indoor air)
- Winter testing is preferred: fully enclosed building, stack effect

$$E_i = \sum_{j=1}^{n} (C_j \cdot t_{ij})$$

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- C_j air concentration of radon at location j,
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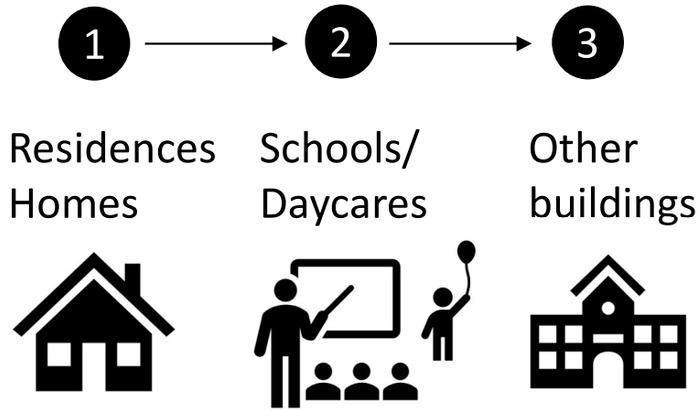
Literature Review: Radon ↔ Buildings

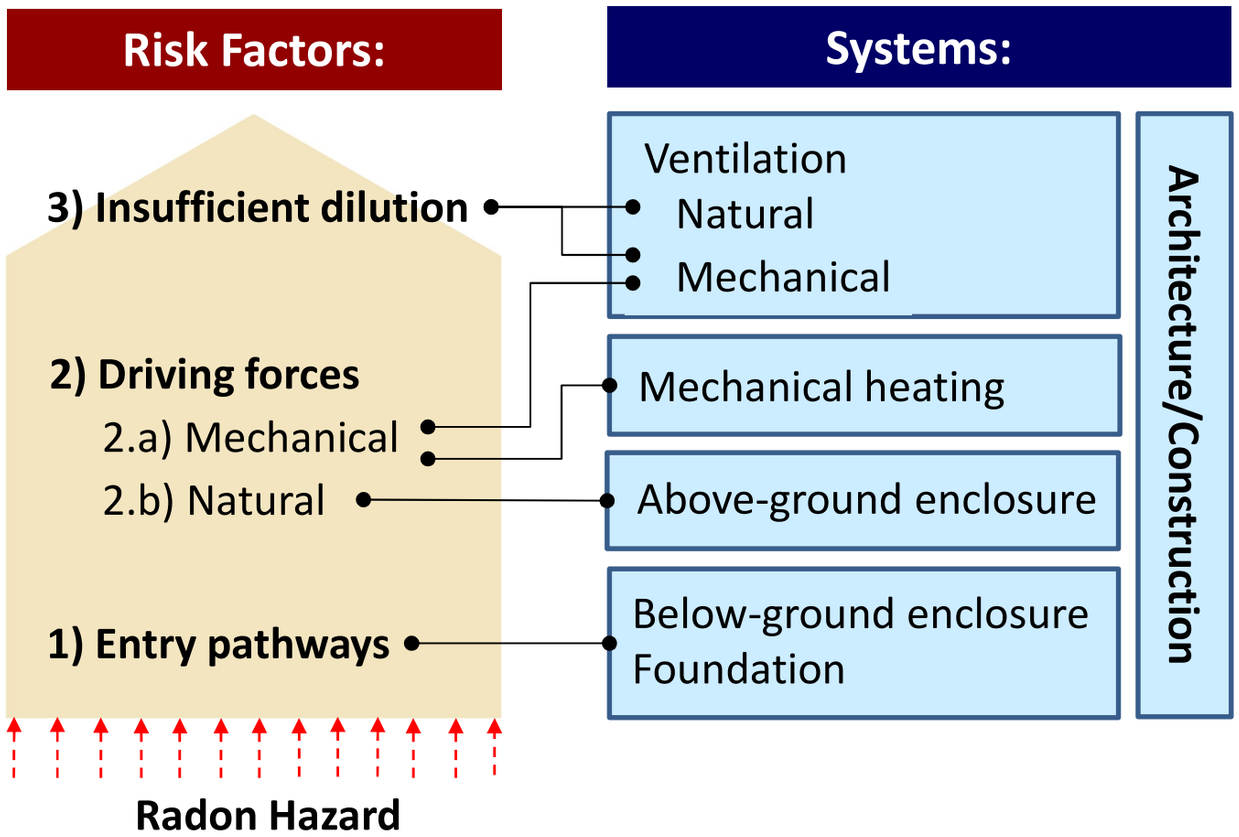
- Evolution in homes: Europe ↓ Canada/USA ↑, why?
- The role of codes and regulations?
- New construction 😕 versus energy retrofits 😟
- Footprint size, type of foundation
- Construction type, enclosure airtightness
- Type of ventilation and reliability of operation
- Human factors:
  - ~ Stakeholder communication and engagement
  - ~ Quality of workmanship
  - ~ Value-action gap: awareness → testing → action

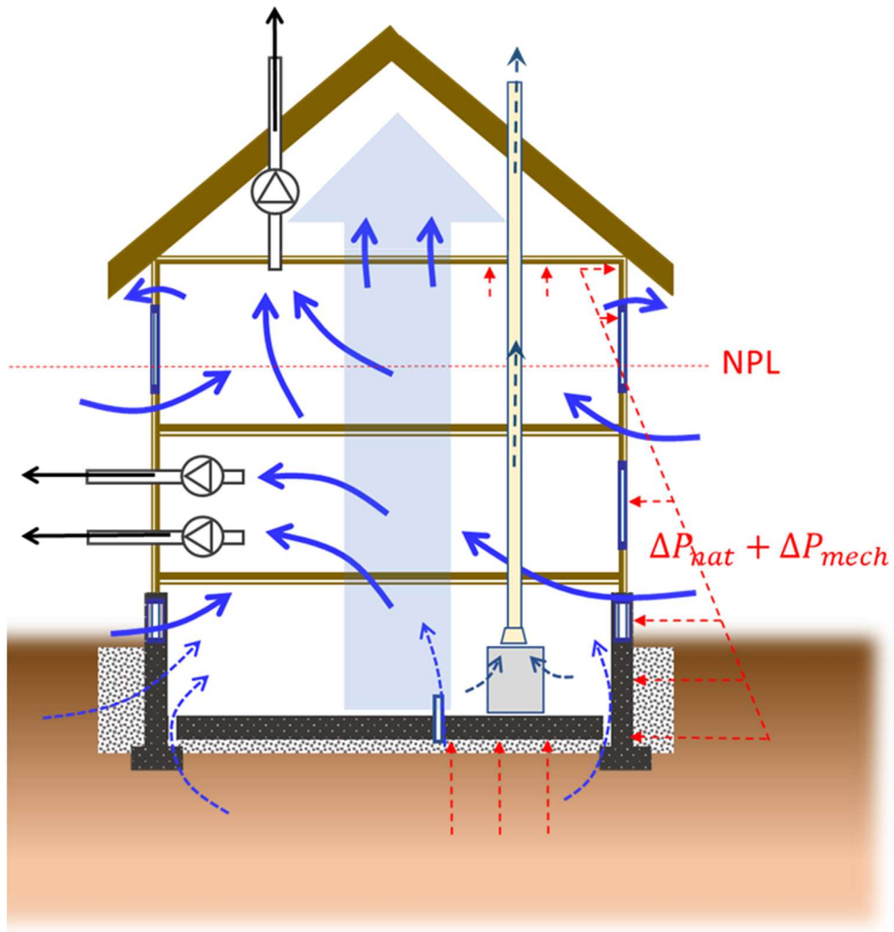


Schools:

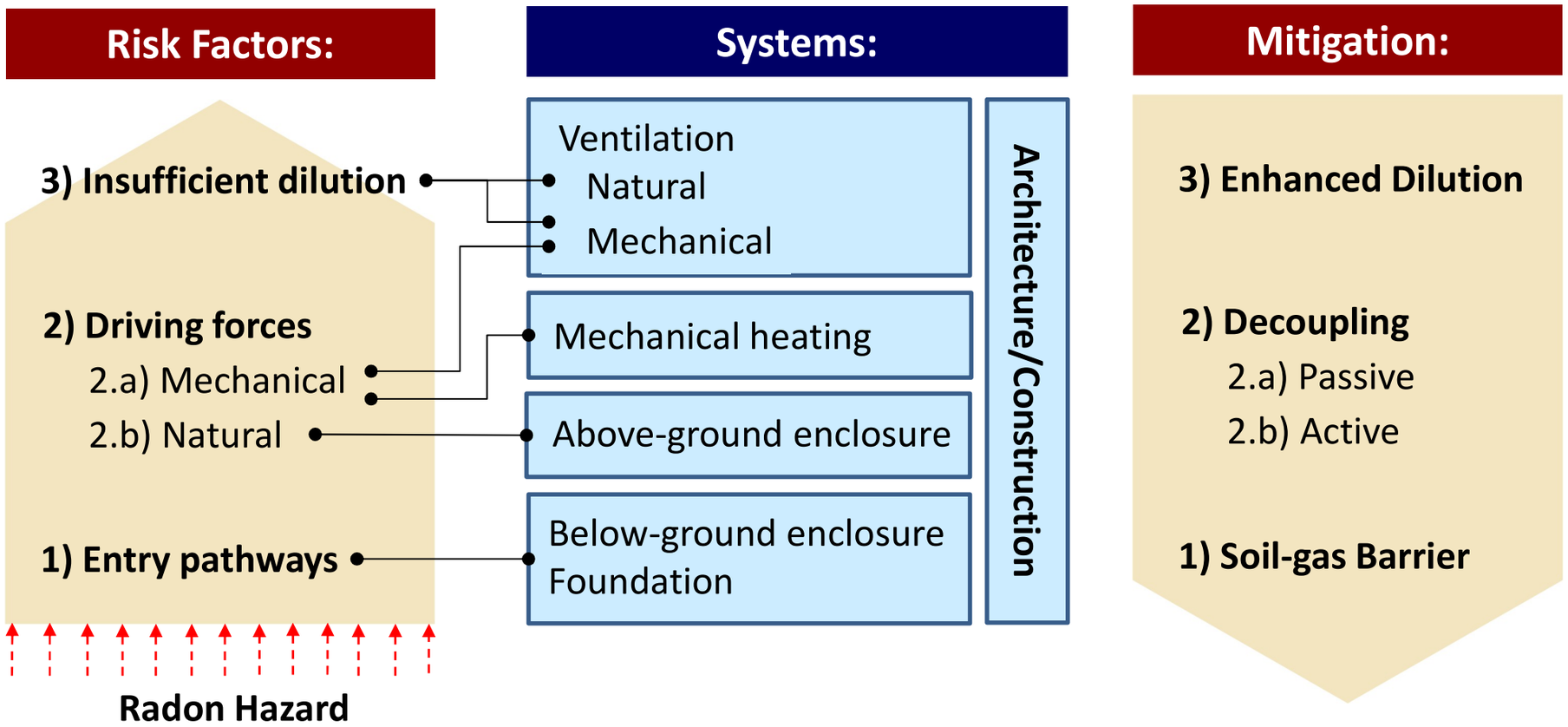
- Often single-storey, large footprint, multizone
- Ventilation, heating, cooling often combined

Building Science/Systems Approach

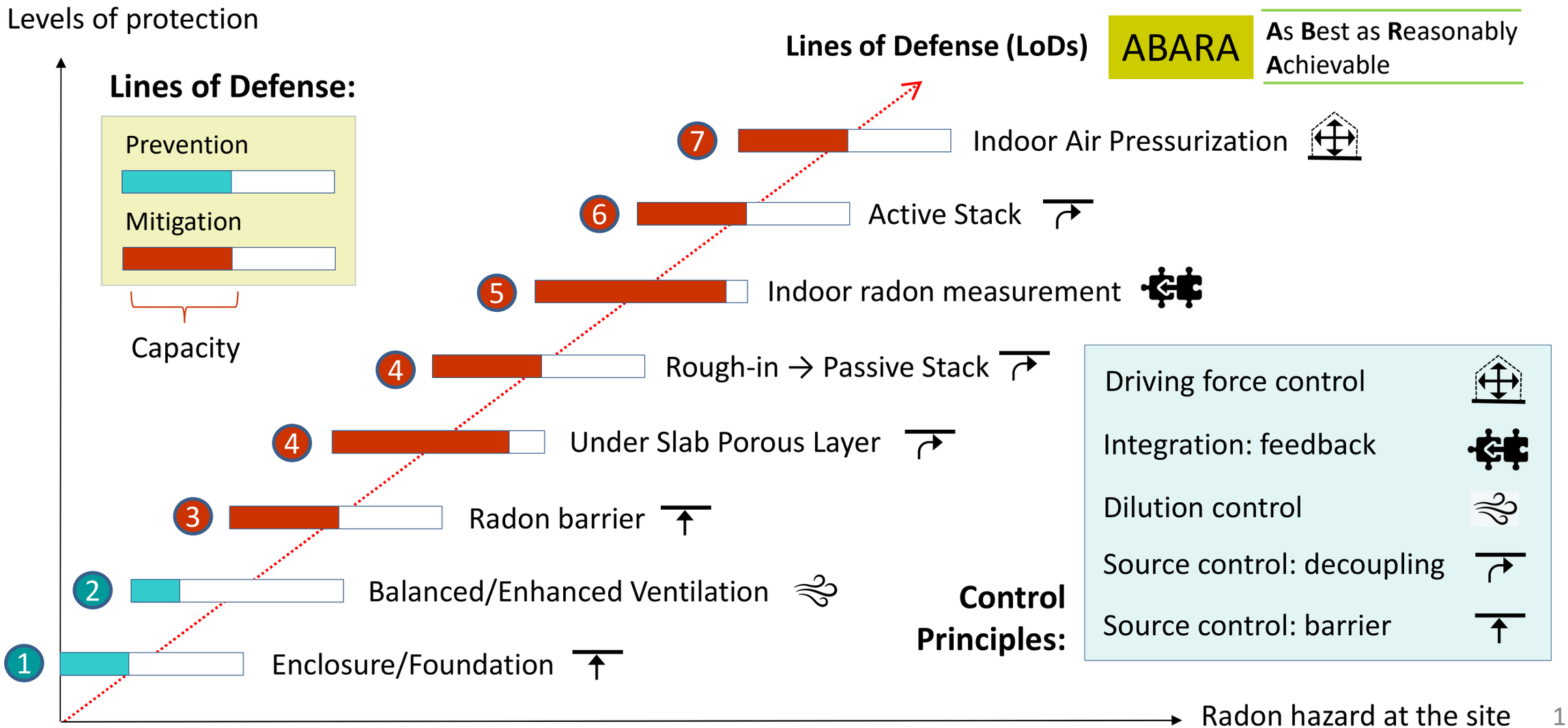




Building Science/Systems Approach



Building Science/Systems Approach



Radon Mitigation and Vulnerabilities

Active Radon Mitigation:

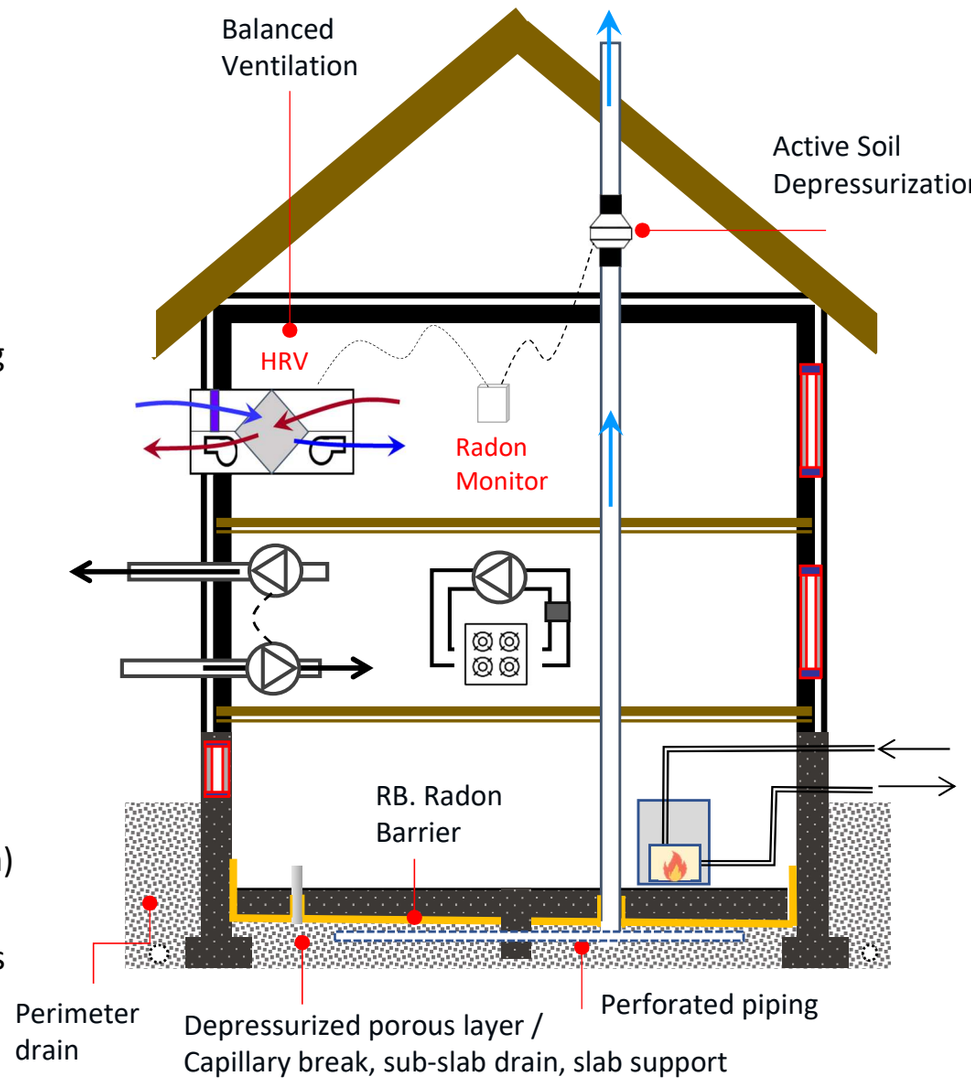
Stage 1: indoor radon level exceeds threshold limiting value (TLV)
→ Run HRV in high-speed "boost" mode
Stage 2: indoor radon level does not decrease below TLV
→ Activate soil depressurization fan

Failure mechanisms:

a) The sub-slab pressure field does not extend through the entire slab footprint resulting in restricted airflow communication through sections of the porous layer
b) The radon barrier has gaps or does not extend to the foundation walls
c) The porous layer is clogged or not porous enough
d) The porous layer and the perimeter drain are connected
e) The depressurization fan is not properly sized
f) The radon monitor stops or fails to work properly

Consequences:

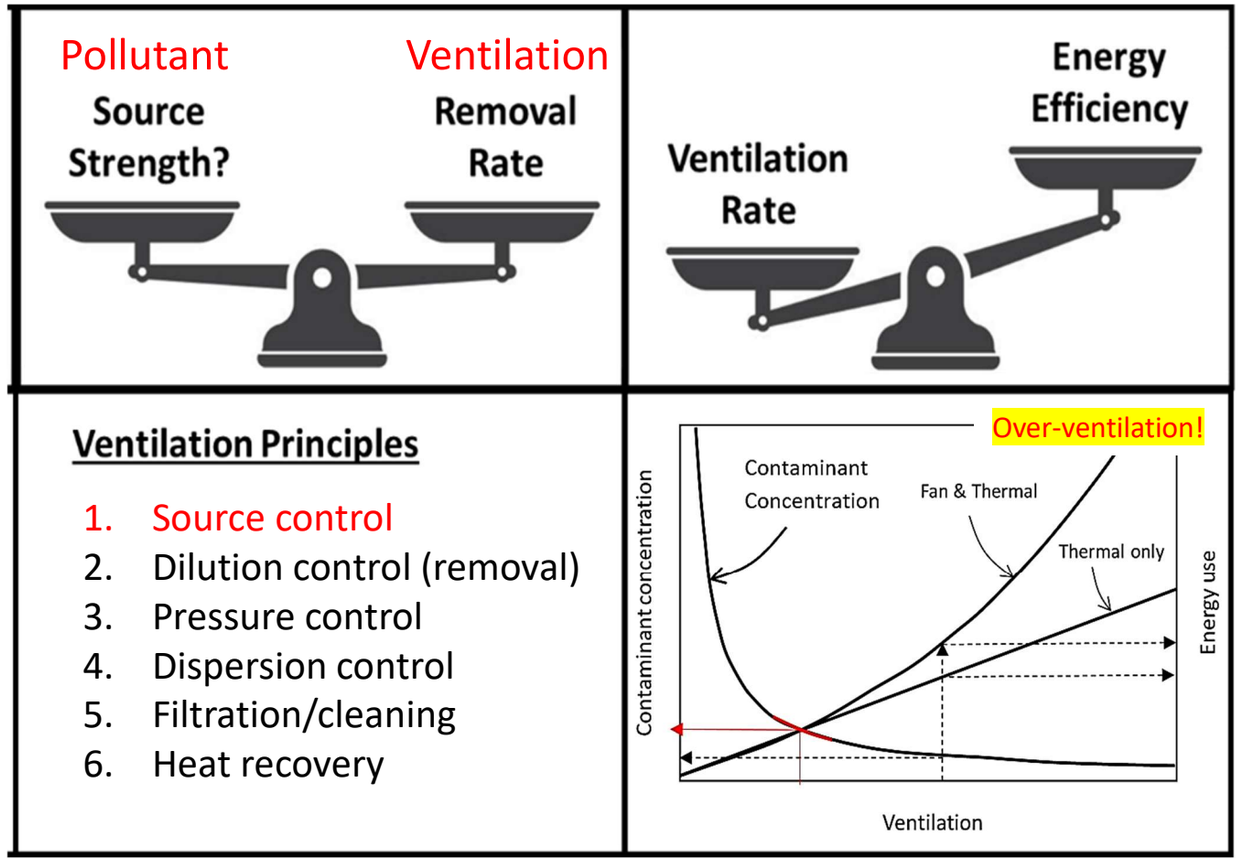
a) Some areas of the building footprint are not well-depressurized or bypassed entirely
b) Radon enters through gaps or the foundation walls rendering the SSD ineffective
c) The radon system effectiveness is reduced, energy use is increased (radon, ventilation)
d) The SSD under slab negative pressure is reduced at the perimeter
e) High energy consumption of the radon fan, the fan is not effective in pulling radon gas
f) Indoor radon is not being monitored



Building Ventilation Principles

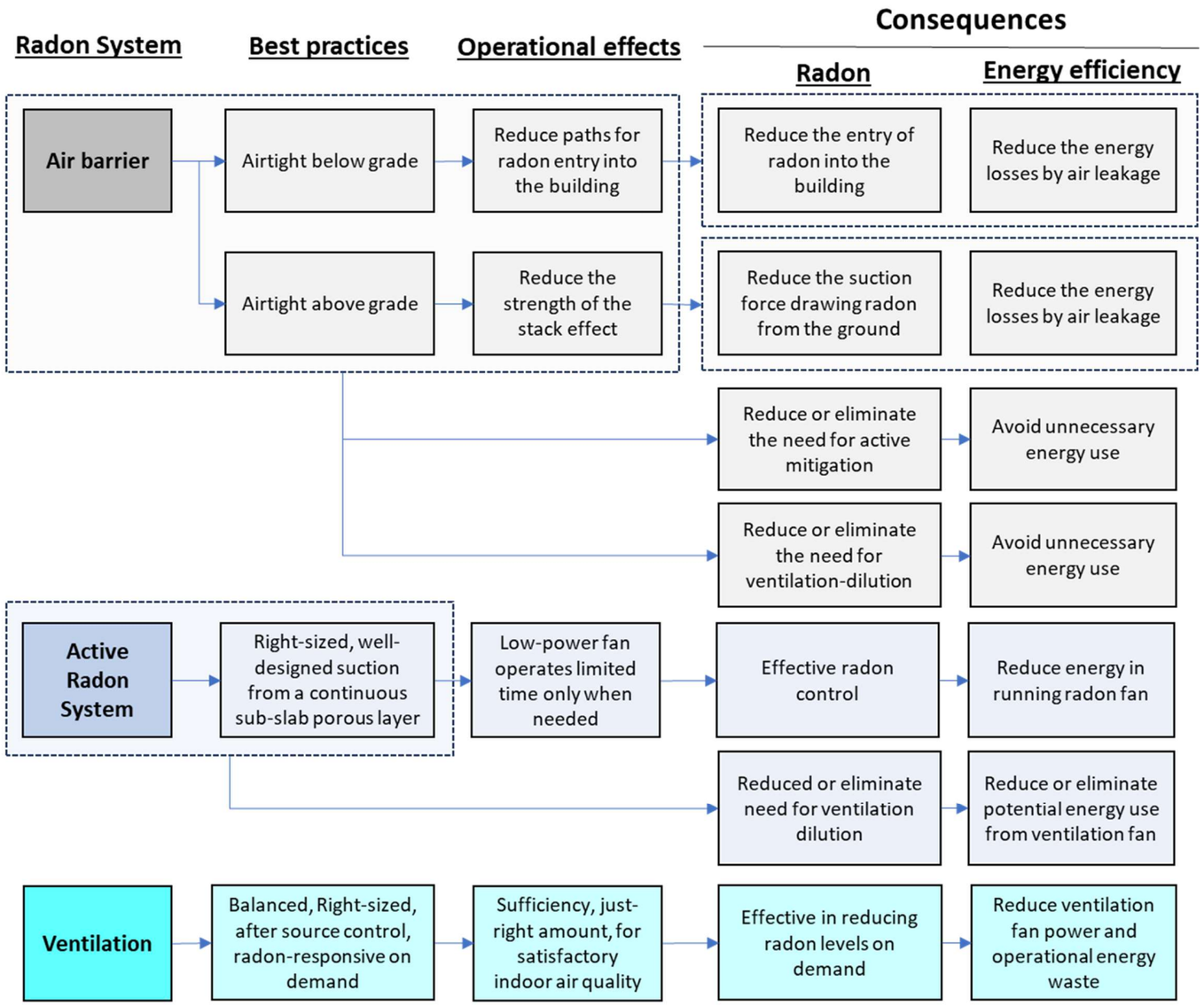
Priority:
Provide Effective Ventilation

1. Source Control
2. Dilution Control: ventilation air
3. Pressure control:
   - ~ Balanced: ↔
   - ~ Positive (radon): +
4. Dispersion Control
   - ~ Cascading effect: clean to dirty
5. Filtration and Cleaning
6. Heat Recovery



Measuring is knowing…
If you know what you are measuring!

Radon Mitigation and Energy Efficiency



Radon Control System Resilience

Radon Control System Line of Defense (LoD)		Professionals Involved	Re1. Robustness Reliability	Re2. Adaptability	Re3. Context- & Self-Awareness Responsiveness Anticipation	Re4. Temporary Backup / Shelter	Re5. Recovery Restore Capacity
1a	Enclosure: Below grade	A/E	✓	✓			
1b	Enclosure: Above grade	A/E	✓				
2a	Ventilation: pressure balanced	ME	✓	✓		✗	
2b	Ventilation: Airflow on demand	ME	✓	✓		✗	
3	Radon barrier	RS, A/E	✓				
4a	Porous layer, incl. soil gas collection piping	RS, GE	✓	✓			
4b	Passive Stack/Stub	RS, ME	✓	✓			
5	Radon monitoring	RS	✓	✓	✓	✗	✓
6	Active stack	RS, ME	✓	✓		✗	✓
7a	Radon Ventilation: pressure positive	RS, ME	✓	✓		✗	✓
7b	Radon ventilation: enhanced airflow	RS, ME	✓	✓		✗	✓

An Integrated Design Approach to Radon Mitigation in Energy Efficient Buildings

By: Shahrzad Pedram (P.Eng.); Adam Jarolim (P.Eng.); Rodrigo Mora (PhD., P.Eng.)

Report in-progress will be available in the BC Housing Technical Library:

- Focuses on new Part 3 Buildings and Existing Building Retrofits
- Motivation:
  - Gap: enclosure engineers, not clear about their roles in radon control and mitigation
- Goals:
  1. Raise awareness among building professionals about radon risks in buildings
  2. Uncover gaps in knowledge and in professional practice
  3. Foster multidisciplinary discussions about professional roles in radon control/mitigation
  4. Collect relevant information to help guide professionals
  5. Propose integrated solutions to the design of radon control and mitigation

Recommended Framework for Roles of Project Professionals in Radon Mitigation for Design & Construction of New Part 3 Buildings and Existing Building Retrofits

By: Shahrzad Pedram (P.Eng.); Adam Jarolim (P.Eng.); Rodrigo Mora (PhD., P.Eng.)

Tasks/Services	Architect / Prime Consultant	Mechanical Engineer	Electrical Engineer	Geotechnical Engineer	Building Enclosure Engineer	Radon Specialist	Contractor	Authority Having Jurisdiction (AHJ)[9]	Building Owner
Radon / Soil Gas Barrier Material Specification	Designs & Specifies				Reviews + Advises	Reviews + Advises			
Radon / Soil Gas Barrier System Installation	Reviews				Reviews	Review	Implements[5]		
Radon Depressurization - Passive / Active System design	Coordinates	Designs & Specifies[1]	Designs & Specifies[2]	Designs & Specifies[3]	Reviews[4]	Reviews + Advises			
Radon Depressurization - Passive / Active System Installation	Reviews	Reviews			Reviews[4]	Reviews	Implements[5]	Reviews	
Radon Depressurization - Active System Commissioning	Reviews	Reviews			Reviews[4]	Reviews + Advises	Implements[5]	Reviews	
Providing Balanced Ventilation (HRV/ERV) in retrofit projects	Reviews	Designs & Specifies[1]	Designs & Specifies[2]		Reviews4	Reviews	Implements[5]		
Long-term Radon level testing - during first heating season	Coordinates	Advises			Advises	Completes[6]		Advises	Completes[7]
Mitigates if radon levels are above recommended levels of 200Bq/m^3 (New Construction)	Coordinates	Advises			Advises	Advises	Implements[5]		
Mitigates if radon levels are above recommended levels of 200Bq/m^3 (Existing Buildings)	Designs & Specifies + Coordinates	Designs & Specifies[8]			Reviews[4]	Reviews + Advises	Implements[5]		

Precautionary Principle

- Assume radon risk, unless otherwise indicated
- Design complete rough-in that can be easily activated
  - ~ Cheaper than retrofitting after construction
- Include testing and commissioning requirements
- Include radon mitigation specialist on design/contractor team

Relevant Standards and Guidelines

Type of document	Low-rise Residential		Other buildings	
	Document	Type of residence	Document	Types of buildings
Standards				
Radon Control New buildings	CAN/CGSB-149.11-2019. Radon control options for new construction in low-rise residential buildings (superseded)	Low-rise residential	**CAN/CGSB-149.11-2024. Radon control options for new buildings**	**Under certain conditions, applicable to buildings other than single family dwellings**
	ANSI/AARST CCAH-2020-0523. Reducing Radon in New Construction of 1 & 2 Family Dwellings and Townhouses – Rev. 5/23	1 & 2 family dwellings and townhouses	ANSI/AARST CC-1000-2018-0523. Soil Gas Control Systems in New Construction of Multifamily, School, Commercial and Mixed-Use Buildings – Rev. 5/23	Multifamily, school, commercial, mixed-use
Radon Mitigation Existing buildings	CAN/CGSB-149.12-2017. Radon mitigation options for existing low-rise residential buildings (superseded)	Low-rise residential	**CAN/CGSB-149.12-2024. Radon mitigation options for existing buildings**	**Under certain conditions, applicable to buildings other than single family dwellings**
	ANSI/AARST SGM-SF-2023. Soil Gas Mitigation Standards for Existing Homes	Homes	ANSI/AARST SGM-MFLB-2023. Soil Gas Mitigation Standards for Existing Multifamily, School, Commercial and Mixed-Use Buildings	Multifamily, school, commercial, mixed-use
Measurements (indoor air testing)	ANSI/AARST MAH-2023. Protocol for Conducting Measurements of Radon and Radon Decay Products in Homes	Homes	ANSI/AARST MA-MFLB-2023. Protocol for Conducting Measurements of Radon and Radon Decay Products in Multifamily, School, Commercial and Mixed-Use Buildings	Multifamily, school, commercial, mixed-use
Guidelines				
Radon Control New buildings	US-EPA (1994). Radon prevention in the design & construction of schools & other large buildings	Homes	US-EPA (1994). Radon prevention in the design & construction of schools & other large buildings	Schools, large buildings
Radon Mitigation Existing buildings	CMHC (2007). A guide for Canadian Homeowners	Homes		
	Health Canada (2010). Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors	Homes		
	US-EPA (2016). A Consumer's Guide to Radon Reduction: How to Fix Your Home	Homes		
Measurements (indoor air testing)	CMHC (2007). Radon – A guide for Canadian Homeowners	Homes	Health Canada (2016, 2021). Guide for Radon Measurements in Public Buildings (Workplaces, Schools, Day Cares, Hospitals, Care Facilities, Correctional Centres)	Public buildings: workplaces, schools, day cares, hospitals, care facilities, correctional
	Health Canada (2017). Guide for Radon Measurements in Residential Dwellings (Homes)	Homes	BC CDC (2022). BC Centre for Disease Control: Radon Measurement and Mitigation in Schools	Schools

Thank you!

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