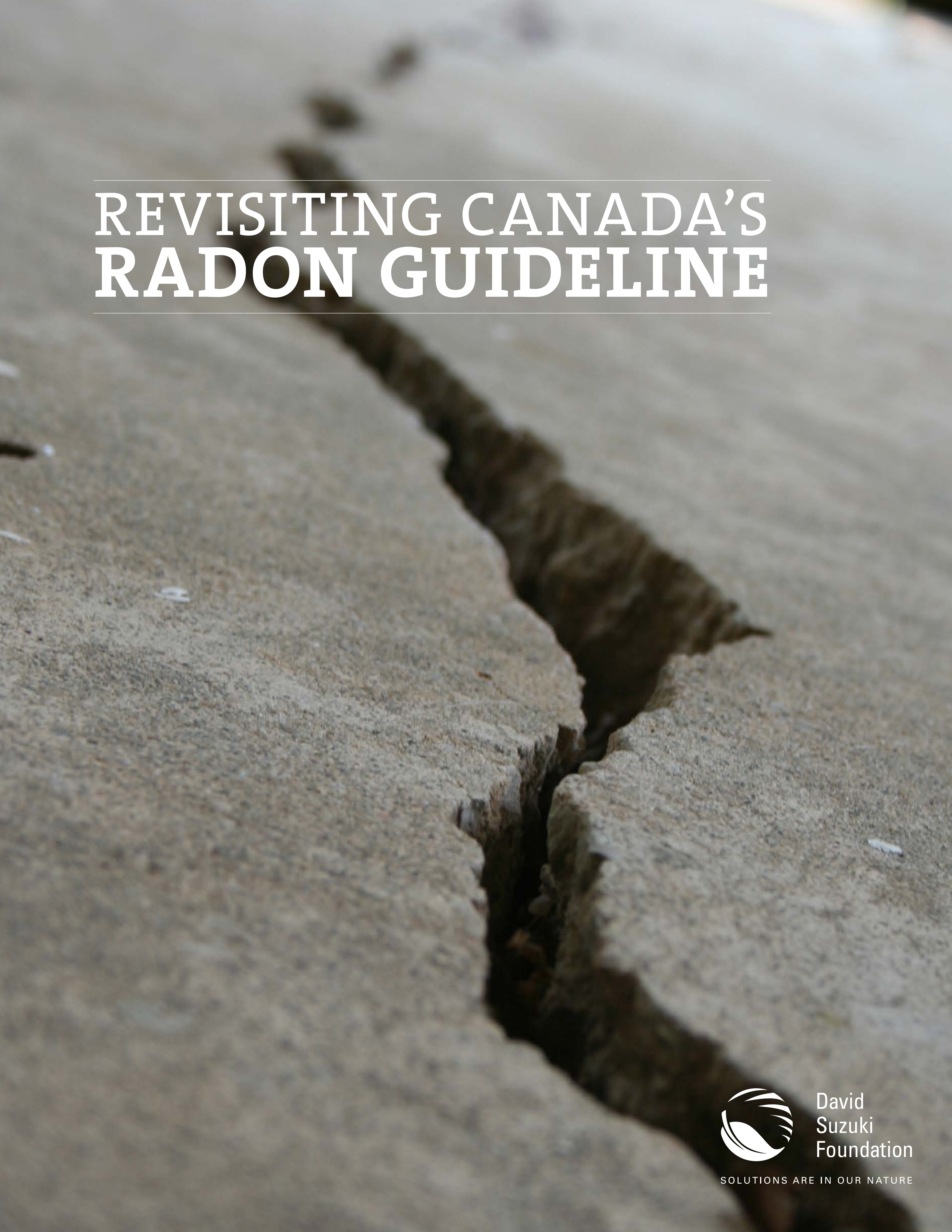

REVISITING CANADA'S RADON GUIDELINE

David Suzuki Foundation
SOLUTIONS ARE IN OUR NATURE

REVISITING CANADA'S RADON GUIDELINE

April 2015

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CONTENTS

EXECUTIVE SUMMARY

Radon is a cancer-causing radioactive gas produced by the natural decay of uranium in rocks and soils. Most Canadians have never heard of radon, but it is the second-leading cause of lung cancer (after smoking) and the primary cause of lung cancer among non-smokers. Health Canada estimates that 16 per cent of lung cancer deaths in Canada are attributable to radon exposure.

Canadians are exposed to radon when it escapes from the ground into the air. Concentrations in outdoor air are low, but radon can become trapped and accumulate in buildings, reaching high levels in indoor air.

In 2007, Health Canada revised the national guideline for radon in indoor air from 800 Bq/m^3 to 200 Bq/m^3, bringing it into line with leading international standards for radon at the time. However, as the David Suzuki Foundation noted in ***Radon: the Unfamiliar Killer*** (2006), three landmark studies published between 2004 and 2006 would soon change the way radon risks are evaluated. These studies concluded radon causes a large number of lung cancer cases in the general population even at concentrations lower than 200 Bq/m^3.

Between 2007 and 2014, three leading international public health and radiation protection agencies — the International Commission on Radiation Protection, World Health Organization and International Atomic Energy Agency — updated their recommendations on radon in response to the new evidence of health risks from low and moderate exposure to radiation.

- The International Commission on Radiation Protection recommends that any radon exposure should be reduced to as low as reasonably achievable in the range of 100-300 Bq/m^3.

- The World Health Organization recommends a national reference level of 100 Bq/m^3.

- The International Atomic Energy Agency recommends that the national reference level should not exceed 300 Bq/m^3 and directs governments to establish an action plan for reducing concentrations as low as reasonably achievable below this level.

In this report, we examine current international guidance on radon and its implications for Canada. We review developments from other industrialized countries and compare Canada's radon guideline to parallel standards and guidelines in leading jurisdictions.

We conclude that international guidance on radon has evolved significantly in recent years, and this necessitates a re-evaluation of Canada's guideline for radon in indoor air. It is once again time for Canada to update its guideline to match leading international standards. At the same time, implementation measures must be reinforced to reduce indoor radon concentrations across the country and minimize (eventually, to zero) the number of homes and public-access buildings with indoor concentrations of radon that exceed the guideline.

To this end, the David Suzuki Foundation offers the following recommendations:

1. Health Canada should establish a new guideline for radon in indoor air of 100 Bq/m^3 and recommend reducing indoor radon concentration to as low as reasonably achievable below this level, in keeping with the principle of optimization of protection. Health Canada should clarify that the standard applies generally to indoor air, including workplaces and public-access buildings, in addition to dwellings.

2. Provincial and territorial governments, in collaboration with Health Canada, should ensure radon prevention, testing and mitigation (where tests indicate concentrations above 100 Bq/m^3) in daycares, schools, hospitals and other public-access buildings.

3. Provincial and territorial governments should ensure that radon prevention measures in the most recent National Building Code (as updated and amended) are incorporated into provincial and territorial building codes and enforced. Further, provinces and territories should consider incorporating a requirement to meet the national guideline for radon in indoor air.

4. Federal, provincial and territorial governments should offer incentives and subsidies to encourage homeowners to test for radon and facilitate mitigation where necessary. For rental properties, provincial and territorial governments should require radon testing and, if necessary, mitigation under tenancy laws.

5. Health Canada and provincial and territorial governments should evaluate and implement innovative approaches to make radon "visible."

WHAT YOU CAN DO

Test your home for radon. One-time radon test kits are available from some hardware stores, businesses specializing in radon detection and mitigation, the Radiation Safety Institute and many lung associations across Canada for $30 to $60. The test device comes with instructions on how to set up the detector and send it to a laboratory for analysis after testing. The lab will calculate your average radon concentration. Some certified radon professionals also sell electronic radon monitors, which show weekly and monthly average concentrations on a digital display. These cost around $150.

Measure concentrations over a period of at least 90 days, ideally during cooler seasons when windows are closed. If test results show elevated levels of radon, look for a certified radon professional in your area to advise you on mitigation options.

The full report can be downloaded from www.davidsuzuki.org/publications.

RADON: THE UNFAMILIAR KILLER

Radon is a cancer-causing radioactive gas produced by the natural decay of uranium, an element present in rocks and soils everywhere. Canadians are exposed to radon when it escapes from the ground into the air. Concentrations in outdoor air are low, but radon can become trapped and accumulate in buildings, reaching high levels in indoor air.

Radon is by far the largest naturally occurring source of ionizing radiation. When radon gas is inhaled, the radiation it emits can damage tissues in the respiratory tract, increasing the risk of cancer. Radon is the second-leading cause of lung cancer, after smoking, and the primary cause of lung cancer among non-smokers. [1] Health Canada estimates that 16 per cent of lung cancer deaths in Canada are attributable to radon exposure.[2] This equates to more than 3,000 lives lost in 2014.[3]

WHAT IS IONIZING RADIATION?

Ionizing radiation carries enough energy to liberate electrons from an atom, causing the atom to become charged, or ionized, during an interaction. This can fragment DNA and cause other damage to cells in living tissue. Exposure to ionizing radiation at high levels or over long periods can trigger the formation of cancer tumours. In addition to radon, sources of ionizing radiation include X-rays, CT scans and nuclear power production/waste. Non-ionizing radiation is lower-energy, such as microwaves, radio waves and visible light.

Radon is drawn into buildings because the air pressure inside is usually lower than in the ground beneath.[i] Drains, cracks in the foundation and slab, and gaps around pipes, and other openings provide points of entry. Energy-efficiency methods that make a building more air-tight (e.g., sealing around windows and doors) reduce passive ventilation and can lead to higher indoor radon concentrations[4] unless complementary radon-reduction strategies are in place.

Radon has no smell, colour or taste. The only way to know if a building has elevated radon levels is to measure concentrations using a specialized testing device. The good news is that some mitigation techniques are generally quite effective at reducing indoor radon concentrations and can have co-benefits for lowering levels of other indoor air pollutants. The "gold standard" in radon mitigation is a technique known as ***sub-slab depressurization***. A pipe is inserted into the sub-slab fill and an electric fan is used to vent soil gas to the outdoors, lowering air pressure beneath the slab and preventing radon from being drawn into the house. Alternative or complementary techniques, depending on conditions, include sealing openings in the slab and foundation walls and venting radon in basement air to the outside.[5] Effective radon mitigation for a typical Canadian home generally costs up to $3,000.[6] Preventative measures at the time of construction, if implemented correctly, are cost-effective and will reduce the number of houses with high radon levels, as new buildings replace existing housing stock[7] (although in practice some preventative measures have been shown to be more reliable than others[8]).

[i] Radon in groundwater may be another source of exposure in some areas. If well water is used in the home, radon may be released from the water into the air. Building materials can sometimes be a source of exposure, as well. However, the World Health Organization considers that soil gas infiltration is the greatest source of exposure, and other sources are less important in most circumstances. ***WHO Handbook on Indoor Radon: A Public Health Perspective*** (Geneva: WHO, 2009), http://whqlibdoc.who.int/publications/2009/9789241547673_eng.pdf.

TEST YOUR HOME FOR RADON

One-time radon test kits are available from some hardware stores, businesses specializing in radon detection and mitigation, the Radiation Safety Institute and many lung associations across Canada for $30 to $60. The test device comes with instructions on how to set up the detector and send it to a laboratory for analysis after testing. The lab will calculate your average radon concentration. Some certified radon professionals also sell electronic radon monitors, which show weekly and monthly average concentrations on a digital display.

Indoor radon levels can vary significantly from day to day or even hour to hour, as well as seasonally. Concentrations are generally higher in winter and at night, when windows and doors are closed. Health Canada recommends running a radon test over a minimum of three months, during the cooler seasons, to determine the average concentration in a home. Buyer beware! Some hardware stores sell only short-term radon detectors. Be sure to select a radon test device that will measure concentrations over a period of at least 90 days.

If test results show elevated levels of radon, look for a certified radon professional in your area to advise you on mitigation options.

HELPFUL LINKS:

- Information on ordering a radon test from the Radiation Safety Institute: www.radiationsafety.ca
- Online sales of radon detectors from the British Columbia, Alberta, Manitoba and Ontario Lung Associations: radonaware.accustarcanada.com
- Online sales of radon detectors from the Association pulmonaire du Québec: www.pq.lung.ca
- Businesses specializing in radon detection and mitigation (Canadian Association of Radon Scientists and Technologists): www.carst.ca
- Certified radon professionals: www.c-nrpp.ca
- National Radon Action Campaign: www.takeactiononradon.ca

1. BUY A RADON DETECTOR

Test your home for radon. One-time radon test kits are available from some hardware stores, businesses specializing in radon detection and mitigation, the Radiation Safety Institute and many lung associations across Canada for $30 to $60.

2. MEASURE CONCENTRATIONS

Measure concentrations over a period of at least 90 days, ideally during cooler seasons when windows are closed.

3. TAKE ACTION

If test results show elevated levels of radon, look for a certified radon professional in your area to advise you on mitigation options.

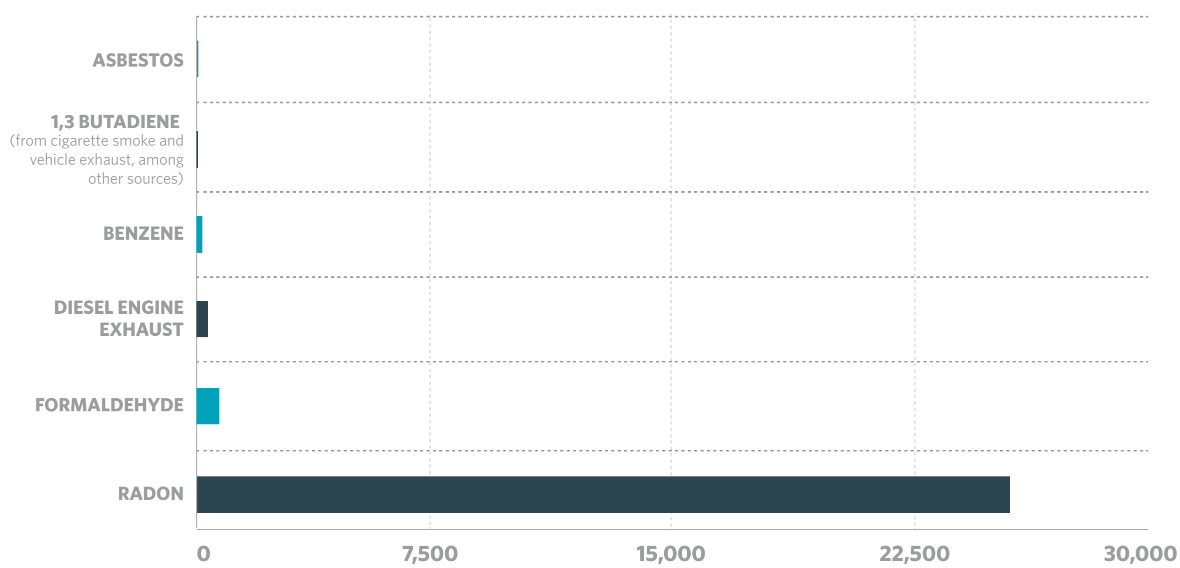
RADON IN CANADA

Radon concentrations are measured in becquerels per cubic metre (Bq/m^3). In Canada, the average outdoor concentration of radon is 10 Bq/m^3.[9] In a national home radon survey conducted by Health Canada from 2009 to 2011, one in four homes had indoor radon concentrations above the World Health Organization's recommended reference level of 100 Bq/m^3. Nearly seven per cent of homes tested exceeded the current Canadian guideline of 200 Bq/m^3. The results of the survey indicate a higher risk of elevated radon levels in Manitoba, New Brunswick, Saskatchewan and Yukon, likely due to geology and building styles, among other factors. But even in provinces where overall risk is lower, some areas or individual houses reported higher radon levels. **No areas of the country are "radon free".** [10]

To illustrate, in British Columbia, provincewide, the Health Canada survey found a lower overall incidence of elevated home radon levels, yet community-level testing by the BC Lung Association identified radon concentrations above the national guideline in more than half the Castlegar homes tested,[11] and one-third in Prince George.[12]

In a comparison of 27 environmental carcinogens evaluated by CAREX Canada, the cancer risk from radon is orders of magnitude higher than other, more familiar environmental contaminants, including formaldehyde, asbestos and diesel engine exhaust. The estimated potential lifetime excess cancer risk from indoor radon is 23,655 per million people. In other words, if 1,000 people were exposed to the average measured indoor radon concentrations, we could expect 23 or 24 extra cancer cases. By comparison, the second-largest lifetime excess cancer risk in indoor air calculated in this study was 487 per million (for formaldehyde, a toxic gas released from some building materials and in smaller quantities from some shampoos and soaps). In general, government agencies consider potential lifetime excess cancer risks between one and 10 per million to be "acceptable" for non-occupational exposures.[13] It is worth noting that such calculations are based on the theoretical risk of exposure to each substance in isolation and do not take into account additive and synergistic effects of multiple carcinogens. The authors of this study note that the real-life scenario of environmental exposure to many carcinogens throughout a lifetime, in conjunction with other factors, is not well understood and cancer risks may be underestimated.

ESTIMATES OF LIFETIME EXCESS CANCER RISK FOR DIFFERENT ENVIRONMENTAL CARCINOGENS IN INDOOR AIR



Source: Setton et al., based on highest available cancer potency factor

CANADA'S RADON GUIDELINE

In 2007, Health Canada revised the national guideline for radon in indoor air from 800 Bq/m^3 to 200 Bq/m^3. Specifically, Health Canada now recommends that:

- Remedial measures should be undertaken in a dwelling whenever the average annual radon concentration exceeds 200 Bq/m^3 in the normal occupancy area.
- The higher the radon concentration, the sooner remedial measures should be undertaken.
- When remedial action is taken, the radon level should be reduced to a value as low as possible.
- Construction of new dwellings should employ techniques that will minimize radon entry and facilitate post-construction radon removal, should this subsequently prove necessary.[14]

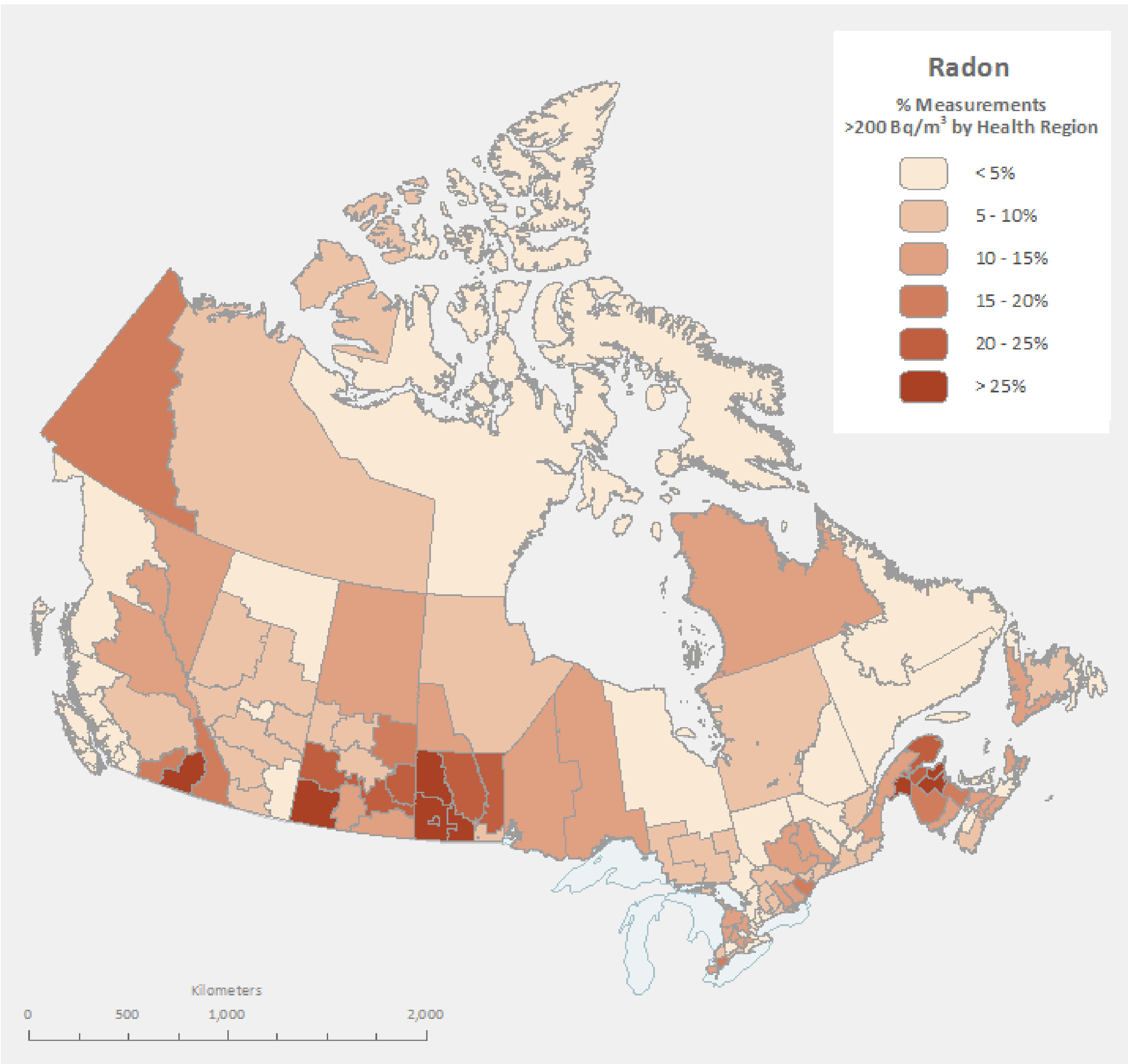
The radon guideline, established pursuant to section 55(3) of the Canadian Environmental Protection Act, 1999, is not directly enforceable. Most regulatory levers that could be used to implement the guideline fall within provincial jurisdiction. There is a Federal/Provincial/Territorial Radiation Protection Committee with a mandate to advance development and harmonization of practices and standards for radiation protection, including implementation of the national radon guideline.[15] However, at present there are no generally applicable legal requirements anywhere in Canada for radon testing, or for mitigation where measured radon concentrations exceed the national guideline of 200 Bq/m^3.

A comprehensive review of radon policy and law in Canada by the Canadian Environmental Law Association identified only three limited exceptions. The Construction Code of Quebec requires radon testing during construction and disclosure of test results, as well as mitigation if test results show indoor radon concentrations above 800 Bq/m^3 — but only in certain locations where the risk of elevated radon levels is considered high. Also, the Ontario Building Code requires the federal guideline of 200 Bq/m^3 to be met, but again only in specified regions known to have high radon levels. (Ontario's new home warranty program, Tarion, also provides coverage for radon mitigation if concentrations exceed the national guideline.[16]) Finally, regulations under the Canada Labour Code limit indoor radon concentrations in federal government workplaces, but still reference the former national guideline of 800 Bq/m^3.[17]

Updates to the National Building Code in 2010 and 2012 strengthened requirements to prevent radon from entering new or substantially renovated homes, and for sub-slab depressurization rough-ins to facilitate future remediation, if necessary. The National Building Code serves as a model and is not enforceable. While several provinces and territories have adopted it in part or in whole in their respective building code regulations, others have not.[18] Where provincial or territorial building codes require radon protection, it is difficult to determine the extent to which they have been effective in the absence of any requirement to measure radon concentrations in new buildings.

Health Canada's radon awareness program, launched in conjunction with the new guideline in 2007, encourages Canadians to voluntarily test radon levels in their homes and to remediate if concentrations exceed 200 Bq/m^3. The department's annual budget for Environmental and Radiation Monitoring and Protection — which includes the radon awareness program, as well as a research component and nuclear emergency monitoring and planning activities — is a modest $14.4 million in 2014-15.[19]

Despite the efforts of this program and a handful of complementary educational initiatives by provinces and non-governmental organizations, awareness of radon in Canada remains persistently low. Fewer than half of Canadians have heard of radon, and even fewer recognize it as a health hazard. Among those who have heard of radon, only five per cent have tested their homes.[20]



CAREX Canada map of measured levels of indoor radon, based on the results of Health Canada's Cross-Canada Radon Survey. Also available online at www.carexcanada.ca. (Look up radon environmental estimate and click on "provincial tables and maps".) Map used with permission from CAREX Canada

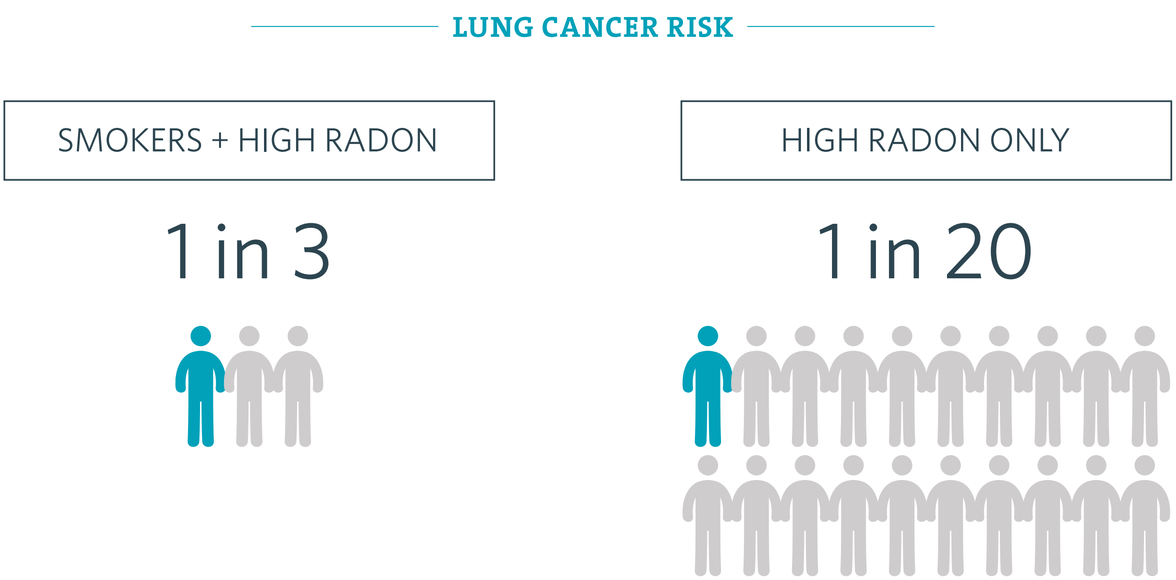
DEVELOPMENTS SINCE 2007

The 2007 revision brought Canada's radon guideline into line — belatedly — with leading international standards for radon at the time. Since 1990, the European Commission had recommended an "action level" of 400 Bq/m^3 for existing dwellings and 200 Bq/m^3 for new construction, which had been adopted by many European countries; in Australia, the action level was 200 Bq/m^3; in the United States, the action level was 150 Bq/m^3. [21]

However, as the David Suzuki Foundation noted at the time,[23] three landmark studies published in 2004, 2005 and 2006 would soon change the way radon risks are evaluated. These studies pooled and re-analyzed data from dozens of smaller studies examining the relationship between indoor radon and lung cancer in the general population. (Previously, radon risk assessments were based primarily on studies of lung cancer rates among uranium miners exposed to much higher concentrations of radon.) All three of the new pooling studies concluded that radon causes a large number of lung cancers in the general population, even at concentrations lower than 200 Bq/m^3. The World Health Organization now considers that the majority of radon-induced lung cancers are caused by low and moderate radon concentrations because a large number of people are exposed at these levels and only a small number of people are exposed to very high levels.[23]

Health Canada developed its proposal for a new radon guideline of 200 Bq/m^3 in 2004, just before the landmark pooling studies were published. Formally announced in 2007, the new guideline was already out of date by the time it came into effect.

Between 2007 and 2014, three leading international public health and radiation protection agencies — the International Commission on Radiation Protection, World Health Organization and International Atomic Energy Agency — updated their recommendations on radon in response to the evidence from the pooling studies.



Source: Health Canada http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radon_canadiens-canadiens/

INTERNATIONAL COMMISSION ON RADIATION PROTECTION (ICRP)

In 2007, the same year that Health Canada established the new national guideline for radon in indoor air, the ICRP overhauled its recommendations for radiation protection. ***Publication 103*** formally replaced the Commission's 1990 Recommendations for a System of Radiological Protection as the common basis for radiological protection standards, legislation, guidelines, program and practice world-wide. ***Publication 103*** also introduced the principle of optimization of protection. Applying this principle, the ICRP now recommends that any radon exposure should be reduced as low as reasonably achievable below the reference level, regardless of the initial level of exposure. Previous recommendations focused on intervening only to prevent exposures above a given action level.[24,25] The significance of this shift is clear in comparing the definitions of ***action level and reference level***:

- Action level was defined as "the concentration of radon at which intervention is recommended to reduce the exposure in a dwelling or workplace."

- Reference level is defined as "the restriction on dose or risk, above which it is judged to be inappropriate to plan to allow exposures to occur, and below which optimisation of protection should be implemented."[26]

ALARA

"As low as reasonably achievable" is a widely accepted safety principle for minimizing exposure to ionizing radiation and controlling releases of radioactive materials. ALARA is the standard approach to controlling risks from ionizing radiation and is a regulatory requirement in many contexts.

In 2010, the ICRP updated estimates of lung cancer risks associated with radon exposure. The commission's revised risk coefficient for radon exposure was approximately twice the value that had been assumed previously. Consequently, the ICRP issued a Statement on Radon revising the upper bounds of its recommended reference level for radon from 600 Bq/m^3 to 300 Bq/m^3.[27]

The ICRP refined this recommendation in 2014 in ***Publication 126***. The commission now "strongly encourages national authorities to set a national derived reference level that is as low as reasonably achievable in the range of 100-300 Bq/m^3, taking the prevailing economic and societal circumstances into account."[28]

The ICRP recommends incorporating preventative measures in building codes. The commission also suggests that the reference level may be enforced in relation to existing legal responsibilities in certain situations. For example, the owner of a house may be legally responsible for certifying certain conditions if the house is rented or sold, and local school authorities may be legally responsible for the health of students and staff. In general, radon protection requirements "should be commensurate with the wider public health policy in the country."[29]

WORLD HEALTH ORGANIZATION (WHO)

In 2009, the WHO reviewed the evidence of health effects of radon and the availability and cost-effectiveness of radon prevention and remediation in the ***WHO Handbook on Indoor Radon***. The ***Handbook*** recommends that countries adopt 100 Bq/m^3 as a national reference level, or "the maximum accepted average annual radon concentration in a residential dwelling." If a reference level of 100 Bq/m^3 cannot be implemented due to country-specific conditions, the WHO recommends the reference level should not exceed 300 Bq/m^3.

The WHO recommendation recognizes that in principle radon levels should be managed to levels that are as low as reasonably achievable, and that a national reference level of 100 Bq/m^3 is justified from a public health perspective.

The WHO further recommends that countries incorporate radon prevention measures in building codes and ensure compliance, but notes that this does not guarantee that radon concentrations will be below the reference level. Radon testing is still needed, even for new buildings.[30]

MAXIMUM ACCEPTED AVERAGE ANNUAL RADON CONCENTRATION IN A RESIDENTIAL DWELLING

< 100 Bq/m^3

The WHO recommends that countries adopt 100 Bq/m^3 as a national reference level

> 100 Bq/m^3

Countries should implement radon prevention and mitigation measures to ensure indoor radon concentrations are below national reference levels.

INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

In 2014, the IAEA updated its Basic Safety Standards for radiation protection. The section on public exposure to radon in indoor air incorporates recommendations from the 2010 ICRP Statement on Radon. The updated Basic Safety Standards direct countries to establish an "appropriate" reference level for radon not to exceed 300 Bq/m^3. Governments are to establish an action plan for reducing concentrations of radon in existing and new buildings, which should include incorporating preventative measures in building codes and optimization of protection, as recommended by the ICRP. The Basic Safety Standards note the need to determine the circumstances under which actions are to be mandatory or voluntary, taking into account legal requirements and prevailing social and economic circumstances.

The Basic Safety Standards also direct governments to ensure information is gathered on radon concentrations in homes and public buildings, such as schools and hospitals, and to provide the public with information about the health risks associated with radon exposure.[31]

RADON GUIDELINES IN OTHER INDUSTRIALIZED COUNTRIES

Many industrialized countries have updated their radon guidelines or standards since 2007 — or are in the process of updating them — in light of recent scientific developments and the new international guidance.[ii]

EUROPE

The European Union adopted Directive 2013/59/Euratom, laying down basic safety standards for protection from exposure to ionizing radiation on December 5, 2013. The Directive requires E.U. member countries to establish national reference levels for radon in indoor air and stipulates that the reference level must not be higher than 300 Bq/m^3. The Directive also requires countries to implement preventative measures for new buildings, which may include specific requirements in national building codes.[32]

This is the first time that the European Union has issued mandatory requirements for radon protection. The previous E.U. Directive on protection from exposure to ionizing radiation (Directive 96/29/Euratom) specifically excluded radon exposure from its application. The European Commission's non-binding recommendation, dating back to 1990, was that remedial action should be considered if radon concentrations exceeded 400 Bq/m^3 in existing buildings, and that new buildings should be designed so that radon concentrations do not exceed 200 Bq/m^3.[33] Many European countries had adopted this recommendation in national regulations or guidelines.

E.U. member countries have until February 6, 2018, to implement the new Directive. As discussed below, some are already compliant, while others are not.

In 2009, radiation authorities of Denmark, Norway, Sweden, Finland and Iceland issued a joint recommendation that the reference level for radon in homes should be in the range of 100 to 200 Bq/m^3, and that remedial measures should be promoted to reduce radon concentrations in existing buildings to as low as reasonably achievable, preferably below 100 Bq/m^3. New buildings should be constructed so that indoor radon concentrations will be as low as reasonably achievable, aiming for less than 50 Bq/m^3.[34] Denmark now recommends "simple and cheap" remedial action if radon concentrations exceed 100 Bq/m^3 and immediate intervention if concentrations exceed 200 Bq/m^3. Norway has an action level of 100 Bq/m^3 for kindergartens, schools, new dwellings and rental accommodations, with a maximum limit of 200 Bq/m^3. Sweden and Finland recommend remedial action at 200 Bq/m^3. Iceland has determined a radon action plan is not necessary, based on a recent survey that found radon concentrations in homes there were very low (average 13 Bq/m^3).

The United Kingdom updated its radon guidance in 2010, maintaining an action level of 200 Bq/m^3 but establishing 100 Bq/m^3 as a new "target level." The target level of 100 Bq/m^3 is "the ideal outcome for remediation works in existing buildings and protective measures in new buildings."[35] Public Health England now recommends that action to reduce the level should be seriously considered if radon concentrations are between 100 and 200 Bq/m^3. The agency unequivocally recommends mitigation if radon levels in a home exceed 200 Bq/m^3.[36]

[ii] References for national radon guidelines given in this section are noted in Table 1 on page 16.

Germany recommends radon concentrations not exceed 100 Bq/m^3. Belgium and Slovakia have adopted references level of 100 Bq/m^3 for new buildings.

Several E.U. member countries, including France and Austria, still reflect the 1990 European Commission recommendation in their national radon guidelines (400 Bq/m^3 in existing buildings and 200 Bq/m^3 for new buildings). A few members of the E.U. have not established country-specific reference levels and radon action plans. These countries can be expected to update their radon policies in the coming years to meet the timeline for implementation of Directive 2013/59/Euratom.

United States

UNITED STATES

The U.S. Environmental Protection Agency has maintained a radon action level of four picocuries/litre (pCi/L) since the 1980s. This is equivalent to approximately 150 Bq/m^3. The EPA notes that concentrations of radon below this level still pose a risk and recommends Americans consider mitigation if radon levels are above two pCi/L.[37]

Many U.S. states require sellers in real estate transactions to disclose radon measurements, if known. Additionally, some states have passed laws requiring radon testing in schools and/or daycare centres.[iii]

U.S. SURGEON GENERAL HEALTH ADVISORY (2005)

"Indoor radon gas is the second-leading cause of lung cancer in the United States and breathing it over prolonged periods can present a significant health risk to families all over the country. It's important to know that this threat is completely preventable. Radon can be detected with a simple test and fixed through well-established venting techniques."

Australia

AUSTRALIA

The Australian Radiation Protection and Nuclear Safety Agency is in the process of reviewing its radiation protection framework in light of updated international guidance. Australia's ***Radiation Protection Series No. 1***, originally published in 1995, establishes a reference level for indoor radon of 200 Bq/m^3. This document is expected to be superseded in 2015 by three new documents dealing respectively with planned, existing and emergency exposures. Radon is to be addressed in the existing exposures document and is expected to reflect current ICRP and IAEA recommendations.

[iii] The following states require radon testing in schools: Colorado, Connecticut, Florida, Rhode Island, Virginia and West Virginia. "Radon in Schools: Overview of State Laws" (Environmental Law Institute, May 2013), http://www.eli.org/sites/default/files/docs/research/radon_updated_may_2014.pdf. Illinois requires radon testing in licensed daycare facilities. "New Law Requires Radon Testing in Day Care Centres" (Illinois Emergency Management Agency, January 2, 2013), http://www.illinois.gov/ready/Press/Pages/130103.aspx.

TABLE 1: RADON GUIDELINES IN OECD-MEMBER COUNTRIES (NON-OCCUPATIONAL)[(a)]

COUNTRY	RADON GUIDELINE OR STANDARD	SUBJECT TO E.U. DIRECTIVE[(b)]
Australia[38]	200 Bq/m³ (under review)	
Austria[39]	Existing buildings: 400 Bq/m³; New buildings: 200 Bq/m³	•
Belgium[40]	Existing buildings: 400 Bq/m³; New buildings: 100 Bq/m³	•
Canada	200 Bq/m³	
Chile	*	
Czech Republic[41]	Existing buildings: 400 Bq/m³; New buildings: 200 Bq/m³	•
Denmark[42]	100-200 Bq/m³	•
Estonia[43]	200 Bq/m³	•
Finland[44,45]	Existing buildings: 400 Bq/m³; New buildings: 200 Bq/m³	•
France[46]	400 Bq/m³	•
Germany[47]	100 Bq/m³	•
Greece[48]	Existing buildings: 400 Bq/m³; New buildings: 200 Bq/m³	•
Hungary[49]	Existing buildings: 400 Bq/m³; New buildings: 200 Bq/m³	•
Iceland[50]	None[(c)]	
Ireland[51]	200 Bq/m³	•
Israel	*	
Italy[52]	None	•
Japan[53]	None	
Korea[54]	None	
Luxemburg[55]	150 Bq/m³	•
Mexico[56]	None	
Netherlands[57]	None[(c)]	•
New Zealand[58]	None[(c)]	
Norway[59]	100-200 Bq/m³	
Poland[60]	Existing buildings: 400 Bq/m³; New buildings: 200 Bq/m³	•
Portugal[61]	400 Bq/m³	•
Slovak Republic[62]	Existing buildings: 200 Bq/m³; New buildings: 100 Bq/m³	•
Slovenia[63]	400 Bq/m³	•
Spain[64]	Proposed: 300 Bq/m³	•
Sweden[65]	200 Bq/m³	•
Switzerland[66]	300 Bq/m³	
Turkey	*	
UK[67]	100-200 Bq/m³	•
US[68]	150 Bq/m³	

(a)Workers' exposure to radon in most workplaces is adventitious and the ICRP therefore considers that it should be managed in line with public exposure guidelines. Occupational exposure standards apply when high radon levels in the workplace are considered a planned exposure situation.
(b) Directive 2013/59/Euratom requires E.U. member countries to establish a national reference level no higher than 300 Bq/m³ by February 6, 2018.
(c) On the basis of national radon surveys, Iceland, the Netherlands and New Zealand determined that indoor radon levels are very low and a national reference level/action plan is not necessary.
*An indoor radon guideline could not be identified for Chile, Israel and Turkey

CONCLUSIONS AND RECOMMENDATIONS

International guidance on radon has evolved significantly in recent years, and this necessitates a re-evaluation of Canada's guideline for radon in indoor air. It is once again time for Canada to update its guideline to match leading international standards. At the same time, implementation measures must be reinforced to reduce indoor radon concentrations across the country and minimize (eventually, to zero) the number of homes and public buildings with indoor concentrations of radon that exceed the guideline.

To this end, the David Suzuki Foundation offers the following recommendations:

1. Health Canada should establish a new guideline for radon in indoor air of 100 Bq/m^3 and recommend reducing indoor radon concentration to as low as reasonably achievable below this level, in keeping with the principle of optimization of protection. Health Canada should clarify that the standard applies generally to indoor air, including workplaces and public-access buildings, in addition to dwellings.

As previously noted, the World Health Organization recommends a national reference level for radon of 100 Bq/m^3 except if this level cannot be achieved due to "country-specific conditions." There is no reason to believe that the WHO-recommended level could not be implemented in Canada. When Health Canada issued the 200 Bq/m^3 guideline for radon in 2007, the department also initiated consultation on a proposed target for new construction of 100 Bq/m^3.[69] This proposal was never implemented but indicates that Health Canada considered 100 Bq/m^3 to be achievable, at least in new buildings.

Furthermore, Health Canada advises that a radon mitigation system in an existing building is effective if the resulting concentrations are less than 100 Bq/m^3, again implying that this level can be achieved.[70] In a survey conducted as part of this project, radon mitigation professionals across the country agreed that radon concentrations in existing buildings could be lowered to below 100 Bq/m^3 (see Appendix). Nearly two-thirds of respondents had never encountered a case where radon concentrations post-mitigation exceeded 100 Bq/m^3. Those who had noted it as an exceptional circumstance, generally involving cases where the homeowner declined more expensive/invasive actions that would have been necessary to achieve further reductions.

Studies cited by the WHO estimate the risk of lung cancer increases by 16 to 23 per cent for every 100 Bq/m^3 increase in long-term average radon concentration.[71] If all Canadian homes with radon concentrations between 100 and 200 Bq/m^3 took action to reduce radon to outdoor levels, more than 700 lung cancer deaths could be avoided each year (over and above the number of lives saved by mitigating radon only in houses with concentrations above 200 Bq/m^3, as currently recommended).[72]

2. Provincial and territorial governments, in collaboration with Health Canada, should ensure radon prevention, testing and mitigation (where tests indicate concentrations above 100 Bq/m^3) in daycares, schools, hospitals and other public-access buildings.

The IAEA Basic Safety Standards direct governments to ensure information is gathered on radon concentrations in homes and public buildings. Health Canada conducted a survey of radon concentrations in homes and has tested radon concentrations in federal buildings, but there is no parallel initiative to comprehensively test for radon in public-access buildings like daycare centres, schools and hospitals. Students and patients, as well as staff, spend considerable amounts of time in these places. Provincial and territorial governments often have a role in regulating public-access buildings and therefore a responsibility to ensure radon concentrations are below the national guideline.

Some provinces have conducted limited surveys of radon in schools, and in 2011, Quebec ordered all schools to test for radon. (Tests were to be completed by July 1, 2014, but the results have not yet been made public.)[73] Other provinces and territories should follow Quebec's example, and expand testing requirements to daycares, hospitals and care facilities. Canadian provinces and territories should also pass laws, as some U.S. states have done, requiring schools and daycares to display the results of a recent radon test and to mitigate if necessary.

3. Provincial and territorial governments should ensure that radon prevention measures in the most recent National Building Code (as updated and amended from time to time) are incorporated into provincial and territorial building codes and enforced. Further, provinces and territories should consider incorporating a requirement to meet the national guideline for radon in indoor air.

Incorporating effective radon prevention measures in the design and construction of new buildings is likely to be more effective than relying on testing and mitigation post-construction and could reduce the need for mitigation over time. Based on Statistics Canada data on housing development, an Ontario study estimated that if effective radon prevention measures were implemented in all ***new*** homes, after 37 years 50 per cent of homes would be built to the new standard, ensuring that half of Ontarians (those living in homes built to the new standard) would no longer face elevated home radon risks.[74] Yet, the Canadian Environmental Law Association identifies a number of provinces and territories that have not yet adopted the latest recommended radon prevention measures in their respective building codes. Furthermore, the extent to which preventative measures, where required, are being effectively implemented is not known.

Ontario's building code states that housing and small buildings in three designated areas of the province "shall be designed and constructed so that the annual average concentration of radon 222 does not exceed 200 Bq/m^3."[75] Provinces and territories could expand on this model and insert a generally applicable requirement to effectively codify the national guideline for new construction and ensure new home warranty programs provide coverage for radon remediation if concentrations exceed the national guideline (as currently offered in Ontario). To improve implementation of code requirements, governments could encourage and facilitate radon education for relevant construction trades.

4. Federal, provincial and territorial governments should offer incentives and subsidies to encourage homeowners to test for radon and facilitate mitigation where necessary. For rental properties, provincial and territorial governments should require radon testing and, if necessary, mitigation under tenancy laws.

The Green Budget Coalition has recommended a federal tax credit for homeowners incurring expenses related to radon mitigation.[76] A new tax credit would not only make mitigation more affordable, but would also help to raise awareness of radon and reinforce the importance of reducing radon levels in homes. In addition, Health Canada should offer a subsidized radon testing and mitigation program for low-income homeowners who may not be eligible for a tax credit. Landlords should be required by law to ensure radon concentrations in rental properties are below the national guideline, in keeping with existing legal responsibilities to maintain rental properties in a state fit for habitation.

5. Health Canada and provincial and territorial governments should evaluate and implement innovative approaches to make radon "visible."

A legal requirement mandating installation of digital radon monitors in all homes and public-access buildings (alongside smoke detectors and carbon monoxide detectors) could significantly improve public awareness of radon and help identify buildings that exceed the national guideline. Such a requirement should be accompanied by a program offering free or subsidized installation of monitors to low-income households. Health Canada currently cannot recommend digital radon monitors because a Canadian protocol to evaluate and approve this technology has yet to be developed.[77] This process should be expedited as the digital display of average radon concentrations has the power to make radon visible.[iv] Universal installation of digital radon monitors would also facilitate complementary measures, such an obligation for the seller in real estate transactions to disclose radon concentrations (as required in Norway, Switzerland, the U.K. and some U.S. states[78]).

Additionally, Health Canada should develop and publish online a national radon potential map, as the U.S. EPA has done. The EPA's radon potential map identifies areas of the United States with high, moderate and low potential for elevated concentrations of radon based on assessment of five factors: the results of surveys measuring indoor radon concentrations, geology, aerial radioactivity, soil permeability and foundation type. National and state-level maps are available free of change on the EPA website to help national, state and local organizations to target resources for radon testing and prevention campaigns.[79] To complement the CAREX map of reported radon measurements in Canadian homes (see page 10), a multifactorial assessment of radon potential in Canada would be a valuable tool in risk communication, and Canadians should have access to this information.

iv The Canadian National Radon Proficiency Program and the Canadian Association of Radon Scientists and Technologists have developed, and are in the process of implementing, performance specifications for home radon alarms — devices that signal when radon concentrations exceed a pre-set level. According to this new certification protocol, home radon alarms may have a visible display indicating radon concentrations, or allow measurements to be read via an output signal (e.g., when connected to a computer). ***The Home Radon Alarm Device Listing Requirements Document. Revision Number 6.24.6,*** CARST Performance Specification Document (CARST), accessed April 1, 2015, http://www.carst.ca/Resources/Documents/Home Radon Alarm Device Listing Requirements Professional review version 6.24.6.pdf.

APPENDIX: SURVEY OF CERTIFIED RADON MITIGATION PROFESSIONALS — RESPONSES

Survey questionnaires were sent by email to approximately 125 certified radon professionals in Canada via the Canadian National Radon Proficiency Program (C-NRPP) in April 2015. The questionnaire allowed for open-ended responses.

TABLE 1: PERCENTAGE OF RESPONDENTS WHO ANSWERED YES OR NO TO SURVEY QUESTIONS 1 AND 2 (N=22)

	YES	NO
Question 1 In your experience, when radon levels in indoor air are high, is it possible to mitigate to reduce concentrations to 100 Bq/m^3 or less?	100%	0%
Question 2 Have you ever encountered a situation when it was not possible to lower radon concentration in indoor air to 100 Bq/m^3 or less, despite mitigation efforts?	36.4%*	63.6%

* In the open-ended response, respondents answering "Yes" to Question 2 noted it as an exceptional circumstance, generally involving cases where the homeowner declined more expensive/invasive actions that would have been necessary to achieve further reductions.

TABLE 2: PERCENTAGE OF RESPONDENTS FROM EACH PROVINCE (N=22)

PROVINCE	% RESPONDENTS
Alberta	4.6
British Columbia	18.2
Manitoba	18.2
New Brunswick	9.1
Ontario	31.8
Quebec	13.6
Saskatchewan	4.6

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Most Canadians have never heard of radon, yet it is the leading cause of lung cancer among non-smokers and responsible for 16 per cent of lung cancer deaths. A radioactive gas produced by the natural decay of uranium in soils, radon can seep into buildings and become trapped, accumulating to high levels in indoor air. Revisiting Canada's Radon Guideline examines current international guidance on radon and compares Canada's radon guideline to parallel standards in leading jurisdictions. In light of significant international developments in recent years, the David Suzuki Foundation argues that Canada should strengthen its guideline for radon in indoor air and ensure effective implementation.

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