



U.S. EPA “State of VI Science” Workshop
Addressing Vapor Intrusion In The Natural Environment Before
Entry To The Human Built Environment

VI Mitigation During Construction or Major Building
Rehabilitation: Cost-Effective Strategies for Builders

Chris Lutes PhD and Kelly Johnson P.G. - Jacobs

Presentation archived at
<https://iavi.rti.org/>

35th Annual International Conference on Soil, Water, Energy and Air, March 16-19, 2026 San Diego CA



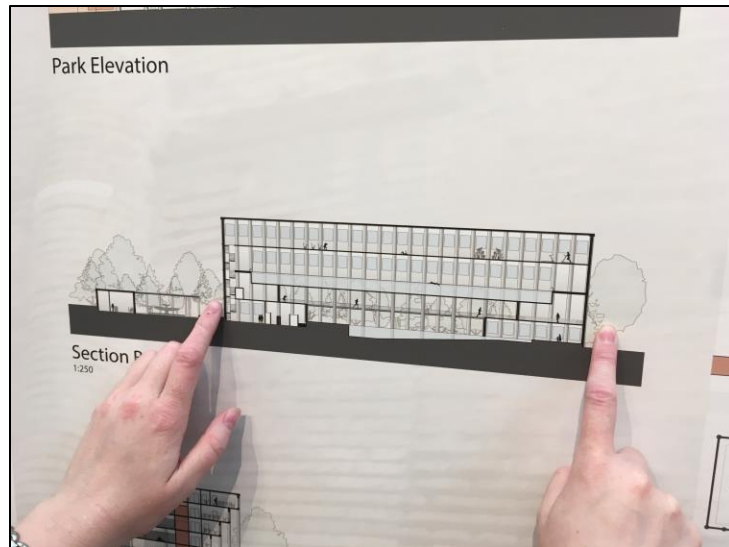
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Outline

- New construction and redevelopment process:
 - Constraints and opportunities
 - Current approaches to individual building mitigation
- Available guidance and consensus standards
- Existing building code provisions provide some steps towards mitigation
- Economic considerations
- Neighborhood scale considerations:
 - Soil vapor extraction vs. individual building mitigation
 - Leveraging other new infrastructure

Constraints and Opportunities of the New Construction and Redevelopment Process

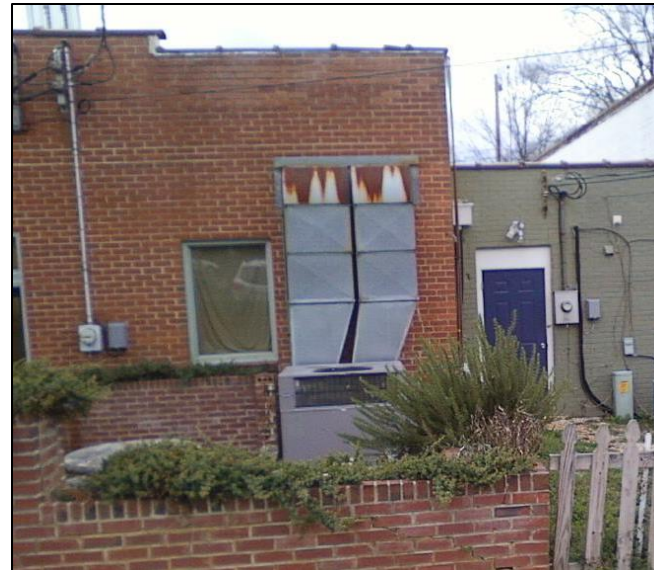
- Need for speed, certainty in outcome
- Access to the building foundation/ground contact floor
- Design choices can minimize VI risk (e.g., elevated slab)
- Excavations for infrastructure can be leveraged



All photos by Chris Lutes

Current Approaches to Individual Building Mitigation During New Construction

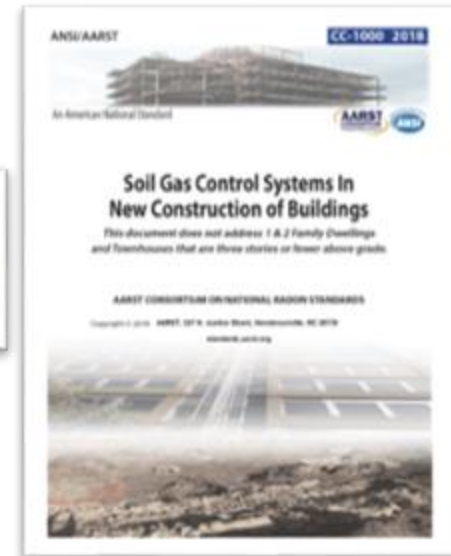
- Design to minimize soil contact
- Radon/soil gas resistant new construction practices
- Design for positive pressure ventilation
- Barrier systems, passive subslab depressurization and provisions for active depressurization



All photos by Chris Lutes or Laurent Levy

Available guidance and consensus standards

- Radon resistant new construction guides i.e. Passive Radon Control System for New Construction (EPA 402-95-012, May 1995)
- ANSI/AARST Soil Gas Control Systems in New Construction of Multifamily, School, Commercial and Mixed-Use Buildings – Rev. 5/23
 - <https://standards.aarst.org/CC-1000-2018/2/>
- ANSI/AARST Reducing Radon in New Construction of 1 & 2 Family Dwellings and Townhouses – Rev. 5/23 CCAH-2020-0523
 - <https://standards.aarst.org/CCA-2020-0523/>
- EPA VI Mitigation Engineering Issue
 - <https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockkey=P100AE72.txt>
- 2021 International Residential Code (IRC)
 - <https://codes.iccsafe.org/content/IRC2021V3.0/appendix-af-radon-control-methods>
- ITRC 2026 Building Design for Passive Vapor Intrusion (VI) Mitigation
 - ITRC 2026 also: Aerated Floor Void Space Systems (VSS), Passive Barrier Systems Tech Sheet
 - <https://itrcweb.org/vapor-intrusion-toolkit/>
- NAVFAC Vapor Intrusion Mitigation in Construction of New Buildings Fact Sheet
 - [Vapor Intrusion Mitigation in Construction of New Buildings Fact Sheet](#)



Existing Building Code Provisions - Steps Towards Mitigation

See: <https://codes.iccsafe.org/content/IRC2021V3.0>

- International Residential Code (2021) – Most common code used in US. Provisions may help reduce VI:
 - R405 Foundation drainage – Provisions for gravel, crushed stone or coarse sand below foundations
 - R406.3.2 Below-grade moisture barrier – 6 mil, sealed with adhesive...bonded to sheathing to form a seal...
 - R303.4 Requires mechanical ventilation or other approved ventilation
 - R1102.4 Limits air leakage
 - M1505.4.3 Specifies the mechanical ventilation rate
 - R408 Specifies ventilation for underfloor spaces including crawl spaces
 - P3201.2 Fixture trap required to have a liquid seal 2-4”
 - P3201.4 Building traps prohibited (viewed as redundant and problematic)
 - P3201.5 Certain trap designs prohibited



No one to my knowledge has evaluated the effect of these provisions on VI attenuation factor directly.

Existing Building Code Provisions - Steps Towards Mitigation

See: <https://www.iccsafe.org>

International Building Code (IBC) is the most common commercial building code in the US:

- 1805.2.1 6 mil polyethylene damp-proofing below floor lapped and sealed
- 1806.3.3 Joints in floors and walls to be watertight
- 1806.4 Floor base course, foundation drainage
- 1202.4 Under floor ventilation requirements (i.e. for crawlspaces)



Companion International Mechanical Code (IMC):

- Chapter 4 ventilation requirements either natural or mechanical
- 401.6 Local sources ... injurious to health shall be provided with an exhaust system...
- 403.1 Mechanical ventilation shall be provided by a method of supply air and return air except residential
- 403.2 and 403.3 Set minimum outdoor air requirements for various occupancy type
- References ASHRAE 62.1 Ventilation for Acceptable Indoor Air Quality



Companion International Plumbing Code (IPC):

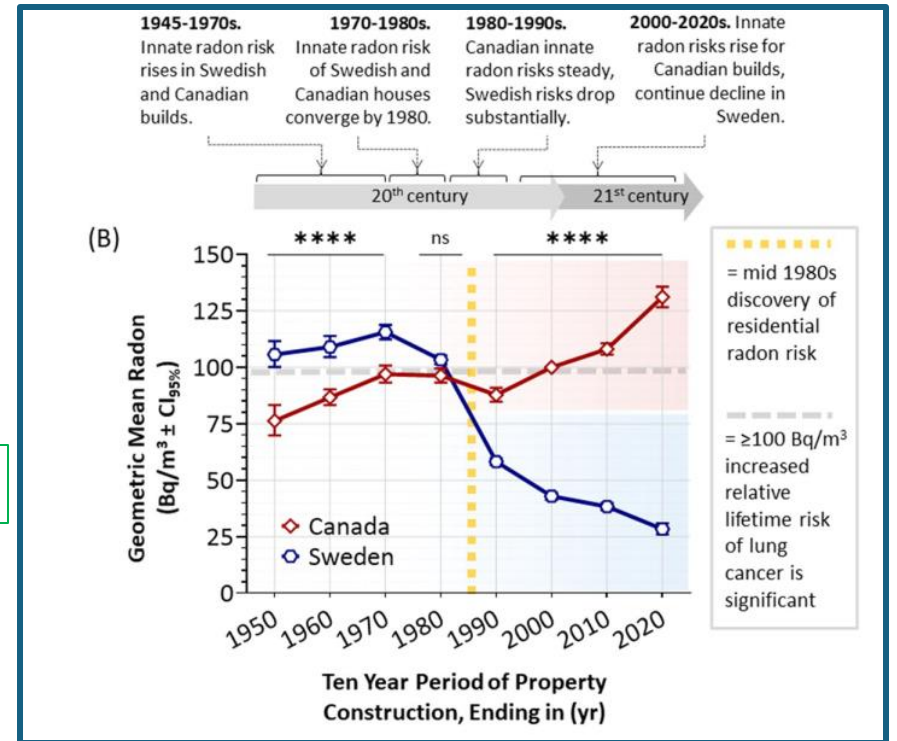
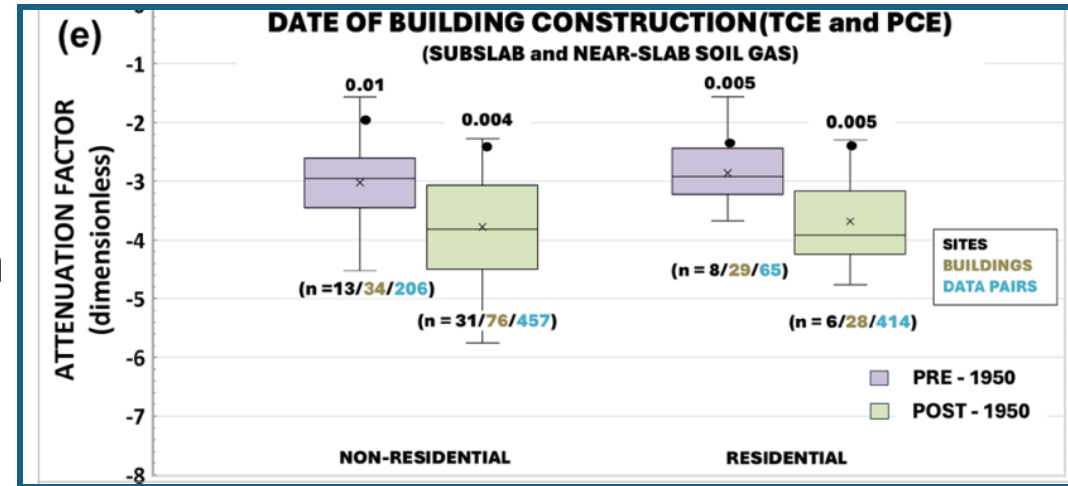
- 1002 Defines acceptable traps requiring 2 to 3" liquid seal per trap and generally prohibits whole building traps
- 714.1 Requires sewer backflow valves when finished floor is below manhole cover



No one to my knowledge has evaluated the effect of these provisions on VI attenuation factor directly.

Are Modern Buildings More Resistant to VI?

- Lahvis et al. 2025:
 - Database of 629 US buildings
 - Statistically significant decrease in attenuation factor (lower indoor concentration) after 1950; attributed to building codes.
- Khan et al. 2021:
 - Dataset of 25,000 Canadian and 39,000 Swedish properties.
 - Indoor radon exposure has gotten much worse in Canada but much better in Sweden:
 - Possible cause could be district heating in Sweden and natural gas in Canada effecting pressures?



$$1 \text{ pCi/L} = 37 \text{ Bq/m}^3$$

Lahvis, M. A., Ettinger, R. A., Abbasi, R., & Jones, W. R. (2025). Scenario-Specific Attenuation Factors for Vapor Intrusion Screening. *Groundwater Monitoring & Remediation*, 45(4), 87-100.

Khan, S. M., Pearson, D. D., Rönnqvist, T., Nielsen, M. E., Taron, J. M., & Goodarzi, A. A. (2021). Rising Canadian and falling Swedish radon gas exposure as a consequence of 20th to 21st century residential build practices. *Scientific Reports*, 11(1), 17551.

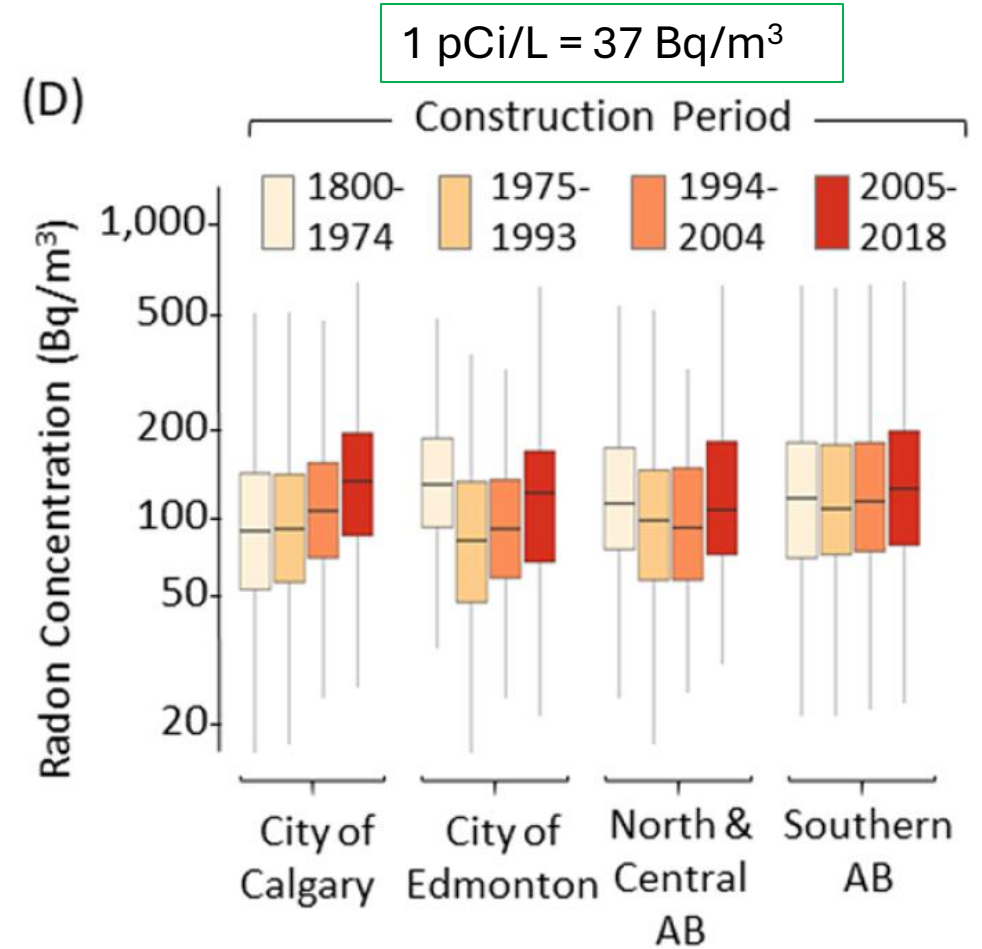
Are Modern Buildings More Resistant to VI?

Stanley et al. 2021:

- 12,000 houses in Alberta and Saskatchewan
- “Modern North American prairie residential environment display... worsening radon exposure,
- more recent construction year, greater square footage, fewer storeys, greater ceiling height, and reduced window opening behavior all associated with increased radon...
- all build types constructed >1990s display an increasingly steep indoor air radon increase”

Rugg 1988 Radon concentrations:

- 5,700 houses in NJ
- Houses less than 40 years old > 40 to 90 years old
- Houses greater than 90 years old > 40 to 90 years
- Post world war II and pre 1900 houses had the higher concentrations



Stanley, F. K., Irvine, J. L., Jacques, W. R., Salgia, S. R., Innes, D. G., Winqvist, B. D., ... & Goodarzi, A. A. (2019). Radon exposure is rising steadily within the modern North American residential environment, and is increasingly uniform across seasons. *Scientific reports*, 9(1), 18472.

Rugg 1988 House Age, Substructure and Heating System; Relationship to Indoor Radon Concentrations; AARST Conference Paper http://aarst-nrpp.com/proceedings/1988/1988_04_House_Age_Substructure_and_Heating_System_Relationships_to_Indoor_Radon.pdf

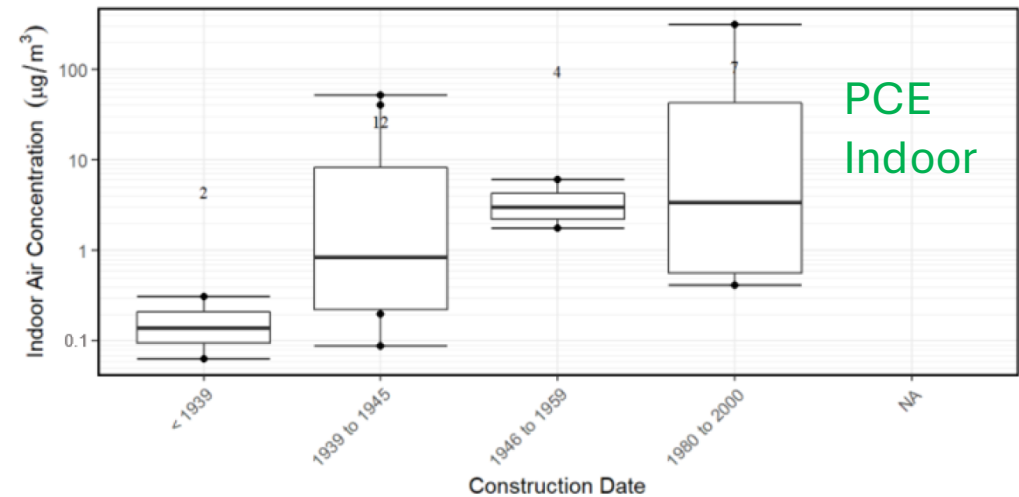
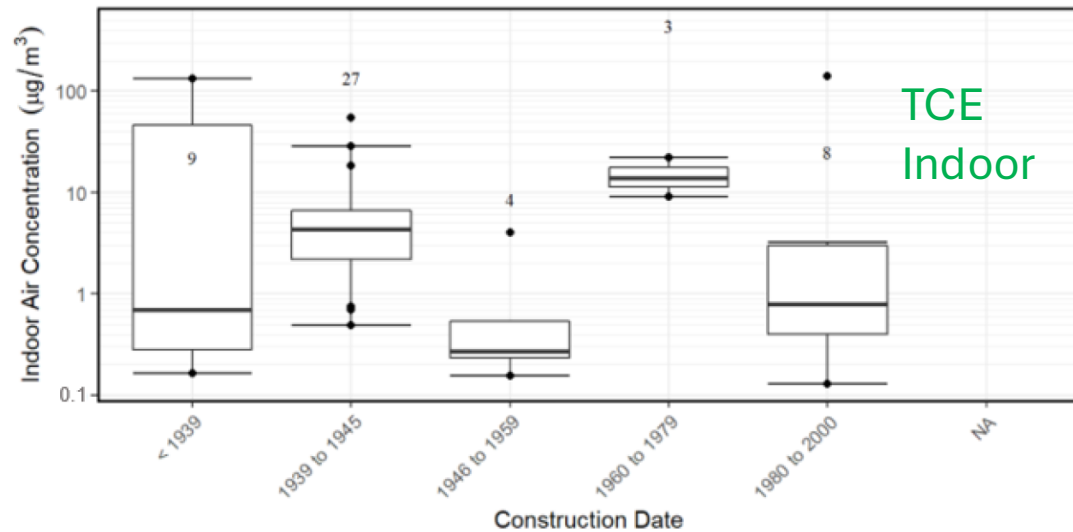
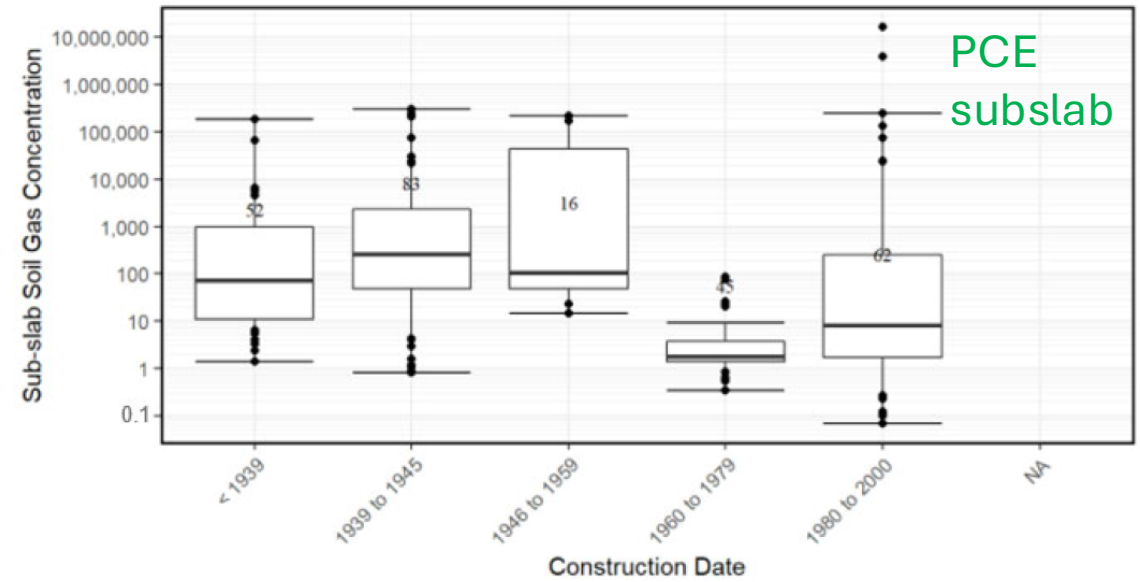
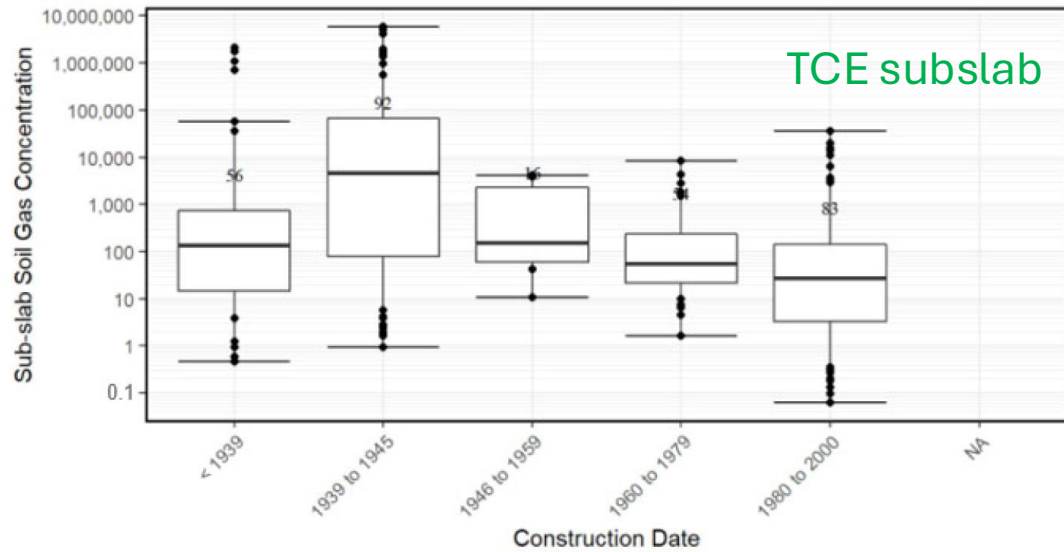
Are Modern Buildings More Resistant to VI?

Lutes (2021) studied database of 79 DoD buildings and concluded:

- Single variable analyses using subslab soil gas concentrations, indoor air concentrations, or AFs (normalized indoor air concentrations) vs. period of construction show buildings constructed during World War II or during the early years of the Cold War (through the late 1950s) tend to be associated with greater VOC concentrations in subslab soil gas.
- The indoor air concentrations and AFs, however, suggest more variability, likely because of poor weatherization and high air exchange rates in buildings from that era.
- Overall, the data suggest that WWII-era buildings often have strong subslab sources and could have elevated indoor air concentrations if they were renovated in a way that increased weatherization or reduced ventilation but did not decrease infiltration exposure.

Lutes, C.C., L.C. Levy, K.E. Hallberg, R. Gonzalez-Abraham, D. Caldwell, L.G. Lund, T.R. Walker and T.B. Lewis “Final Reanalysis of Department of Defense Vapor Intrusion Database of Commercial and Industrial Buildings” November 2021. Prepared for NAVFAC EXWC and NAVFAC Atlantic by CH2M HILL, Inc.
https://exwc.navy.mil/Portals/88/Documents/EXWC/Restoration/er_pdfs/v/Reanalysis_of_DOD_VI_Database_of_Comm_Ind_Buildings_Final_NOV21/Reanalysis%20of%20DOD%20VI%20Database%20of%20Comm%20Ind%20Buildings%20Final%20NOV21.pdf?ver=ujOoxNHdndzSmKvGzP-Q3w%3d%3d×tamp=1652983111487

Are Modern Buildings DoD More Resistant to VI?

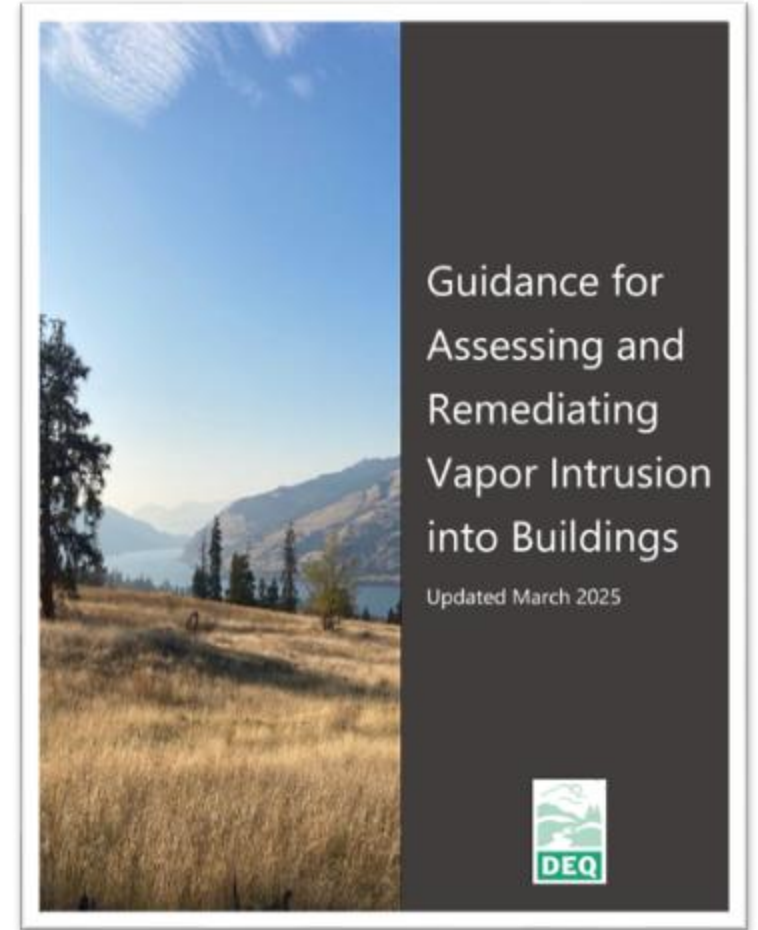


Lutes, C.C., L.C. Levy, K.E. Hallberg, R. Gonzalez-Abraham, D. Caldwell, L.G. Lund, T.R. Walker and T.B. Lewis "Final Reanalysis of Department of Defense Vapor Intrusion Database of Commercial and Industrial Buildings" November 2021. Prepared for NAVFAC EXWC and NAVFAC Atlantic by CH2M HILL, Inc.

https://exwc.navy.mil/Portals/88/Documents/EXWC/Restoration/er_pdfs/v/Reanalysis_of_DOD_VI_Database_of_Comm_Ind_Buildings_Final_NOV21/Reanalysis%20of%20DOD%20VI%20Database%20of%20Comm%20Ind%20Buildings%20Final%20NOV21.pdf?ver=ujQvNHdDzSnKvGzP-Q3v%3d%3d×tamp=1652983111487

Are Modern Buildings More Resistant to VI?

- Oregon DEQ Guidance 2025:
 - “Generally, older buildings present comparatively more VI pathways than newer buildings due to aging infrastructure, such as degraded building slabs, increased number of entry points for VI, multiple foundation depths, or subsequent building additions, as well as higher potential for poor ventilation or limited to no building pressurization”



<https://www.oregon.gov/deq/Hazards-and-Cleanup/Documents/ecVaporGuidance.pdf>

Economic Considerations

- Mitigation of VI is much less expensive when done as part of new construction or major renovation vs. when retrofitted.
- Retrofit mitigations often require building upgrades and thus can be quite costly; estimates:
 - DiLorenzo, 2014: average \$32,600
 - New England. Cites: clutter, unstable foundations, electrical problems as cost drivers
 - Regan, 2022: \$19,950 to \$61,650 per house; Median \$33,600
 - Midwest and NE US. Cites: structural, access, storage, mold and asbestos as issues
 - Quadri/CH2M, 2019: average \$23,000
 - New Mexico. Cites: building envelope changes often required
- New construction design and installation of mitigation is generally small percentage of building cost.
 - Values of \$2.50 to \$6.75/ft² (NAVFAC). Alpine Environmental <\$2.50/ft².
 - For median size home (2,146 ft² this would be <\$5,350) and single unit of multifamily (1104 ft² = \$2,760).
- Winfield & Associates cites 1999 estimate for Gardena, CA of \$12,000 per new townhouse.
- Kansas State estimates radon resistant new construction at \$350-\$500 per single family home.
- Krop et al. (2025) US EPA estimate in 2023 dollars is \$1,151 for passive radon reducing features in new homes.

References: J. DiLorenzo, "Sub-slab Depressurization (SSD) Highlights and Hurdles in EPA New England" C. Regan AEHS, 2022 Presentation "Older Residential Homes: Sub-Slab Depressurization Lessons Learned for Successful Mitigation"; Quadri, S. "Recommendation for Pre-Emptive Mitigation at the Petoskey Manufacturing Company (PMC) Superfund Site, Petoskey, Michigan" September 10, 2019; NAVFAC "Vapor Intrusion Mitigation in Construction of New Buildings Fact Sheet" [Vapor Intrusion Mitigation in Construction of New Buildings Fact Sheet](https://www.alpineenv.com/vapor-encroachment); <https://www.alpineenv.com/vapor-encroachment>; <https://latestcost.com/vapor-barrier-cost-per-square-foot/> ; <https://sosradon.org/rmc-install>; Krop, Richard A. "Analysis of Benefits and Costs of Radon Reduction Strategies Recommended by the EPA: Cost-Effective Interventions for Lung Cancer Prevention", October 2025 <https://www.epa.gov/system/files/documents/2025-12/analysis-of-benefits-and-costs-of-radon-508.pdf>; Sizes from 2024 national data: <https://www.census.gov/construction/chars/highlights.html>

Neighborhood Scale Considerations – Soil Vapor Extraction (SVE) vs. Individual Building Mitigation

- SVE may be more desirable because it allows mitigation to be performed centrally instead of in each home and moves vapors away from the structures. This can reduce resident inconvenience and simplify maintenance.
- An economic analysis comparing SVE to active subslab depressurization suggests that SVE will be the low-cost option if the buildings are close together and/or if both technologies require the same degree of air pollution control.



Groundwater
Monitoring & Remediation

Field Study of Soil Vapor Extraction for Reducing Off-Site Vapor Intrusion

by Lloyd Stewart, Chris Lutes, Robert Truesdale, Brian Schumacher, John H. Zimmerman and Rebecca Connell

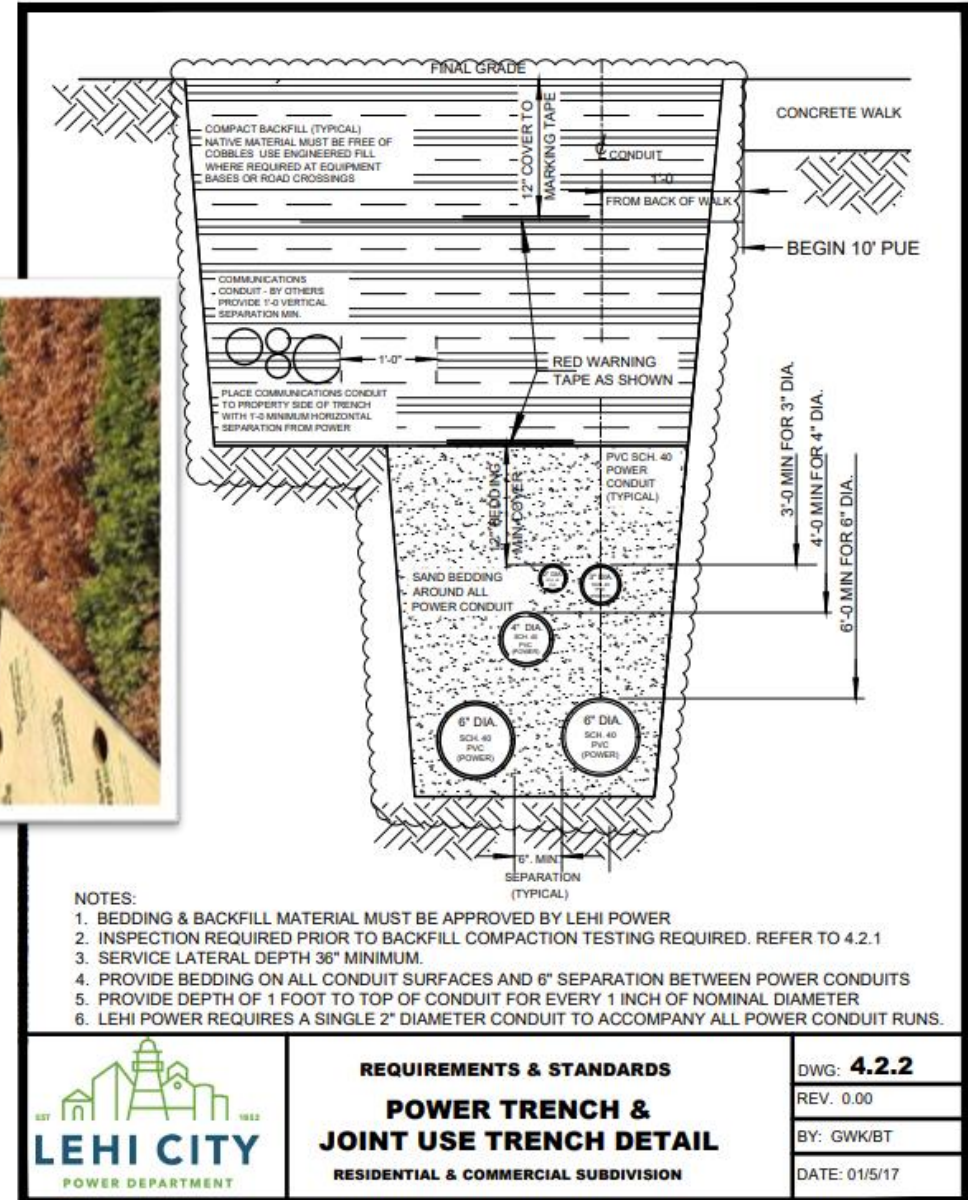
Groundwater
Monitoring & Remediation

Cost Comparison of Soil Vapor Extraction and Subslab Depressurization for Vapor Intrusion Mitigation

by Christopher Lutes , Lloyd Stewart , Robert Truesdale, Jose De Loera, John H. Zimmerman and Brian Schumacher

Neighborhood Scale Considerations – Leveraging Other New Infrastructure

- SVE has previously been implemented with horizontal wells.
- New developments often require new underground infrastructure for water, sewer, power and communications.
- Could a joint utility trench be leveraged for ongoing soil gas protection?



Summary

- New construction whether of a building or a neighborhood is a golden opportunity to implement mitigation inexpensively.
- Many guidance documents are available for this.
- Following current codes provides a number of first steps towards vapor intrusion resistance