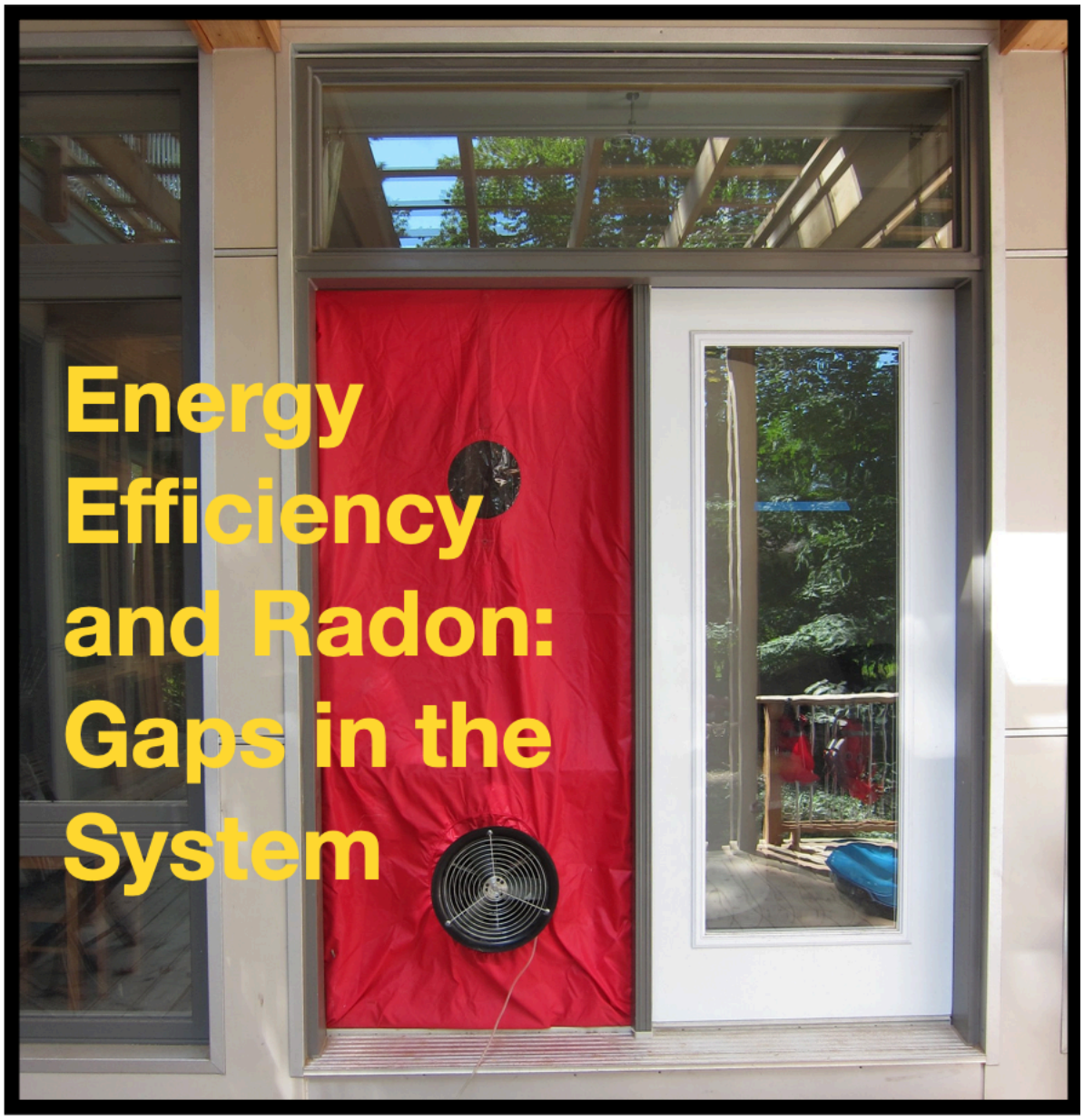

Energy Efficiency and Radon: Gaps in the System

BC LUNG FOUNDATION

Executive Summary

Radon is a colourless odourless and radioactive gas that eminates from the ground. When dispersed to the outside it is dilluted and is relatively harmless, but it can accumulate in buildings to levels that pose significant health risks. While over 3000 Canadians a year die from radon induced lung cancer, these numbers can be significantly reduced through ensuring homes and workplaces are tested, and radon prevention systems put in place.

Our project on Energy Efficiency and Radon highlights how efficiency measures can make radon worse without due care and attention. Radon can accumulate in buildings which are made more airtight, or which have reduced air pressure, but measures can be taken to test for radon and take steps to prevent it building up. In *Energy Efficiency and Radon: Making the Connection* we review academic literature on the links between efficiency measures and radon. In a further legal analysis, titled *Energy Efficiency and Radon: Recognizing Legal Liabilities* we emphasize that there is a duty of care on personnel in the energy efficiency industry to ensure they do not put clients at elevated health risk. We suggest energy advisors and contractors need to ensure clients are properly warned, and precautions taken to ensure radon levels are not elevated after the retrofit process is completed. In *Energy Efficiency and Radon: Solutions Moving Forward* we give our final project recommendations.

In this report, we analyze the current energy efficiency system in Canada, how newer homes are made increasingly efficient, and efforts to support energy upgrades in older homes. We discuss Building Codes, green building standards, and the process of energy efficiency policies and programs in Canada. We examined guidance to Canadians on energy efficiency, and certification and standardization of work of energy advisors by Natural Resources Canada. We reviewed key efficiency programs in British Columbia and Ontario and conducted qualitative interviews with energy advisors.

We note that radon is recognized as a problem in building codes across Canada, but with varying degrees of technical requirements. We were pleased to see that most voluntary green building standards did include attention to radon, with notable exceptions for energy efficiency standards such as Canada's Energy Star for New Homes, and the International Passive House Standard. However, we found that radon is ignored in most incentive and subsidy programs and there is significant lack of awareness of the problem among energy advisors. This suggests consumers are not getting the message about radon, and that Canada's energy efficiency system may be making radon exposure worse. This creates significant risks of liability which need to be addressed. Alternatively, we found the links between radon and energy efficiency are increasingly being made elsewhere— in national Radon Action Plans in European countries and in specific guidance on energy efficiency and indoor air quality from the United States Environmental Protection Agency, Department of Energy and National Renewable Energy Laboratory. This suggests Canada's energy efficiency system can and should do better: Government regulators, tincentive providers, the financial community, energy advisors, and contractors need to recognize efficiency programs can make radon worse, that home owners and occupants need to be aware of the problem, and measures taken to ensure efficiency upgrades do no harm.

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To find project documents, visit BC Lung's website on Radon and Energy Efficiency, at https://bclung.ca/programs-initiatives/healthy-indoor-environments-program/current-projects/radon-and-energy

About our program. The BC Lung Foundation's Healthy Indoor Environments program is focused on providing education, resources, and policy options for addressing priority indoor air pollutants in British Columbia. Canadians spend 90% of their day indoors, with about 70% at home and 20% at work or school. The air we breathe indoors can contain particulates, gases, allergens and fumes that can significantly affect our health in both the short and long term. Knowing the main indoor air pollutants, their sources, and how to reduce them are key to reducing harm to our health. Radon has been identified as the leading environmental carcinogen in Canada. For more information visit our website at https://bclung.ca/programs-initiatives/healthy-indoor-environments-program

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1. Energy Efficiency Measures Can Make Radon Worse

Energy efficiency measures (also sometimes called 'winterization' and 'weatherization') aim to reduce the amount of energy homes and other buildings use. Broadly this can be done through:

- Reducing the amount of air that needs to be heated or cooled, through minimizing leaks through windows and door joints, ceilings, attics, and foundations
- Reducing the amount of water that needs to be heated through improved faucets or appliances
- Reducing loss of energy across the building envelope. This has traditionally been done through better sidewall and roof insulation, but Heat Recovery and Ventilation Systems (HRVs) and Energy Recovery and Ventilation Systems (ERVs) allow for capturing energy in air as it leaves a building and transferring it to incoming air
- Upgrading lights and appliances (including heating and cooling systems) to be more energy efficient or to use less fossil fuels. Commonly today, heat pumps and district energy systems are seen as improvements over oil, natural gas or wood heating because electricity based systems can be emit relatively few carbon emissions when the electricity is itself generated from renewable or hydroelectric sources.

Energy efficiency measures are often sold as a way to reduce heating costs, but can also achieve important social and environmental goals, when widely implemented, including saving scarce energy resources, avoiding new dams or power plants being built, and reducing greenhouse gas emmissions. Unfortunately, if energy efficiency measures are not done right the result can be increases of indoor air contaminants, including radon gas.[1]

Radon occurs naturally when uranium breaks down in rock and soil. It is an invisible, odourless, and tasteless radioactive gas. When radon leaves the ground it is usually diluted in air and is relatively harmless. However, radon can seep into indoor spaces (i.e. homes, which this guide focuses on) through small cracks and openings where the building contacts the soil. In some homes it can accumulate in higher concentrations, posing a health risk. When radon is breathed in, it can damage lung cells and cause lung cancer. Radon gas is the number one cause of lung cancer in non-smokers. In Canada alone, radon causes approximately 3,360 deaths each year. Elevated radon has no side effects or warning signals until the person develops lung cancer.[2] Health Canada has developed a national guideline for radon in indoor spaces to 200 becquerels per cubic metre (200 Bq/m^3). Any level above 200 Bq/m^3 constitutes elevated radon.[3] Health Canada recommends all homes be tested, and if elevated levels are found, the problem can be remedied for less than the cost of replacing a furnace by radon mitigators. The Canadian National

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[1] Fisk, W.J., Singer, B.C. and Chan, W.R., 2020. Association of residential energy efficiency retrofits with indoor environmental quality, comfort, and health: A review of empirical data. *Building and Environment*, *180*, p.107067. Francisco, P., Gloss, S., Wilson, J., Sun, Y., Dixon, S.L., Merrin, Z., Breysse, J., Tohn, E. and Jacobs, D., 2020. *Building Assessment of Radon Reduction Interventions with Energy Retrofits Expansion (The BEX Study)* (No. ORNL/TM-2020/1769). Oak Ridge National Lab.(ORNL), Oak Ridge, TN (United States).

[2] Health Canada, 2014. Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors (2010) www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radon_contractors-entrepreneurs/index-eng.php retrieved 2022-04-14. at p 2.

[3] Health Canada, 2014, ibid. pp. 1 and 5

Radon Proficiency Program ("C-NRPP") has a training program and certification system for mitigators.

In a companion document, *Energy Efficiency and Radon: Making the Connection* we review research that shows energy efficiency measures, whether in new homes or upgrades in older homes, can increase radon levels unless further steps are taken to test for and mitigate radon.[4] When efforts are made to make a home more airtight, the result can be less airflow and less chance to dillute radon. Renovations may also change how air pressures work. Radon is sucked into a home because lower parts of the home often have lower air pressure relative to the air outside and below the home. In an airtight home, exhaust fans in kitchens and bathrooms can lower air pressures throughout the building. Newer mechanical ventilation systems may also be poorly calibrated, further lowering inside pressure. Health Canada is clear: Homeowners should always consider re-testing whenever major renovations are performed that might substantially change the ventilation or airflow in the home or the use of the rooms in the lowest-occupied level.[5]

In a further document, *Energy Efficiency and Radon: Recognizing Legal Liabilities*, we provide a legal analysis which suggests ignoring radon creates significant legal liabilities for persons who build homes, produce energy efficient products that make homes more air tight, and who advise and conduct on energy retrofits. Existing Canadian legal duties create a broad need for energy efficiency industry participants to ensure that consumers and homeowners are informed as to the risks of energy efficiency measures on indoor air quality and radon, and to ensure that steps are taken to mitigate the risks.

In what follows, we explain how Canada's energy efficiency system works, and, gaps around radon in the system that need to be addressed.

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4. see Fisk et al. and Francisco et al. ibid.

5 Health Canada, 2017. Guide for Radon Measurements in Residential Dwellings (Homes). https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/guide-radon-measurements-residential-dwellings.html#a5 retrieved 2022-03-24 at s. 5.1

2. Canada's Energy Efficiency System

Codes for New Homes

Since the 1970s there has been a broad movement to make homes more efficient. For instance, ASHRAE's Standard 90, Energy Conservation in New Building Design, was first developed in 1975.[6] In Canada, the federal government helped develop the R-2000 standard as a joint industry and government certification initiative in the early 1980s, and required homes to have reduced air leakage (1.5 air exchanges per hour (ACH) under pressure, e.g. using a 'blower door test', about half of the air leakage of a standard house at the time).[7] The Canadian federal government introduced the EnerGuide for Houses (EGH) in 1998.[8] At first this was focused on creating an assessment tool, training program for auditors, marketing resources and technical support for independent energy auditors. It also included the EnergGuide rating systems for homes, and the Energy Star® certification system for products and appliances. [9]

As concerns around climate change and greenhouse gas emissions grew in the 2000s and 2010s there has been a focus on very low or 'net-zero' homes. For instance, Harmony House, in Burnaby, British Columbia, was built as part of the EQuilibrium Sustainable Housing Demonstration Initiative, sponsored by Canada Mortgage and Housing Corporation. It features R-40 walls, less than 1 ACH@50Pa, triple-glazed windows, a heat-recovery ventilator, a solar water heater and an efficient heat pump. It also featured daylight sensors that turn lights off as the sun rises, a "green switch" that can power down all non-essential systems from a single control, a cooling tower to help moderate summer heat gain, and 111 square metres of photovoltaic solar panels on the south face of the roof. During daylight hours, the photovoltaic panels generate more electricity than the house requires which can be fed into the electricity when not needed by the home.[10]

A variety of voluntary standards now provide detailed guidance on very low energy homes, such as Passive House, and the Canadian Home Building Association's Net Zero Home™ and Net Zero Ready Home™.[11] The federal government has also worked on pilot projects to develop its own "Net Zero" homes—e.g. which produce as much energy with solar panels as they consume

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[6] This has gone through multiple iterations up to the present, with ASHRAE 90.2-2018 now covering Energy-Efficient Design of Low-Rise Residential Buildings and ASHRAE 90.1-2019 now providing an Energy Standard for Buildings Except Low-Rise Residential Buildings

[7] Gamtessa, S.F., 2013. An explanation of residential energy-efficiency retrofit behavior in Canada. *Energy and Buildings*, *57*, pp.155-164; see also Waugh, J. 2016. Presentation to the New Brunswick Select Committee on Climate Change. https://www.nben.ca/en/climate-change-climate-change-public-consultation-2016-submissions?download=4426:low-energy-housing-in-canadaa-brief-history-narrative-for-the-presentation-to-the-select-committee-on-climate-change-joe-waugh-august-30-2016&start=20 retrieved 2022-04-14.

[8] Hoicka, C.E. and Parker, P., 2018. Assessing the adoption of the house as a system approach to residential energy efficiency programs. Energy Efficiency, 11(2), pp.295-313.

[9] Parekh, A., Mullallhy-Pauly B., and Riley, M. The EnerGuide for Houses Program.A Successful Canadian Home Energy Rating System. https://www.eceee.org/static/media/uploads/site-2/library/conference_proceedings/ACEEE_buildings/2000/Panel_2/p2_20/paper.pdf retrieved 2022-03-24

[10] Paulsen, M. 2012. High-performance homes. Canadian Geographic, July 1, 2012. https://www.canadiangeographic.ca/article/high-performance-homes. Retrieved 2022-03-24. See also Habitat Design and Consulting, 2022. About the Harmony House Project. https://harmony-house.ca/about retrieved 2022-03-24.

[11] Canadian Home Builders Association, 2022. CHBA Net Zero Home Labelling Program https://www.chba.ca/CHBA/HousingCanada/Net_Zero_Energy_Program/CHBA/Housing_in_Canada/Net_Zero_Energy_Program/NZE_Program_Landing_Page.aspx retrieved 2022-04-14.

— with an eye to incorporating these into future codes and standards.[12] In Table 1 we review ten key voluntary standards in Canada. We were encouraged that a majority do make provisions for radon. Unfortunately some standards are more exclusively focused on energy performance, and among those, three out of four did not address radon directly, or treat ventilation requirements as a sufficient solution. This is indicative of a reductive approach that does not contemplate the internal connections in how buildings operate between efficiency, indoor air quality and the creation of harm. Certification standardized homes continue to be a small part of the housing market.

Government mandated building codes have also gradually adopted increased efficiency standards. By 2012, the R-2000 energy requirements were incorporated into the National Building Code. The Pan-Canadian Framework on Clean Growth and Climate Change (2016) signals the intention for model building codes to reach net-zero energy ready standards by 2030. Individual province's climate policies, such as British Columbia's Clean BC: Roadmap to 2030, is in line with that, envisioning transition to zero-carbon new buildings by 2030. Initial steps to carry this out included the "Step Code" which sets out measurable energy-efficiency requirements for new construction, but allows municipalities some leeway in when these are introduced. The regulation sets performance targets for new construction and groups them into "steps" that apply across various building types and regions of the province. The lower steps are relatively straightforward to meet; the upper steps are more ambitious. Authorities having jurisdiction over the BC Building Code—including local governments—can choose to require or incentivize builders to meet one or more steps of the BC Energy Step Code as an alternative to the code's prescriptive requirements. For part 9 homes (primarily single family and low rise residential), step 1 means enhanced compliance (e.g. energy modelling), step 2 is 10% more efficient, Step 3 is 20% more efficient, step 4 is 50% more efficient, and step 5 signals net zero energy ready (or 80% more efficient).[13]

[12]Net Zero: Future Building Standards. https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-homes/buying-energy-efficient-new-home/netzero-future-building-standards/20581 retrieved 2022-04-14.

[13] BC Energy Step Code, 2022. How the BC Energy Step Code works. http://www.energystepcode.ca/how-it-works/ retrived 2022-04-14

Table 1: Radon in Voluntary Building Standards in Canada		
Name	**Summary**	**Radon**
Holistic Standards		
Built Green Canada	Industry-driven home certification programs to encourage and facilitate sustainable business practices for residential builders.The programs take a holistic approach with energy efficiency as a key focus. There are seven key areas of sustainable building the certification programs aim to address, including indoor air quality.	**Yes.** Addition in 2019 to Single Family Checklist—s. 3.6 provides for builders to give homeowner a do-it-yourself radon test kit to be conducted for a three-month duration (1 point), coupled with radon education materials available through Health Canada's website (1 additional point). (see Built Green, 2019. Updates to Single Family Checklist. Guiding Principles.https://www.builtgreencanada.ca/program-updates-2019-single-family-checklist).
Living Building Challenge	The LBC is a holistic approach that utilises "Petals" to represent seven different performance categories.There are Core Imperatives divided within each certification category, which detail the fundamentals of each Petal. All Core Imperatives are required to be met for Petal Certification.	**No**. The "Health & Happiness" Petals' priority focus is to promote indoor air quality and a healthy indoor environment. Healthy Interior Environment includes complying with ASHRAE 62 (without specifying further, when ASHRAE Now includes 62.1 and 62.2). This includes ventilation but no specific provisions for radon (see International Living Future Institute. 2019. Living Building Challenge 4.0. Available at https://www2.living-future.org/LBC4.0?RD_Scheduler=LBC4)
LEED v.4.1 Residential Single Family Rating System.	An independent verification system with both requirements and optional credits to gain more points for certification.	**Yes**. LEED require projects in high-risk radon areas (Classified by the Environmental Protection Agency as radon zone 1 or equivalent outside the U.S.A) to be built with radon-resistant techniques or require testing during renovation if no slab work is being performed, with action taken if the results are over 4 pCi/L (148bq/m^3) see LEED v4.1 Residential Single Family Rating System. (2020).t https://www.cagbc.org/CAGBC/Programs/LEED/LEEDv4/LEED_v4.1.aspx#residential
WELL Building Standard v.2	A performance-based system for measuring, certifying, and monitoring features of buildings that impact the health and wellbeing of people who occupy them.	**Yes**. Radon is incorporated into WELL v2 through section A01 "Air Quality" part 4."Meet Thresholds For Radon". Incorporates EPA Radon action level of 4 pCi/L (148 Bq/m^3) and requires all spaces to either be tested for radon or have mechanical ventilation https://v2.wellcertified.com/en/wellv2/air/feature/1
Green Globes Design for New Construction and Major Retrofits v.2	Certification and assessment tool. Modules for new constructions, sustainable interiors, and existing buildings. Certification system draws heavily on ASHRAE standards as well as the ANSI/GBI 01-2010: Green Building Assessment Protocol for Commercial Buildings[13]	**Yes**. Section G.2 Source Control and Measurement of Indoor Pollutants. The radon requirements consist of conducting a "site-specific assessment of radon potential and specifying mitigation measures as needed." http://www.greenglobes.com/newconstruction/Green_Globes_Design_for_New_Construction_v2_Summary.pdf

BOMA Best Sustainable Buildings Certification 3.0 v.2.	Assessment tool for builders and building owners to assess 10 areas of environmental performance and management.	**Yes.** Section 05.02.01 asks whether radon risk assessments/radon measurements have been completed for the building, using the Canadian Radon Guideline (200 Bq/m^3) and whether mitigation measures have been taken. See https://www.bestsustainablebuildings.org/wp-content/uploads/2020/11/TCR-32-Radon-assessment-and-mitigation.pdf
Energy Focused Standards		
Canada's Energy Star for New Homes™ Standard V12.6 (2015).	This standard specifically looks at energy efficiency of new homes, and by purchasing an energy star rated home buyers are able to know that the home is energy efficient. The program was developed by NRCan, and is updated to work in conjunction with regional building codes.[19] NRCan oversees the standard at a national level, while service organizations and energy advisors ensure the standard is being upheld before labels are given to new homes.	**No**. Air quality is referenced once in Section 4.7.1.5 on Ventilation of Public Corridors in MURBs, by reference to ASHRAE 62.1 on Ventilation for Acceptable Indoor Air Quality. There are also general ventilation standards .https://www.nrcan.gc.ca/energy-efficiency/energy-star-canada/about-energy-star-canada/energy-star-announcements/energy-starr-new-homes-standard-version-126/14178#a47
R-2000 Standard™ (2012)	Voluntary national standard for residential homes. The technical requirements of the R-2000 Standard focus on energy, air quality, and environmental responsibility.[21] The standard addresses practices both during construction and during occupation.	**Yes, but optional.** Radon is found under " Indoor air quality features". This section outlines a list of 9 different features, and includes radon and the use of sub-slab depressurization system as a protection. However, the standard gives the option of choosing 3 features, making radon essentially a voluntary option. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/files/pdf/2012%20R2000%20Standard%20EN.pdf
Canadian Home Building Association's Net Zero Home™ & Net Zero Ready Home™	Labelling program, indicating homes produce clean energy at the same rate that they use energy, or are "ready" to do so pending installation of a renewable energy system.	**No.** However, some features such as sub-slab insulation and ventilation requirements may incidently improve radon. Based on personal correspondence with program manager.
International Passive House Standard	Uses intelligent building design to optimize energy efficiency through superior insulation, thermal bridge-free construction, an airtight building envelope, high-performance windows and doors, and heat recovery ventilation.	**No.** However, contain specific requirements for balanced mechanical ventilation systems and a minimum ventilation rate of 8.33 L/s/person/ There is also a continuous air and vapor barrier at the foundation to control moisture ingress. https://passiv.de/downloads/03_building_criteria_en.pdf

Retrofits

Thermal renovations of existing homes is a highly effective and relatively inexpensive method for short term reduction of CO_2 emissions.[14] When considering future climate targets, such as total building emissions in 2030, it is important to recognize that at least 75% of the anticipated building stock will be buildings already built today. As such, retrofitting the existing building stock has become more pressing.[15] Starting in 2003 the EnerGuide for Homes program included financial incentives for advisors and for retrofits.[16] The Conservative government headed by Stephen Harper cancelled the incentive program in 2006[17] but initiated a new ecoEnergy Retrofit Program that ran from about 2007 to 2012.[18] Retrofitting has been significant part of the Justin Trudeau government's climate efforts. The 2021 federal budget included a $4.4-billion investment over five years, with funds for recruitment and training of EnergGuide energy advisors, and grants to homeowners for EnergGuide advising and retrofit work.[19] Federal grants and subsidies also exist alongside provincial programs, such as British Columbia's LiveSmart program in the 2000s and now the Clean BC initiative. This centralizes information and grants which can come from natural gas and electricity utilities and provincial programs and will provide grants to offset the costs of particular items, such as heat pumps.

To date, retrofitting has only been partially standardized. Typically, energy advisors are certified and trained by Natural Resources Canada, use specialized software from NRCan (HOT2000). This is to provide an initial assessment of a home's energy performance and fuel consumption. This training process and software ensures standardization in energy modelling and evaluation and for comprehensive databases for research and program evaluation purposes. Directing consumers to advisors is an important way to overcome 'information deficits' and ensure homeowners are aware of potential energy saving opportunities.[20] NRCan also produces a consumer guide— *Keeping the Heat In* that describes retrofits. However, the advisors role is ultimately to provide suggestions on potential improvements to homeowners, who have wide latitude in deciding what to implement. Homeowners often use independent contractors to perform specific tasks (one contractor might replacing windows, another the furnace).[21] There is a relative shortage of skilled trades in many of the required fields, and many of these contractors do not

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[14] Gamtessa, S.F., 2013. An explanation of residential energy-efficiency retrofit behavior in Canada. Energy and Buildings, 57, pp.155-164. R. Galvin, Thermal upgrades of existing homes in Germany: the building code, subsidies, and economic efficiency, Energy and Buildings 42 (6) (2010) 834–844.

[15] Hoicka, C.E. and Das, R., 2021. Ambitious deep energy retrofits of buildings to accelerate the 1.5° C energy transition in Canada. The Canadian Geographer/Le Géographe canadien, 65(1), pp.116-127.

[16] Gamtessa, ibid. see also.Hoicka, C.E. and Parker, P., 2011. Residential energy efficiency programs, retrofit choices and greenhouse gas emissions savings: a decade of energy efficiency improvements in Waterloo Region, Canada. *International Journal of Energy Research*, *35*(15), pp.1312-1324)

[17] Bird, T. 2006. Harper Cuts EnerGuide. Alternatives Journal Vol. 32, No. 2, , pp. 7-8

[18] McKie, D. 2013. EcoEnergy home retrofits' early end left funds unspent. CBC News, Dec. 3, 2013, (https://www.cbc.ca/news/politics/ecoenergy-home-retrofits-early-end-left-funds-unspent-1.2447081 retrieved 2022-04-14.

[19] Bulowksi, N. Critics throw shade at federal budget cash for home retrofits. National Observer, April 21st 2021, https://www.nationalobserver.com/2021/04/21/news/critics-federal-budget-2021-home-retrofits retrieved 2022-04-14.

[20] Hoicka, C. E., Parker, P., & Andrey, J. (2014). Residential energy efficiency retrofits: how program design affects participation and outcomes. Energy Policy, 65, 594–607.

[21] Hoicka, C.E. and Parker, P., 2011. Residential energy efficiency programs, retrofit choices and greenhouse gas emissions savings: a decade of energy efficiency improvements in Waterloo Region, Canada. *International Journal of Energy Research*, *35*(15), pp.1312-1324.

need specific qualifications or certification, such as home Heating Ventilation and Air Conditioning installers, or project managers (in renovation companies that do want to coordinate the process). [22]

Homeowner actions are highly variable. There is considerable research on the efficiency process by researchers. As part of the Hot2000 software individual home energy assessments and reports are placed into large datasets. Hoika and Parker (2018) analyzed 19,552 residential energy evaluations conducted by a single agency in the Region of Waterloo, in the Province of Ontario, Canada, between 1999 and 2011. They found that homeowners did not systematically attend to retrofits from a house-as-a-system approach, often ignoring insulation of the building envelope. Often, furnaces and windows were often upgraded as singular actions, meaning efficiency savings were far under potential. [23] There is widespread recognition of the need to move towards "deep energy retrofits" that reduce on-site energy use by at least 50%. However there remain significant barriers such as a lack of financial return as an investment for homeowners or landlords, to a lack of standardized products and skills in the industry.[24] Given the important of retrofits for meeting greenhouse gas reduction goals, and the need to coordinate and improve the industry, many governments have begun processes for standardizing retrofits through specific Codes. As Table 2 illustrates these continue to be works in progress.

[22] Frappé-Sénéclauze, T.-P., Heerema, D., and Tam Wu, K. 2017 Deep emissions reduction in the existing building stock: Key elements of a retrofit strategy for B.C. Pembina Institute.

[23] Hoicka, C.E. and Parker, P., 2018. Assessing the adoption of the house as a system approach to residential energy efficiency programs. Energy Efficiency, 11(2), pp.295-313.

[24]Canadian Mortgage and Housing Corporation, 2021. Advancing Building Retrofits. https://www.cmhc-schl.gc.ca/en/professionals/housing-markets-data-and-research/housing-research/research-reports/nhs-outcomes/research-insight-advancing-building-retrofits retrieved 2022-03-25. See also Frappé-Sénéclauze, T.-P., Heerema, D., and Tam Wu, K. 2017 Deep emissionsreduction in the existing building stock: Key elements of a retrofit strategy for B.C. Pembina Institute.; Kennedy, Madi and Frappé-Sénéclauze, T.-P. 2021. *Canada's renovation wave: A plan for jobs and climate*. The Pembina Institute.

Table 2: Key Initiatives to Standardize Retrofits		
Voluntary Certification Standards	ANSI/ASHRAE/IES Standard 100-2018: Energy Efficiency in Existing Buildings (Standard 100). Standard 100 applies to existing buildings and provides procedures and program essentials through improved energy efficiency and performance in existing buildings.	The BC Government has helped produced the ASHRAE 100 User's Guide
Government of Canada	Standardization to facilitate building retrofits was mandated under the Pan Canadian Framework on Climate Change (2016). NRCan has created the Joint CCBFC/PTPACC Task Group on Alterations to Existing Buildings (JTG AEB)	An initial report has been created, which lays out key principles for establishing an alterations code (See National Research Council, 2020. Final report - Alterations to existing buildings. https://nrc.canada.ca/en/certifications-evaluations-standards/codes-canada/codes-canada-publications/final-report-alterations-existing-buildings
BC Provincial Government	BC's climate action framework identified the need to make existing buildings more energy efficient. The 2020 Climate Change Accountability Report specified a goal of creating an Alterations Code for Existing Buildings by 2024. The Building Standards and Safety Branch is responsible for the development of the alterations code, and to ensure it aligns with the federal governments similar initiative.	A process is now being conducted under the Existing Buildings Renewal Strategy, and has featured a Phase 1 consultation report with a 2022-2023 timeline for a new Code. Government of British Columbia, Stakeholder Consultation Report: Alterations to Existing Buildings Project, Fall 2019. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/construction-industry/building-codes-and-standards/reports/wwh_alterations_to_existing_buildings_web_final_may2020.pdf
City of Vancouver.	The City of Vancouver has had energy efficient measures for renovation in its 2019 Building Bylaw. The *Climate Emergency Home Heating and Cooling Plan* is exploring ways to improve energy efficiency in existing buildings as a way to meet climate targets.	Current proposals for updating the Building By-Law are being workshopped (as of February 15, 2021)

3. How Radon is Being Overlooked

New Homes

It is relatively easy to address elevated radon, whether in new construction or in older buildings, regardless of whether the home is designed for high energy efficiency performance. Technical standards have been developed by Health Canada[25] and the Canadian General Standards Board. For new homes, a "sub-slab depressurization system" can be installed at the point of construction. Such a system is commonly described in terms of 'levels' with each subsequent level assuming completion of the first:

- Level 1 is also called a 'rough in with stub'. This includes a gas permeable layer of aggregate rock below the foundation, an impermeable membrane just below the slab, good sealing of foundations, and piping which collects soil gas and passes through the slab at a suction point and which sticks up (at least 6 inches) from the floor and is capped. This is required in the National Building Code with the rationale that installing this at the point of construction is inexpensive and allows for a later introduction of further Levels.
- Level 2 is a full passive stack— this is ideally a vertical run, which continues the piping through the home and which terminates outdoors.
- Level 3 is a full active system, in which an electric fan is added to the piping to drive air flow.[26]

It is common to see energy efficiency specialists point to ventilation requirements in some green building standards as proof of concern for indoor air quality and radon.[27] The importance of ventilation cannot be overstated given air tight building envelopes can otherwise trap in a range of pollutants.[28] Radon scientists and technicians do tend to see ventilation as an important step—and professional radon mitigators do check to see if increasing ventilation rates in mechancial systems can help resolve high radon levels. However, ventilation works primarily by dilluting radon, and in many buildings this will not be sufficient to lower levels below Radon Guidelines.[29]

A well planned and executed radon system should have minimal electrical draw. Older research has suggested passive systems can be effective at reducing radon, but do not consistently ensure homes are under Canada's Radon Guideline of 200 Bq/m^3.[30] More recent research by the National Research Council has shown that if passive systems are built with a vertical stack and with good insulation, and operate in homes with heat recovery ventilators, there

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[25] Health Canada, 2010. Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors. https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/radiation/reducing-radon-levels-existing-homes-canadian-guide-professional-contractors-health-canada-2010.html retrieved 2022-03-24

[26] see Canadian General Standards Board, 2019. Radon control options for new construction in low-rise residential buildings. CAN/CGSB-149.11-2019. https://publications.gc.ca/collections/collection_2019/ongc-cgsb/P29-149-011-2019-eng.pdf retrived 2022-03-24.

[27] Moreno-Rangel, A., Sharpe, T., McGill, G. and Musau, F., 2020. Indoor air quality in Passivhaus dwellings: A literature review. *International journal of environmental research and public health*, *17*(13), p.4749

[28] Borsboom, W., De Gids, W., Logue, J., Sherman, M.H. and Wargocki, P.J.I.E., 2016. Technical note AIVC 68 residential ventilation and health. *Brussels: INIVE*. See also Health Canada, 2022. Improve Indoor Air Quality in Your Home. https://www.canada.ca/en/health-canada/services/air-quality/improve-indoor-air-quality-in-your-home.html retrieved 2022-03-28

[29] see Health Canada, 2010. Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors, ibid. Chapter 7 Mitigation by Ventilation Methods.

[30] Rogaza, D., Roberts, H., Swoveland, B. 2014. A Comparison of Three Radon Systems in British Columbia Homes: Conclusions and Recommendations for the British Columbia Building Code. British Columbia Lung Association.

is a very high likelihood of reducing radon to below Canada's Radon Guideline of 200 Bq/m^3 even before the addition of a fan.[31] Mitigators report that if such systems do need to be completed with with a fan, then with proper air pressure testing prior to installation most likely on the lowest commercially available fans, at 20 watts, will be needed.

There do exist a series of legal protections that theoretically protect new homes from radon. When elevated radon occurs in new homes, it is likely that efficiency initiatives contribute to the problem, but they cannot be separated from the entire system design.

- There are radon provisions in the National Building Code and provincial building codes as detailed in Table 3.[32] However, the radon provisions are not in effect in many areas, such as much of Ontario, and in many provinces only the rough-in with stub is required. In British Columbia, there is a requirement for an extended rough-in (e.g. with full vent piping and so similar to Level 2), but builders are allowed to put in horizontal runs in the pipe, meaning even if well built these systems are not reliably effective without a fan. All radon provisions in Canadian building codes anticipate post-occupancy testing for completion of the radon system, however none actually require testing. Likewise, municipal permitting offices apply existing buidling codes, but do not require radon testing prior to occupancy. Evidence suggests that very little post occupancy testing is occuring. Statistics Canada research suggests that across Canada as a whole, about 3 percent of homes have tested for radon.[33]
- Construction law principles squarely give architects, engineers and builders the responsibility to ensure buildings are safe, and risks of elevated radon (whether due to efficiency measures or otherwise) should be avoided through design elements.[34] However, there are currently no legal cases directly on point on radon—likely due to a combination of low testing rates, home occupants inattention to the issue, and the low costs for remediation making litigation unlikely.
- Elevated radon should be considered a defect under New Home Warranty programs.[35] However, to date this has only been recognized in In Ontario where, Tarion, the provincial home warranty provider, has incorporated this into policy.[36] In other provinces, homeowners' lack of awareness, the relatively low cost for mitigation, and the complexities of persuing legal claims make it difficult for legal precedents to be set.

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[31] Zhou, L.G., Berquist, J., Li, Y.E., Whyte, J., Gaskin, J., Vuotari, M. and Nong, G., 2021. Passive soil depressurization in Canadian homes for radon control. Building and Environment, 188, p.107487.

[32] National Building Code of Canada, 2015 includes radon provisions, as documented in Health Canada, 2017, Guide for Radon Measurements in Residential Dwellings (Homes), Annex 5 - Radon Preventive Measures in New Construction. https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/guide-radon-measurements-residential-dwellings.html#a12, retrieved 2022-03-17; the National Code is followed in Saskatchewan, Manitoba, New Brunswick, Nova Scotia, Newfoundland and Labrador, Northwest Territories, Yukon, Nunavut and Prince Edwarrd Island, see National Research Council, 2020. Model code adoption across Canada https://nrc.canada.ca/en/certifications-evaluations-standards/codes-canada/model-code-adoption-across-canada retrieved 2022-03-17. As well as included in the Alberta Edition, 2019. Distinct radon provisions are also found the British Columbia Building Code, 2018, at s. 9.13.4,https://free.bcpublications.ca/civix/document/id/public/bcbc2018/bcbc_2018dbp9s913r2, retrieved 2022-03-17 Ontario Building Code, 2017, s. s.9.13.4.2.4(a) and Supplementary Standard SB-9,, Quebec Construction Code, 9.13.4.6.https://www.legisquebec.gouv.qc.ca/en/pdf/cr/B-1.1,%20R.%202.pdf retrieved 2022-03-17

[33] Statistics Canada. Knowledge of radon and testing. Table: 38-10-0086-01 https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3810008601r retrieved 2022-03-25

[34] Quastel, N. 2020. Radon: Rights and Liabilities in Construction Law. Legal Brief No. 2. Healthy Indoor Environments, British Columbia Lung Association. https://bclung.ca/programs-initiatives/healthy-indoor-environments-program/current-projects/radon-and-bc-building-code retrieved 2022-03-25.

[35] This is further spelt out at BC Lung, 20202. New Home Warranty Providers.https://bclung.ca/radon-rights-and-duties-for-new-home-warranty-providers retreived 2022-03-25, and Quastel, ibid.

[36] Tarion. 2022. Radon Gas and Your Home Warranty. https://www.tarion.com/homeowners/your-warranty-coverage/radon-and-your-warranty retrieved 2022-03-25.

Overall, Canadian homes continue to have poor radon protection and researchers are finding that radon levels continue to persist in newer homes in Canada, and that radon levels are increasing.[37]

Table 3: Building Codes in Canada and Radon System Requirements

Building Code	If Limited Area of Application	Soil Gas Barrier only	Radon rough-in with stub only	Extended rough in with vent pipe
National Building Code of Canada, 2015			Explained here	
Followed in Saskatchewan, Manitoba, New Brunswick, Nova Scotia, Newfoundland and Labrador, Northwest Territories, Yukon, Nunavut. PEI in major municipalities.			Explained here	
British Columbia Building Code, 2018	Select municipalities predominantly east of Coast Mountains, see Table C-4 Locations in British Columbia Requiring Radon Rough-Ins			s. 9.13.4
National Building Code – 2019 Alberta Edition			Explained here, to be augmented with testing and other design as per 6.2.1.1 and "good engineering practice'	
Ontario Building Code, 2017 in Conjunction with Supplementary Standard SB-9, providing three options	Areas of Ontario with known radon problem	s.9.13.4.2.4(a) and Supplementary Standard SB-9, explained here	Supplementary Standard SB-9, explained here	9.13.4.2. 4(b) and Supplementary Standard SB-9, explained here
Quebec Construction Code		Quebec Construction Code A-9.13.2.1.(3) (prior to Sept 2020)	Quebec Construction Code, 9.13.4.6. (as of September 2020),	Quebec Construction Code, 9.13.4.6. (as of September 2020), if test results show need

[37] Stanley, F.K., Irvine, J.L., Jacques, W.R., Salgia, S.R., Innes, D.G., Winquist, B.D., Torr, D., Brenner, D.R. and 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), pp.1-17; Chen, J., 2021. A summary of residential radon surveys and the influence of housing characteristics on indoor radon levels in Canada. *Health physics*, *121*(6), pp.574-580. Simms, J.A., Pearson, D.D., Cholowsky, N.L., Irvine, J.L., Nielsen, M.E., Jacques, W.R., Taron, J.M., Peters, C.E., Carlson, L.E. and Goodarzi, A.A., 2021. Younger North Americans are exposed to more radon gas due to occupancy biases within the residential built environment. Scientific reports, 11(1), pp.1-10.

Retrofits

If homeowners and contractors are aware of radon and ready to act, there are easy steps that can be taken to ensure a home does not have high radon after a retrofit. Some steps are already included in the normal repertoire of energy upgrades, such as being careful to ensure there are no gaps or cracks in the foundation, or exposed plumbing cut-outs. One of the main causes of increased radon from retrofits is decrease in ventilation, but this can be in part remedied through a mechanical ventilation system with a heat recovery ventilator. If the mechanical ventilation system is maintained to ensure proper balancing of indoor and outside pressure, this will also help avoid the build up of radon gas. Once energy upgrades are completed and testing shows radon levels are still elevated, a professional radon mitigator can instal an active sub-slab depressurization system in one to two days, with an average cost of 3,000 dollars. Unfortunately, when it comes radon, there remain many gaps in Canada's building retrofit system.

Incentives and Subsidy Programs

In *Energy Efficiency and Radon: Recognizing Legal Liabilities* we argued that its important for all members of the energy efficiency industry to send the message to consumers of the risks of making homes more air tight, and to take steps to ensure they are not contributing to increased lung cancer risks. We suggest that in order to make sure energy efficiency retrofits are safe, the best way to do this is to see addressing related indoor air quality issues and radon as vital to the process. Radon testing and necessary mitigation should be seen as an important element of the retrofit process.

There are now a wide variety of incentive and subsidy programs for energy efficiency initiatives in both new homes and older homes across Canada. These tend to be a combination of electricity and natural gas savings measures— sponsored by utilities such as BC Hydro or Enbridge (in Ontario) —and direct grants for greenhouse gas reduction (such as Canada Greeneer Homes, and BC's CleanBC program). Many subsidy and incentive programs continue to make use of Natural Resources Canada certified energy advisors, with them serving to first evaluate homes and then suggest to homeowners necessary upgrades (as in the Canada Greener Homes program). Some incentive programs will subsidize the costs of hiring advisors, and, specific upgrades that advisors recommend. Commonly, however, some upgrades will be offered at low cost or given away free to homeowners, who are trusted to implement them on their own. For example, BC Hydro offers a free energy saving kit for qualifying low income households, that includes weatherstripping to put around doors and windows.

We reviewed a selection of major efficiency initiatives across Canada, reviewing websites and speaking to personnel on phone lines (see Table 4). We found almost none extended subsidies or incentives to ventilation systems or radon mitigation. While Natural Resources Canada does produce materials warning homeowners about indoor air quality and radon, this was not reflected in the grant program under Canada Greener Homes. Almost all programs are structured around reducing fossil fuel use or total energy use, and do not incorporate the idea that energy retrofit work needs to be accompanied by measures (from ventilation to radon mitigation) to ensure the retrofit work does not decrease indoor air quality or increase health risks. We were struck by the lack of attention to heat recovery ventilators and mechanical ventilation systems, and to radon

mitigation, in efforts by Canada Greener Homes, Clean BC, Ontario's Independent System Operator and Enbridge.

We did find some exceptions which help illustrate the gaping holes found elsewhere. CleanBC's Income Qualified Program specifically reocgnizes indoor air quality issues and that there may be necessary health and safety and ventilation upgrades as part of a retrofit. However, this is limited to pest, asbestos, and mould issues. Other exceptions include programs that provide general incentives and subsidies for home renovation and upgrades, such as the Government of Saskatchewan Home Renovation Tax Credit, Yukon Housing Corporation Home Repair Loan, the Habitation Durable program started in Victoriaville, Quebec, and Manitoba Hydro's Energy Finance Plan.

Table 4: Radon in Select Energy Efficiency Grant Programs in Canada

Name	Program Details	Radon Policy/Program
Canda Greener Homes. Natural Resources Canada	Grants to homeowners for hiring energy advisors) and to offset costs of energy efficient retrofits. Items covered include: • Advisors ($600) • Home insulation (up to $5000) • Air-sealing (Up to $1,000) • Windows and doors (up to $5,000) • Smart thermostats (up to $50) • Space and water heating (up to 5,000) • Photovoltaic solar panels up to $5,000	Uses NRCan certified energy advisors. Radon mitigation not included. Ventilation and HRVs not included. Does include "resiliency measures" to protect home from environmental damages when combined with another energy efficiency retrofit)up to $2, 625. However, resiliency measures included do not include radon.https://www.nrcan.gc.ca/energy-efficiency/homes/canada-greener-homes-grant/start-your-energy-efficient-retrofits/learn-about-the-initiative/23476
CMHC Green Home. Canada Mortgage and Housing Corporation	A partial refund up to 25% on the cost of mortgage loan insurance for homeowners who build, buy or renovate for energy efficiency.	For homes built under a CMHC-eligible energy-efficient building standard automatically qualify for a premium refund. For high rises, this LEED Canada New Construction standard (Certified, Silver, Gold and Platinum) or BUILT GREEN® High Density standard (certified Gold and Platinum). (Both LEED and BUILT GREEN provide ventilation standards, and LEED has explicit radon requirements reflecting US EPA Guidance.) For all other buildings, eligibility is based on the level of energy efficiency in the building design compared to the energy provisions of the applicable building code. https://www.cmhc-schl.gc.ca/en/professionals/project-funding-and-mortgage-financing/mortgage-loan-insurance/mortgage-loan-insurance-homeownership-programs/energy-efficient-housing-made-more-affordable-with-mortgage-loan-insurance

Energy Affordability Program, Ontario Independent System Operator	Free assessments from NRCan advisors and approved upgrades for income qualifying households, including: • LED light bulbs • High-efficiency showerheads • Faucet aerators • Drying line for clothes • Energy-efficient refrigerator • Window air conditioner • Smart power strip • attic or basement insulation • Weatherstripping • Smart thermostats	Uses NRCan certified energy advisors (will attend for free) .No provisions for ventilation, HRV.No provisions for radon. https://saveonenergy.ca/For-Your-Home/Energy-Affordability-Program
Home Winterization Program. Enbridge.	Natural gas utility demand management program. Applies in Ontario. Free assessments from NRCan advisors and approved upgrades for income qualifying households including • Wall, attic or basement insulation • Draft proofing • Smart thermostat	Uses NRCan certified energy advisors. No mention of indoor air quality, ventilation or radon https://www.enbridgegas.com/residential/rebates-energy-conservation/home-winterproofing-program
CleanBC Better Homes and Home Renovate Rebate Program	This combines BC government, BC Hydro and Fortis BC sponsored rebates and applies in BC. List of rebates includes: • Heat pumps • Water heater rebates • Window and door upgrade rebates • Insulation • Woodfire stove exchange rebate • Electrical service upgrade rebates	No radon-based rebates or information on radon. No rebates for mechanical ventilation or heat recovery ventilators. See https://betterhomesbc.ca/rebate-results/?buildingType=Renovating%20a%20home&heatingType=Not%20sure,%20view%20all%20rebates
CleanBC Better Homes Low Interest Financing Program	Up to $40,000 applies only to homes switching from fossil fuels to heatpumps.	Does not fund other energy upgrades, no mention of indoor air quality or radon issues. https://betterhomesbc.ca/rebates/financing/
CleanBC Income Qualified Program	enhanced rebates for qualifying low income households. Maximum rebate values of: • Insulation: Up to $5,500 • Windows and doors: Up to $9,500 • Heat pumps: Up to $9,500 • Heat pump water heaters: Up to $3,500	Does reconize indoor air quality issues and will offer rebates for “necessary health and safety and ventilation upgrades”, including up to $800 for removal of pest, asbestors and/or mould issues found during the installation of a heat pump, heat pump water heater, insulation or windows/doors. Radon not mentioned. https://betterhomesbc.ca/rebates/income-qualified/

Planet Wise Renovation Solutions— Home Renovation Loans. Vancity Credit Union.	Offers tailored packages with preferred interest rates comprising term loans, credit lines and as part of a mortgage. For instance, for the term loan, financing can be obtained up to 15 years, loans range from 3,500 to 50,000 and a Preferred interest rate of Vancity Prime Rate + 0.75% (which would now be 2.7) so thats much less than prime plus 4.	No discussion of radon or indoor air quaity in their energy retrofitting loan program materials. Renovation loans require NRCan certified energy advisor assessment and will cover recommended steps from that assessment. See https://www.vancity.com/Loans/TypesOfLoans/PlanetWiseRenovationSolutions/
Home Renovation Tax Credit. Government of Saskatchewan	Allows homeowners to claim a 10.5% tax credit on up to $20,000 of eligible home renovation expenses. The eligible expenses include the cost of labour, professional services, and the building materials required or radon reduction measures.	Radon mitigation included as an eligible home renovation expense https://takeactiononradon.ca/congratulations-to-saskatchewan/
Yukon Housing Corporation. Home Repair Loan	program with reduced interest up to $50,000	includes radon mitigation https://yukon.ca/en/news/take-action-radon-yukoners-urged-test-homes-radon-winter
Habitation Durable. Victoriaville Quebec and seven other communites.	Provides financial incentives a range of energy efficiency upgrades	Includes subsidies for radon mitigation as one of a range of sustainability upgrades. https://carst.ca/resources/Conference%202018/Presentations2018/Radon%20-%20réduction%20de%20l'exposition%20(anglais)%20Victoriaville.pdf
Manitoba Hydro Energy Finance Plan	On bill financing program offer loans for upgrades to energy systems in homes.	Will finance radon mitigation.https://www.hydro.mb.ca/your_home/loans_financing/energy_finance_plan/

NRCan Energy Advising Process

We focused on the NRCan certified energy advisors and the advising process. Many programs, such as Canada Greener Homes, the Ontario Independent System Operator's Energy Affordability Program and Vancity's Planet Wise Renovation Solutions loan program, use the NRCan certified advisors as gatekeepers for which expenses can be subsidized.

NRCan has set up a standardized system for data collection, house observations, software analysis and energy modelling and rating. Advisors undergo a limited training process that involves an initial Foundation Level Exam and the Energy Advisor (House) Exam, and need to be affiliacted with an NRCan-linceses service organisation. Candidates are only required to work with a service organization for the final steps of confirming practical skills and registration with NRCan. NRCan estimates that persons with significant building related experience and knowledge can become NRCan-registered EAs in less than one month.[38] When working with clients, advisors follow a regimented process of pre-evaluation telephone interviews, on-site house evaluation and energy modelling and analysis.[39] Central to this standardization is the HOT2000 Software, which allows advisors to input measured building characteristics to develop an energy model and to issue standardized assessments and reports to homeowners.

We interviewed 14 energy advisors located in BC and Ontario, using computer-based video links and telephone. We recruited by radomly contacting advisors by email based on listings in public databases and by referral from advisors we had previously contacted. Very few advisors we contacted replied, leading us to think our sample overly reflects advisors with an interest in indoor air quality or radon. For instance, 5 of 14 advisors had some training on radon: Three were certified as radon mitigators through C-NRPP (Interview Subject ('IS') 3, IS8, and IS9), one had university training in building science from a European university with radon in the curriculum (IS5), and one was doing a PhD in building science (IS6).

We asked advisors some general questions to estimate knowledge of radon. We found results strongly linked to prior training, in that those with some knowledge could answer basic questions (such as how radon entered a home). For instance when asked if guidelines were sufficient or energy efficiency measures could make radon worse, some simply said they did not know or evaded answering (IS1, IS2, IS7, IS11, IS13, IS14).

Generally, radon was not discussed between advisors and clients. We asked if clients asked about radon. Seven responded negatively, saying :'No' (IS3, IS6, IS7); 'I don't think there is much client notice about this' (IS5); 'Never, despite hundreds or thousands of assessments' (IS 10); 'homeowners are not asking' (S4); and 'doesn't come up' (IS14). Most others said there were times when it came up, but it was rare, using words such as 'very few' (IS 9) 'only about 1%' (IS11), or that "In my 12 years as an advisor I have had less than a handful ever ask' (IS12). One advisor, located in a widely recognized high radon region did say clients asked about radon

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[38] Natural Resources Canada, 2022. How to Become an NRCan Registered Energy Advisor. https://www.nrcan.gc.ca/energy-efficiency/homes/professional-opportunities/become-registered-energuide-rating-system-energy-advisor/20566#spbea retrieved 2022-04-14.

[39] Parekh, A., Mullallhy-Pauly B., and Riley, M. The EnerGuide for Houses Program.A Successful Canadian Home Energy Rating System. https://www.eceee.org/static/media/uploads/site-2/library/conference_proceedings/ACEEE_buildings/2000/Panel_2/p2_20/paper.pdf retrieved 2022-04-14.

(IS2). Three advisors who worked with new homes said it came up as part of building plans or Building Code requirements (IS3, IS5, IS13).

We asked if advisors discussed radon with clients. Many advisors did not generally independently raise the topic (IS 2, EIS7, EIS10, IS11, IS12, IS14). Some did say the mentioned it:

> *When clients ask I tell them that they should get testing done and where to get tests (IS2)*
>
> *I told the advisors who work under me to mention that we live in a high radon area, that its impossible to know without a long term test, done in the heating season between October and April (IS3).*
>
> *We sometimes bring it up. However, what comes up more is indoor air quality and ventilation (IS4).*
>
> *I do sometimes raise radon, but my location is not a hot zone. But some places it could be an issue —I refer them to the materials—I am also a certified mitigator. Also I care a lot about IAQ issues— we build houses for occupants (IS9)*
>
> *I did tell them about radon testing. I have also done work with friends and lent them my radon detector so they could get a reading (IS13)*

Two advisors (IS3, and IS8) specifically refered to radon information in the HOT2000 software genereated reports, which we further discuss below.

Most advisors did not take steps to educate clients on radon. (IS1, IS2, IS4, IS7, IS12, IS14 — IS9 and IS10 did not answer but from the overall conversation it can be inferred they did not.). Again, the situation was different with advisors who knew about the problem:

> *So if we go into a house and there's a crawl space that's not sealed and bare dirt, then there's exposure to the living space or heated volume, we would recommend to seal it off and tell them that there's a risk of radon. The limited information that we know about it is has consequences on health but for remediation or further services we would refer them (IS1)*
>
> *We explain why its important to implement that and why its in the building code (IS5)*
>
> *I tell clients its something to be aware of, and if they want to know levels should get a radon detector, especially if its pre-Building Code where radon systems not built in (IS6)*
>
> *If clients are concerned I give them information to help them make an educated decision to test for radon (IS9)*
>
> *I explained radon to clients orally, but do not hand out materials (IS3)*

Two energy advisors who were also mitigators expressed at this point that they felt caught up in potential conflict of interest— they did not want to be seen as promoting their own business interests and so stuck with general information on the need to test for radon. Here the emphasise was on equipping clients with tools to make edcuated decisions on their own (IS3, IS8). One advisor spoke of giving particular advise if they saw particular house conditions, such as

"smells" (SI9). One advisor also worked checking drawings for new homes in BC, and would look to see whether the radon rough-in (as required by the Building Code) was included (IS5). We asked advisors if they provided test kits to clients, and no advisor reported doing this. Two advisors who were radon mitigators thought this would give the appearance of conflict of interest (IS3, IS8).

NrCan Advice on Radon, HOT2000 and the Warning Process

In the current NRCan system, *there is some information* on radon. However, its not clearly presented to homeowners, or is unlikely that homeowners will access it.

NRCan does have materials on efficiency which mention radon, such as *Keeping the Heat In*[40] and *Health and safety considerations for energy-efficient renovations*- a section of its website on *Renovating for Energy Efficiency.*[41] In both materials, the same language is used:

> Radon is a naturally occuring radioactive gas that is colourless, odourless and tasteless. It is formed form the radioactive decay of uranium, a natural material found in some soil, rock and groudnwater. When radon is releasted into the outdoor air, it gets diluted to low concentrations and is not a concern. However, in enclosed spaces like houses, it can sometimes accumulate to high levels, which can pose a risk to both your or your family's health. For more information, visit Health Canada's website.

As this take additional effort and it is not well advertised, there is a low likelihood that homeowners will access these materials. As well the information is vague —simply saying radon can accumulate to high levels in homes and pose a health risk. The information is not designed to make persons clearly aware of the problem of how radon causes lung cancer or how efficiency upgrades impact on the problem.

A further potential source of information on radon is provided in the HOT2000 Software package. All the adivsors told us that they used the HOT2000 software with all of their work. Advisors use the sofware program on their own computers, and input house specific information obtained from on site visits into specific information boxes. For renovation upgrades, the program generates a report which is sent to homeowners sometime after the home visit. The final Renovation Upgrade Report includes a standardized disclaimer about indoor air quality and radon concerns.

> **Health and Safety Information**
>
> If your energy advisor has identified a potential health or safety concern related to insufficient outdoor air, risk of combustion fumes being drawn into the home or the presene of vermiculite, a warning has been including in your Homeowner Information Sheet. However, energy advisors are not required to have expertise in health and safety matters and it is the sole responsibility of the homeowner to consult a qualified professional to determine potential hazards before undertaking any upgrades or renovations. Visit Natural Resoures Canada's webpage *Health and Safety considerations for energy efficient renovations…*

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[40] Natural Resources Canada, 2021. Keeping the Heat In. https://www.nrcan.gc.ca/energy-efficiency/homes/make-your-home-more-energy-efficient/keeping-the-heat/section-1-introduction/15628 retrieved 2022-04-14. see s. 1.4.3.

[41] Natural Resources Canada, 20222. Renovating for Energy Efficiency https://www.nrcan.gc.ca/energy-efficiency/homes/make-your-home-more-energy-efficient/renovating-energy-efficiency/20569 retrieved 2022-04-1

The Report then lists a number of concerns, including radon, and repeats the wording as reproduced above from *Keeping the Heat In.*

Most energy advisors we interviewed did not know the HOT2000 software or reports contained any information on radon (IS1, IS2, IS4, IS5, IS7, IS9, IS10, IS11, IS12, IS14). This included some advisors who otherwise showed some knowledge of radon (IS5, IS9, IS12). We asked advisors to explain how HOT2000 incorporates radon warnings and were given answers such as: "The software doesn't report radon but it does include warnings for lack of ventilation, vermiculite but not radon" (IS1); "I am not aware that there is anything like that" (IS5); "No I cannot. I have not seen it" (IS 7); and "It doesn't provide radon warnings, but warnings are provided for asbestos" (IS10).

It is worth noting that two advisors we spoke with were trained in radon mitigation and helped draw our attention to the radon warning, indicating it is visible for advisors who are concerned about the issue (IS3, IS8). One advisor explained that he did not normally see the final report due to how the software is designed and was surprised to find this after checked on his own computer during the interview (IS12). A follow up interview with one advisor confirmed that advisors likely do not review the final report, for which some of the contents are supplied automatically by the HOT2000 Software (IS3). One advisor, who worked primarily with new homes, said he never downloaded the software for generating reports, and instead simply sent data to the service organization and NRCan, who would format and send out reports directly to his clients (IS 13).

Overall, we we think it is highly unlikely that homeowners are learning about radon through engaging with NRCan or its advisors. Most advisors do not raise the issue of radon, take steps to educate clients or draw clients attention to the issue.

Education and Training

When we asked advisors about formal training on radon, none indicated this was provided by NRCan as part of the training process. While some of the advisors we spoke to told us they knew very little about radon, others made misleading or inaccurate claims. We heard, for instance that:

- The BC Building Code provisions ensured radon was not an issue: "For new house construction it's built right into the code and designers take care of that end of things to make sure it's a part of the design, so it's outside of our scope" (IS1) (*The BC Code provides for a radon 'rough-in' with a vent pipe, but which still requires home occupants to test and if necessary install an electric fan*).

- Energy efficiency would improve radon exposure (IS9). We also heard three times that a tighter home would stop radon from entering the home (IS4, IS6, IS13), with one person identifying a tight home doing so because it would have a well sealed concrete foundation (IS4). (*Sealing the foundation is one tool, and is important for radon mitigation but is rarely sufficient; as well, homes with low air exchanges per hour under pressure may still have some cracks and fissures in the foundation that let radon through*).

- Ventilation is a solution for radon, and that poor ventilation was an indication of a radon problem. When asked about notifying clients about radon, one person said "if the building is at

a certain airtightness level and it's under ventilated then there are warnings that are provided (IS10), (*This conflated radon warnings with recommendations to install mechanical ventilation*). Another person, when asked about radon warnings in the HOT2000 softwared noted that "it doesn't specifically allude to radon warnings except for a scenario based on ventilation and geometry of a home" (IS11). One advisor, when we asked whether energy efficiency improvements might make radon worse, that an HRV with good air sealing would resolve radon issues (IS 14).*(These answers ignore the difference between reducing radon levels through ventilation and ensuring radon levels are at safe levels)*.

There was a high level agreement that more education on radon was needed. Some pointed to this being included in the initial training for new adivsors (IS1, IS5). We were directed to speak with organizations that oversee energy advisor training, such as Blue House Energy, a firm in Nova Scotia. We also heard that it could be part of ongoing training from the Canadian Association of Consulting Energy Advisors (CACEA) (IS1) or Home Builders Associations (IS7) .

Radon seems closely related to the energy advisor job, so there should be more information in energy advisor course or consequential education (IS5).

I would like to see more information on how to educate the clients even if its just the basics (IS5).

If there was a Certification program I would get staff tested (IS10).

One person noted some challenges:

"When we do training there is a small section that says radon causes lung cancer, and there is a Guideline. So I teach this to other advisors. There are over 209 learning objectives, and you cannot spend a lot of time on each one. But if you put in that much information, their brains will fry. (IS9)

Others felt that educated would need to be supplanted by further policy and procedure changes (IS11), specific guidance from NRCan to advisors to speak about radon and address liability issues (IS2), subsidies for advisors to buy test kits to distribute to clients (IS11), and general awareness in the population (IS11). We were generally struck by the degree to which advisors were open to discussing shortcomings in the system with us and willing to learn more.

We chose to do in-depth semi-structured interviews with a small number of advisors. We recognize this gave us a small sample size that may not be statistically representative of advisors across Canada. However, we were able to have extensive discussions with advisors on these issues, and the complexities of addresing radon in the advising process. The interviews left us with the impression that there was a need for significant changes to how NRCan directs advisors to discuss and deal with health and safety issues in energy retrofits, but that advisors would be willing to adust their practices.

3. Making the Link

United States' Guidance

The US has developed a framework for handling radon in energy efficiency retrofits. Guidance is provided by the Environmental Protection Agency and incorporated into the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) and the National Renewable Energy Laboratory (NREL) Standard Work Specifications (SWS) for single-family, multifamily, and manufactured housing energy upgrades. This guidance is specially designed to ensure that retrofit personnel provide information, advice, and rectify rindoor air quality problems, including radon that are associated with retrofits.

EPA's Healthy Indoor Environment Protocols for Home Energy Upgrades, 2014.[42] These protocols apply to existing single-family and multi-family low-rise residential buildings. The protocols were intended for use by the home energy retrofit industry and government weatherization and housing programs. They provide guidance for conducting home assessments and undertaking the responses necessary to maintain or improve indoor air quality and safety. There is specific guidance on radon, alongside other indoor air contaminants.

The EPA guidance asks contractors to follow one of two testing options to determine the radon level in a retrofit—either before and after energy upgrade work (Option 1) or only a post-work test (Option 2). In any event, the guidelines indicate the need for a post-work test.

Option 1, through introducing short term tests before and after the retrofit, putatively allows for a site-specific determination of whether the energy efficiency upgrades contribute to increasing radon levels. A series of precautionary measures are to be considered at the outset (e.g. after testing but before work starts), which minimize the chances a retrofit could increase radon levels. These include covering exposed earth, air sealing open sumps, ensuring floor drains have traps and that traps are not dry. These should be considered (e.g. are not strictly necessary) if the first tests show results below 2 piC/L (74 Bq/$m^{3,}$ or one half of the EPA's Radon Guideline of 4 piC/L or, in becquerels, 148 Bq/m^3). However, if results are over 2 pCi/L the guidance directs that these be taken. In addition, the Guide recommends installing ventilation measures as necessary to meet ASHRAE Standard 62.2-2010 requirements for whole-building ventilation.

Under option 1 there are diverse instructions depending on the results of post-upgrade testing. This ensures that retrofit personal address any increases in radon levels.

- If radon levels are between 2 pCi/L and 4 pCi/L (148 Bq/m^3—EPA's Radon Guideline) minimum actions include completing foundation air sealing strategies. As well, the EPA suggests expanded actions that include referring clients to EPA's *Citizen's Guide to Radon* and the EPA's *Consumer's Guide to Radon Reduction* and/or mitigate in accordance with specified mitigation procedures.

- If test results are under 4 pCi/L and not higher than pre-work level, no further steps are necessary.

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[42] EPA, 2014. Healthy Indoor Environment Protocols for Home Energy Upgrades, https://19january2017snapshot.epa.gov/indoor-air-quality-iaq/healthy-indoor-environment-protocols-home-energy-upgrades_.html retrieved 2022-03-18

- If test results are under 4 pCi/L and higher than pre work level, retrofit personnel are instructed to verify that foundation air sealing strategies were completed appropriately and correct deficiencies. Expanded actions include referring client to EPA radon materials and/or mitigating following specific standards.
- If test results are equal or greater than 4 pCi/L but *not* higher than pre-work level clients are to be referred to EPA guidance on radon reduction. Expanded actions include mitigation in accordance with specific standards.
- If ≥4 pCi/L and *higher* than pre-work levels, the instructions are for the retrofit personnel to ensure mitigation in accordance with specified standards.

This guidance cannot be applied in Canada insofar as it relies on short term radon testing (e.g. to facilitate before and after testing). Short term testing has been criticized as a 'myth' that replaces science with allegiance to industry pragmatics.[43] It is rejected by Health Canada, because radon levels fluctuate significantly. In Canadian context, where the 91 day test is standard, there would be a need to use only the post-work testing option—required testing and mitigation if levels are above Canada's Radon Guideline.

The EPA's option 2 (no pre-work test) directs industry participants to consider precautionary radon-reduction actions at the outset. After work is complete (and testing conducted) if test results are under 4 pCi/L there are no minimum actions but expanded actions include refering clients to EPA radon materials and/or mitigating in accordance with specified standards. But if test results are equal or greater than 4 pCi/L there should be mitigation in accordance with specified standards as a minimum action. This is more easily translated into the Canadian experience, and reflects an awareness that the efficiency industry should do no harm, and a risk adverse approach that works in the chance that the retrofit process contributed to elevated radon levels.

National Renewable Energy Laboratory's 2017 Standard Work Specification Tool, 2017. Here the focus is on completing work "without increasing occupant exposure to radon".[44] This Specifies that radon testing and mitigation will be done in accordance with the EPA's Healthy Indoor Environment Protocols for Home Energy Upgrades. The standards are currently being updated and new versions will be released this year.

Weatherization Assistance Program. US Department of Energy's Weatherization Health & Safety Guidance, WPN 17-7, dated 2017 provides for radon protocols within the Weatherization Assistance Program (WAP).[45] This is a funding program for low-income housing. Here, there is not, strictly, funding for radon mitigation. However, there are requirements for informed consent. The Guidance requires clients to sign an informed consent form that addresses radon prior to receiving services. A model form is provided.[46] As well, clients are to receive EPA radon materials that inform them of radon related risks as well as information on how radon levels can increase when building tightness is improved, and precautionary measures WAP will install. As well, there is guidance to perform precautionary measures before retrofitting work is complete, based on the

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[43] Edelstein, M.R. and Makofske, W.J., 1998. *Radon's deadly daughters: science, environmental policy, and the politics of risk*. Rowman & Littlefield. p. 122

[44] National Renewable Energy Laboratory. 2017. Standard Work Specifications for Home Energy Upgrades. https://sws-2017.nrel.gov retrived 2022-04-14. see sec. 2.0501.1.

45 Department of Energy, 2017. Weatherization Assistance Program, WPN 17-7. https://www.energy.gov/eere/wap/downloads/wpn-17-7-weatherization-health-and-safety-guidance retrieved 2022-04-14.

46 Department of Energy, 2017. Sample Radon Informed Consent Language available at https://www.energy.gov/sites/default/files/2017/09/f36/radon-informed-consent-language-sample.pdf retrived 2022-04-14.

EPA's Healthy Indoor Environment Protocols for Home Energy Upgrades. This Guidance also includes ventilation requirements meeting ASHRAE 62.2 – 2016 and allows grantees to voluntarily elect to adopt more recent versions. WAP will also allow grantees to access radon testing in areas with high radon potential. The Guidance also requires that auditors assessors and inspectors to have knowledge and to be trained on radon.

Our view is that this guidance is insufficient to capture the fact that retrofit measures can increase radon levels. It appears to ignore the degree to which precautionary measures and ventilation may not be sufficient to ensure that energy retrofitters 'do no harm'. It falsely assumes that installing ventilation will ensure the retrofit process does not exacerbate radon- in effect short-circuiting a detailed causal analysis of how energy retrofits may change radon levels.

EPA's Energy Savings Plus Health: Indoor Air Quality Guidelines, 2021.[47] This updates the older guidance from 2014, and now features different resources for single family and multi-unit buildings.[48] (The guidance is similar for single family and for multi-unit housing, but references different technical specifications.) While the basic framework remains similar to the 2014 Guidelines, there is now delineated education and messaging for home occupants, assessment protocols, and listed minimal and expanded actions. The EPA calls for clients to be told that: The only way to know the radon level in a home is to test for it; the government recommends testing all home; to mitigate if levels are over guidelines; and to make sure that any existing radon mitigation system is functioning properly. Assessment protocols include having all houses be tested for radon, clients to be told test results, and all clients to be given a copy of EPA radon materials. Pre- and post-upgrade testing as part of an energy upgrade is strongly encouraged, as is assessing whether a home has a radon mitigation system.[49] Minimum steps for contractors is in line with the earlier guidance—e.g. precautionary measures, and if with increased emphasis on whole-dwelling ventilation. When post-work tests show radon over guidelines, mitigation should be completed. The EPA continues to provide an option for short-term testing, but its recommendations for education and post-work mitigation easily translate into the Canadian context.

Energy Efficiency in European Radon Action Plans

The European Union provides systemic attention to radon, with the Basic Safety Standards (EU-BSS) requiring all its member states to develop National Radon Action Plans. A review of National Radon Plans shows some recognition of the problem with energy efficiency.

- The UK National Radon Plan describes this as an emerging area of investigation.[50]
- The Czech Republic National Radon Action Plan states: that "As a result of lifestyle changes in recent decades following the energy saving measures for buildings, the radon load needs to be examined and appropriate measures proposed in case of its potential

[47] Environmental Protection Agency, 2021. Energy Savings Plus Health: Indoor Air Quality Guidelines. https://www.epa.gov/indoor-air-quality-iaq/energy-savings-plus-health-indoor-air-quality-guidelines, retrieved 2022-04-14.

[48] See EPA, 2021. Energy Savings Plus Health: Indoor Air Quality Guidelines for Single-Family Renovations. At https://www.epa.gov/indoor-air-quality-iaq/energy-savings-plus-health-iaq-guidelines-single-family-renovations retrieved 2022-04-14. EPA, 2021 Energy Savings Plus Health Indoor Air Quality Guidelines for Multifamily Renovations https://www.epa.gov/indoor-air-quality-iaq/energy-savings-plus-health-indoor-air-quality-guidelines-multifamily retrieved 2022-04-14.

[49] EPA, 2021. Energy Savings Plus Health: Indoor Air Quality Guidelines for Single-Family Renovations ibid. see AP 11.1 to 11.3, p. 41.

[50] Public Health England, 2018. UK National Radon Plan. sec. 1.2.6. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766090/UK_National_Radon_Action_Plan.pdf retrieved 2022-04-14.

increase." As such it calls for a survey of radon concentrations to gage changes effected by energy consumption measures. [51]

- The Federal Republic of Germany Radon Action Plan includes as Measure 3.3 the development and implementation of national coordinated radon education for experts and specifically targets energy consultants. [52]
- The French National Action Plan for Radon Risk Management that "Particular attention should be given to IAQ and radon issues in energy renovation, as many studies have have found that work undertaken to improve energy efficiency is not systematically accompanied by actions ensuring sufficient indoor air ventilation and replacement. In this case, the effects are potentially harmful because radon is trapped in premises and its concentration can increase significantly"[53]

More recently, the European Commission has highlighted the issue in a communication from the Commission to the European Parliament. The European Commission's *Renovation Wave for Europe--Greening our Buildings, Creating Jobs, and Improving Lives* specifies "high health and environmental standards as an important component of 'Key principles for building renovations towards 2030 and 2050'." As such, building renovations need to not only reduce energy use, but also ensure high air quality, and protection against radon, among many values.[54]

Switzerland is not part of the EU but also has a National Radon Action Plan 2021-2030 ("SNRAP") SNRAP highlights the evidence from research studies demonstrating the impact that energy efficiency building standards have on the radon concentration in homes. As a result of this, the Swiss's NRAP first line of action is 'Radon protection in building stock must be sustainably improved, in particular by creating synergies with energy-efficiency measures in buildings.' SNRAP aims to enhance cooperation between partners involved in energy efficiency policy to create continuous improvements on lowering the risk of high radon exposure. The Swiss Federal Council has implemented the "Energy Strategy 2050" and as energy efficiency upgrades are increased throughout Switzerland, the SNRAP is pushing for radon to be 'factored into the planning of energy efficiency measurements.' [55]

Health Canada has produced Radon Action Guides for Provinces and Territories, hoping to stimulate radon planning across the country. Those guides have distinct section on energy efficiency, and recommend education and outreach on the links between efficiency measures and increased radon levels, and that any government (or agency)-linked incentive and financing programs include incentives for radon testing and mitigation along with efficiency and other 'green building' improvements.[56]

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[51] Czech Republic, State Office for Nuclear Safety, 2019. National Action Plan for Control of Public Exposure to Radon.https://www.sujb.cz/fileadmin/sujb/docs/radiacni-ochrana/PZIZ/Radon/RANAP_ENG.pdf retrieved 2022-04-14

[52] Federal Republic of Germany, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2019. Radon Action Plan for the sustainable reduction of radon exposure. https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/radonmassnahmenplan_en_bf.pdf retrived 2022-04-14. p. 18

[53] Republique Francaise, 2021. Plan national d'action 2020-2024 pour la gestion du risque lié au radon , https://solidarites-sante.gouv.fr/IMG/pdf/plan-radon20-24-interactif-bd-18fev21.pdf retrived 2022-04-14. at p. 12 (translation by author).

[54] European Commission. A renovation wave for Europe – greening our buildings, creating jobs, and improving lives. 14.10.2020, COM(2020) 662 final, Brussels. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0662&rid=5 retrieved 2022-04-14

[55] Swiss Confederation, Federal Office of Public Health, 2020. Swiss National Radon Action Plan 2021-2030. https://www.bag.admin.ch/bag/en/home/strategie-und-politik/politische-auftraege-und-aktionsplaene/radonaktionsplan.html retrieved 2022-04-14.

[56] Drafts of Health Canada's Radon Action Guide for Provinces and Territories Is on file with the author, and expected to be released in May 2022.

4. Conclusion

Radon is increasingly recognized as a problem in new construction, with provisions in Building Codes and in voluntary green building standards. However, green building standards are not predominant enough to make population level health changes, and too often building codes offer only incomplete radon protection. The result is that as buildings are built to higher efficiency standards, radon is getting worse.

Our research suggests consumers who use energy efficiency products, advisors and contractors are not getting the message about radon, and that Canada's energy efficiency system may be making radon exposure worse. This creates significant risks of liability which need to be addressed and is likely creating real harm in the form of exposure to carcinogenic radiation, increased lung cancer and death.

We found the links between radon and energy efficiency are increasingly being made elsewhere— in national Radon Action Plans in European countries and in specific guidance on energy efficiency and indoor air quality from the United States Environmental Protection Agency, Department of Energy and National Renewable Energy Laboratory.

There is still a real need in Canada to make the link between energy efficiency and radon better known. We need to increase awareness, and to incorporate the link into efficiency policies and programs. This suggests Canada's energy efficiency system can and should do better: Government regulators, tincentive providers, the financial community, energy advisors, and contractors need to recognize efficiency programs can make radon worse, that home owners and occupants need to be aware of the problem, and measures taken to ensure efficiency upgrades do no harm. In *Energy Efficiency and Radon: Solutions Moving Forward* we spell out in more detail our suggestions for change.