

# Radon:

## What We Have Learned From Retrofit Studies

Stacy Gloss, research specialist  
Indoor Climate Research and Training  
University of Illinois

**In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,**

**“This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying 1.5 hours of credit toward Building Officials and Residential Contractors continuing education requirements.”**

**For additional continuing education approvals, please see your credit tracking card.**



# Learning Objectives

- Identify radon zones on EPA's radon zone map.
- Describe differences in radon levels from two residential ventilation strategies.
- Recognize some patterns of correlation between temperature and radon.
- List pros and cons of different radon test methods.
- Discuss patterns of variability of radon from multiple factors.
- Describe impacts of different retrofit measures.

# Topics

- ▶ What is radon?
- ▶ How is it identified? (test methods)
- ▶ What do research studies tell us about radon and residential retrofit?
- ▶ What policies tell us to do when practitioners find radon in a home.
- ▶ Wrap up and Conclusions.



# Disclaimer:

- ▶ I am not a Ph.D. scientist.
- ▶ I'm not a policy wonk.
- ▶ I'm not an epidemiologist.
  
- ▶ I have been spending some time in people's crawlspaces and basements testing radon before and after residential retrofits for research.
  
- ▶ I look forward to sharing with **you** what I've learned.



# Survey Question #1

- ▶ Do you consider yourself to have moderate to advanced level of radon knowledge?

(Raise your hand. Don't be shy.)

# Survey Question #2

- ▶ Have you ever tested a home for radon?

# Survey Question #3

- ▶ Are you familiar with active soil depressurization and other radon mitigation techniques?





# What is radon?



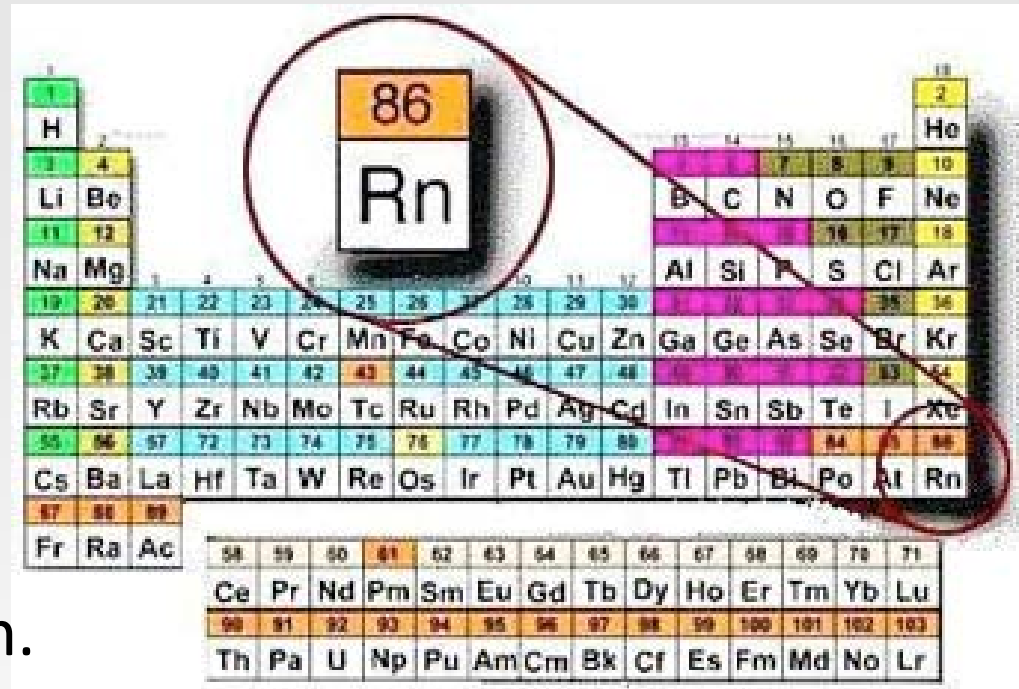
# What is radon?

- ▶ Naturally occurring radioactive gas that can cause lung cancer.
- ▶ You can't see or smell or taste radon.
- ▶ Radon can have a big impact on indoor air quality. (EPA)



# Radon Science

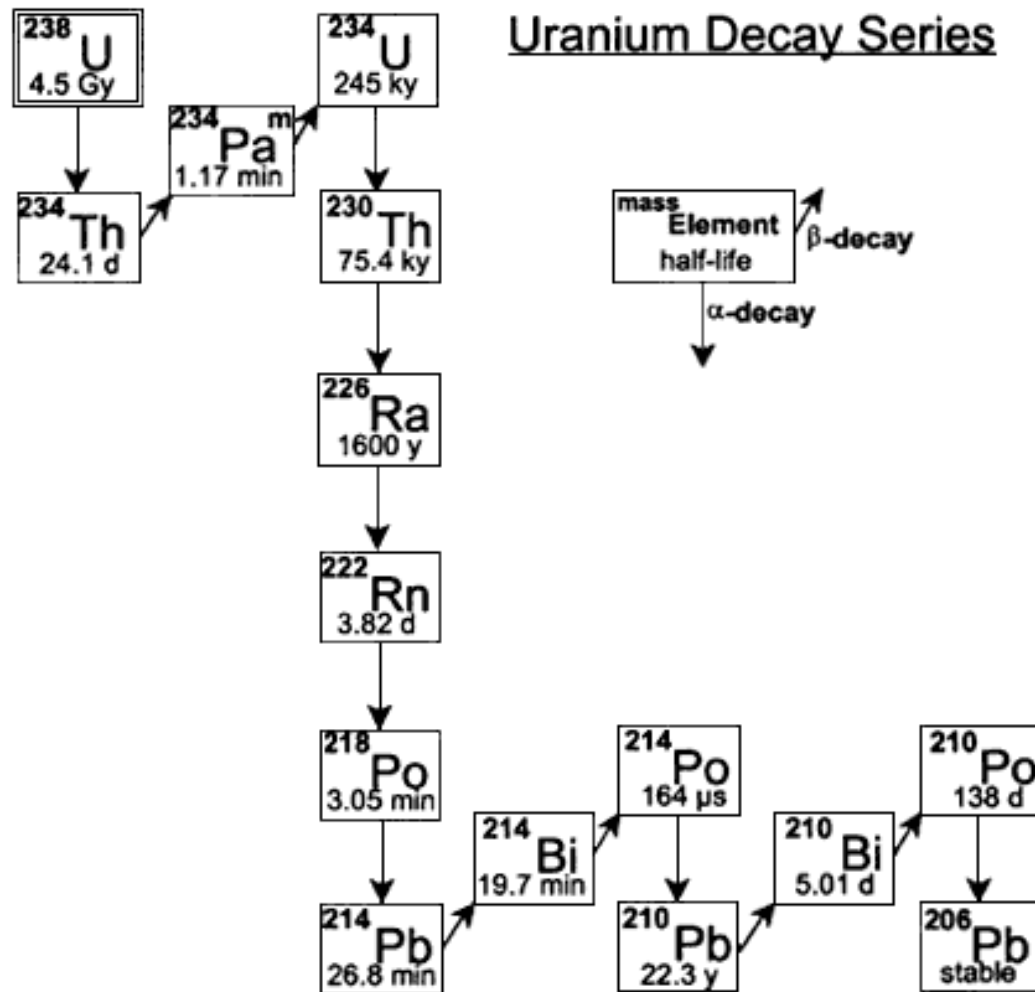
- ▶ Chemical element with symbol **Rn**.
- ▶ Occurs naturally as a decay product of radium.
- ▶ Half-life of 3.8 days.
- ▶ Alpha particles from Ionizing Radiation are dangerous to human health.



The image shows a periodic table of elements. The element Radon (Rn) is highlighted with a magnifying glass. The magnified box shows the atomic number 86 and the symbol Rn. The periodic table is color-coded by groups, and the noble gases (Group 18) are highlighted in purple. The element Xenon (Xe) is also highlighted in orange.

1																	18						
H																	He						
3	4											7	8	9	10								
Li	Be											B	C	N	O	F	Ne						
11	12											13	14	15	16	17	18						
Na	Mg											Al	Si	P	S	Cl	Ar						
19	20	21	22	23	24	25	26	27	28	29	30					35	36						
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr						
37	38	39	40	41	42	43	44	45	46	47	48					53	54						
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe						
55	56	57	72	73	74	75	76	77	78	79	80					84	85	86					
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn						
87	88	89															112	113	114	115	116	117	118
Fr	Ra	Ac	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118			
		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu								
		90	91	92	93	94	95	96	97	98	99	100	101	102	103								
		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr								

# Uranium decay chain



# What are we concerned about?

- ▶ Radon decay products – alpha particles.
  - Alpha particles are solids and can stick to surfaces such as dust particles in the air that are breathed in.
- ▶ Radon can get into the lung through respiration, and can decay to radioactive solids or radon progeny.
- ▶ Can damage lung cells and cause lung cancer

# Radon measurement units

Most common unit in U.S.

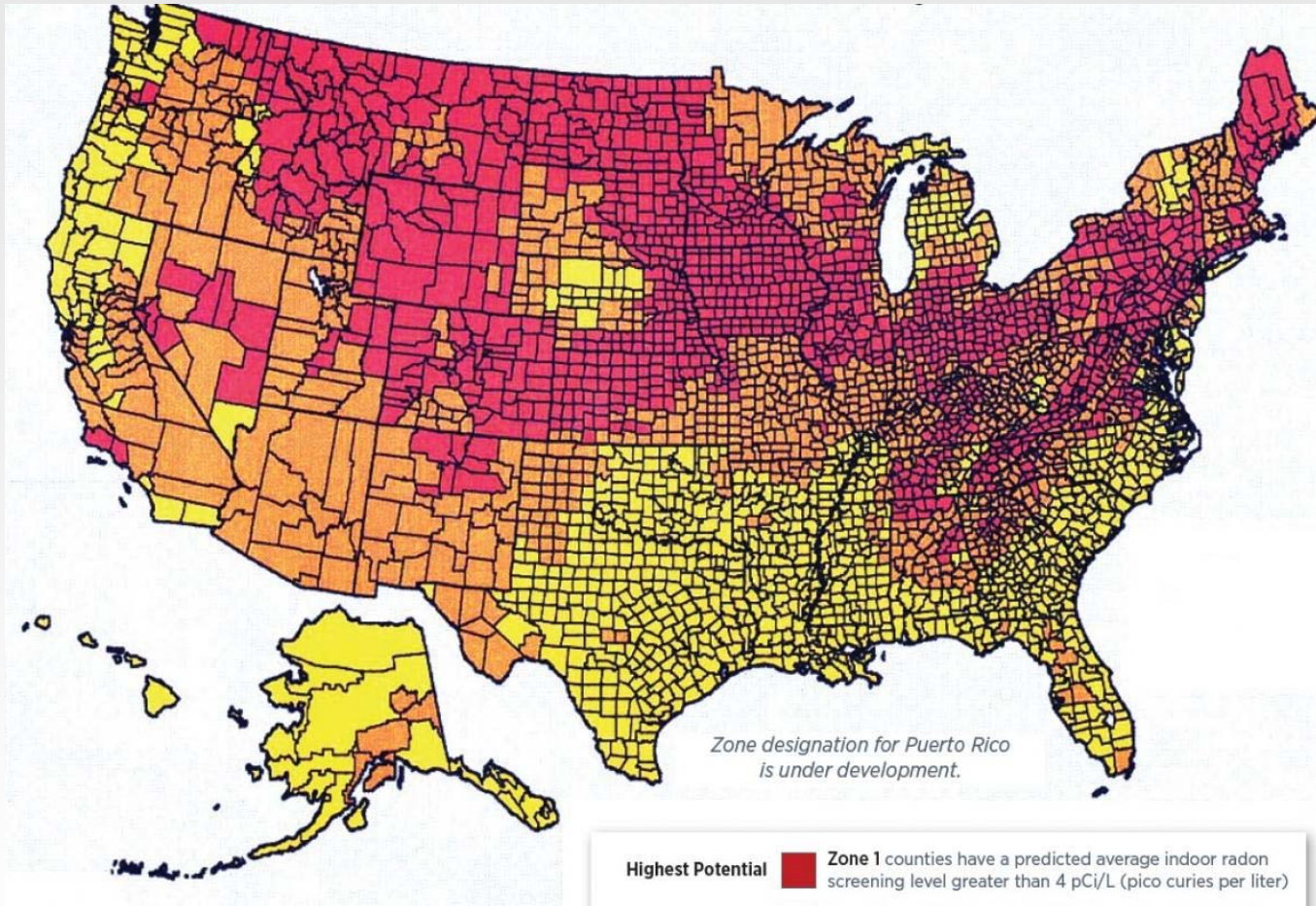
- ▶ pCi/l = picocuries per liter
  - For each pCi/l there are 2.2 radioactive disintegrations per minute (source: radon-faq.com)
  
- ▶ EPA Threshold 4.0 pCi/L






# Where is radon?



# EPA Radon Map

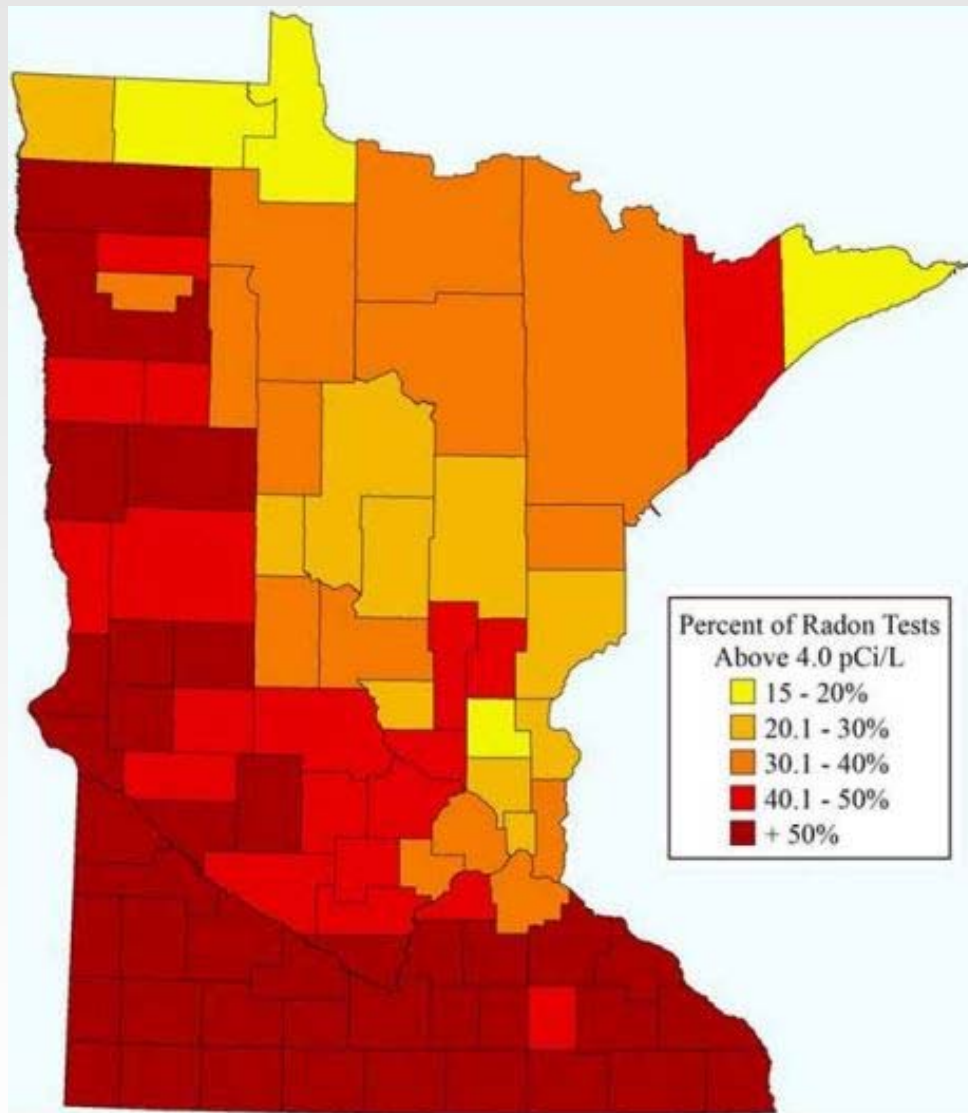


*Zone designation for Puerto Rico is under development.*

<b>Highest Potential</b>		<b>Zone 1</b> counties have a predicted average indoor radon screening level greater than 4 pCi/L (pico curies per liter)
<b>Moderate Potential</b>		<b>Zone 2</b> counties have a predicted average indoor radon screening level between 2 and 4 pCi/L
<b>Low Potential</b>		<b>Zone 3</b> counties have a predicted average indoor radon screening level less than 2 pCi/L

EPA Radon Zone Map  
(Source: [www.epa.gov/radon/zonemap.html](http://www.epa.gov/radon/zonemap.html))





# EPA Radon Policy

- ▶ Developed in early 1980s
- ▶ Recommend mitigation for levels  $> 4$  pCi/l

# The Story of Stanley Watrous

**The Watrous house tested at 2,700 picocuries per liter,  
700x the recommended level.**

# How to measure radon and variability in results



# Measurement of Radon

- ▶ Many methods
  - SHORT TERM - 2 – 4 day tests
  - For example, short term electrets with short term sampler



# Measurement of Radon

- ▶ Charcoal canisters - ~ 2 – 7 days, averaging
  - Most common type of test kit



# Measurement of Radon

- ▶ LONG TERM - Alpha-Tracks (~91 days or greater, averaging)



- ▶ LONG TERM ion chambers, more than 3 weeks, any period, averaging



# Measurement of Radon

- ▶ ANY DURATION– Continuous Radon Monitors



10 Days max – Hourly Data

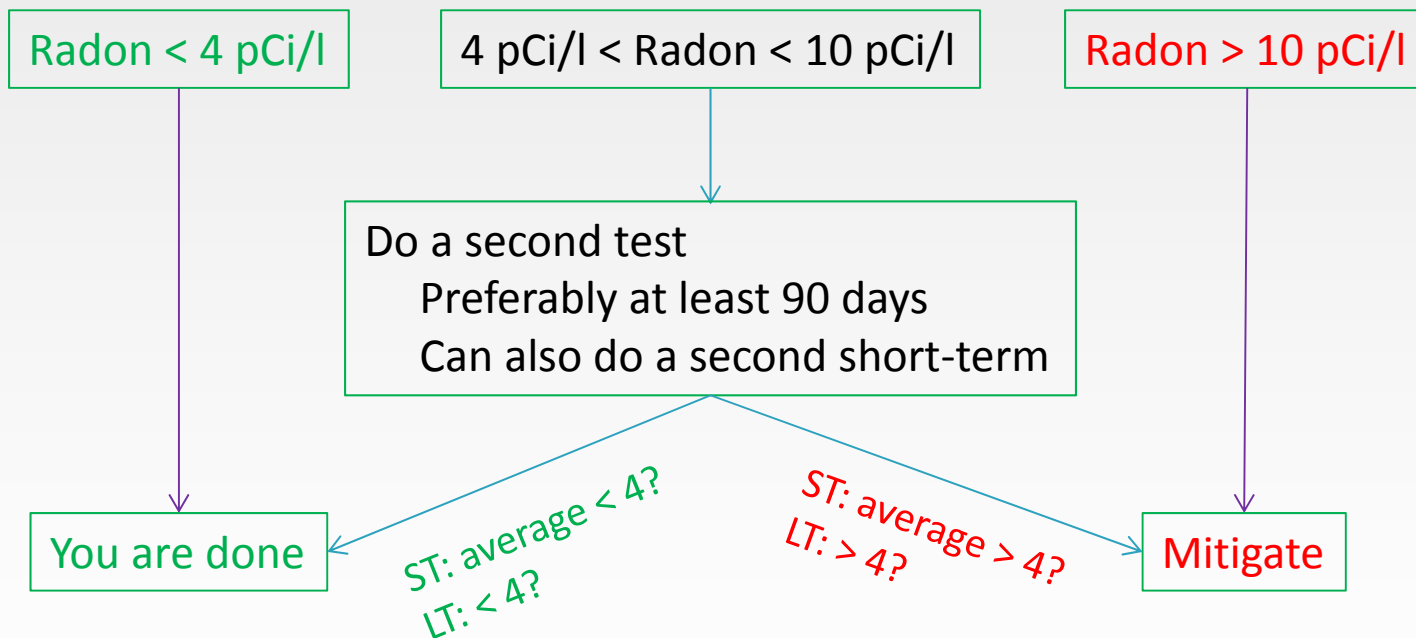


Modified for research - Hourly Data, Unlimited Days



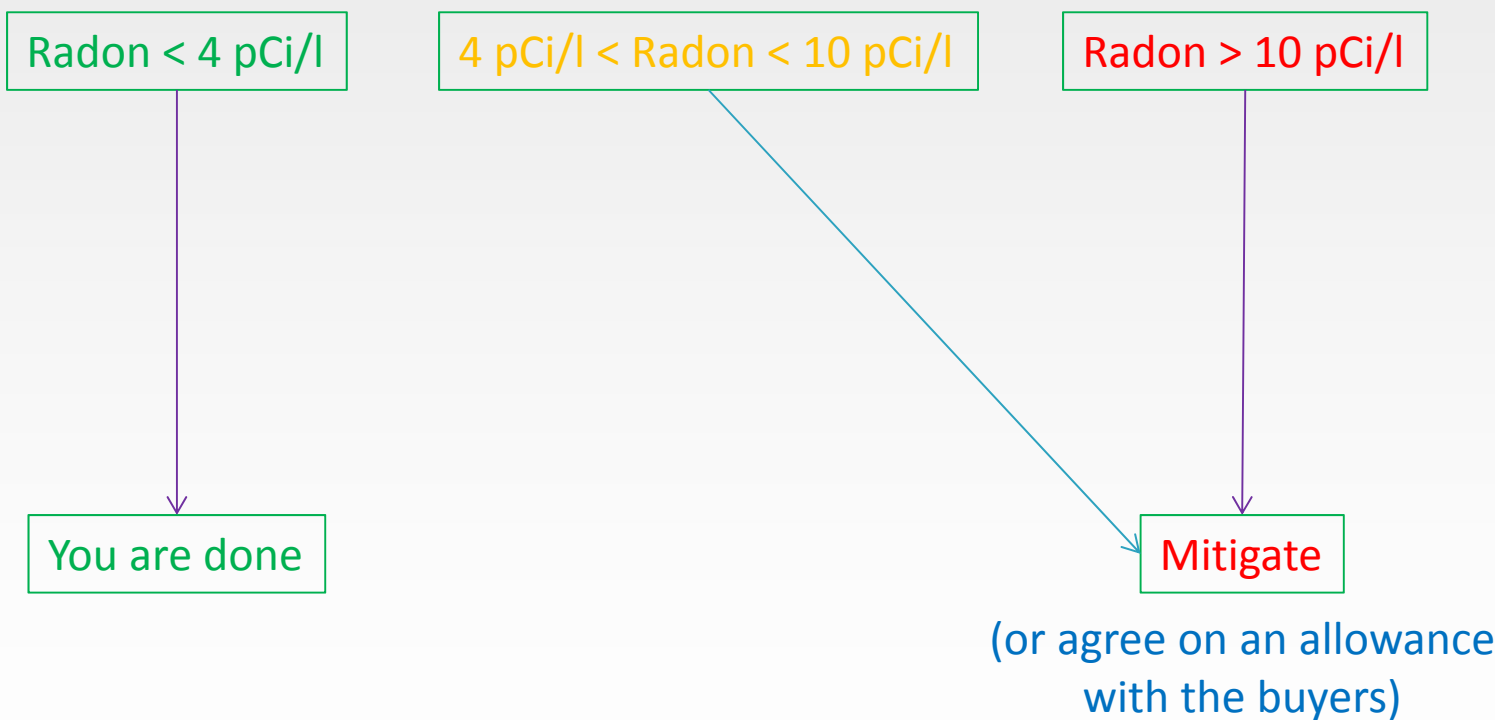
# Measurement of Radon

- ▶ What EPA says (EPA 1993):
  - Do a short-term test



# Measurement of Radon

- ▶ What is usually done (esp. for real estate transactions):
  - Do a short-term test



# Measurement of Radon

- ▶ Remember, action level is intended to be an ANNUAL AVERAGE
- ▶ Lots of work on variability by Steck et al.
  - Variability around an annual average for multiple periods
  - Annual variability (year-to-year)

# Steck et al. variability around annual average (Steck 2005)

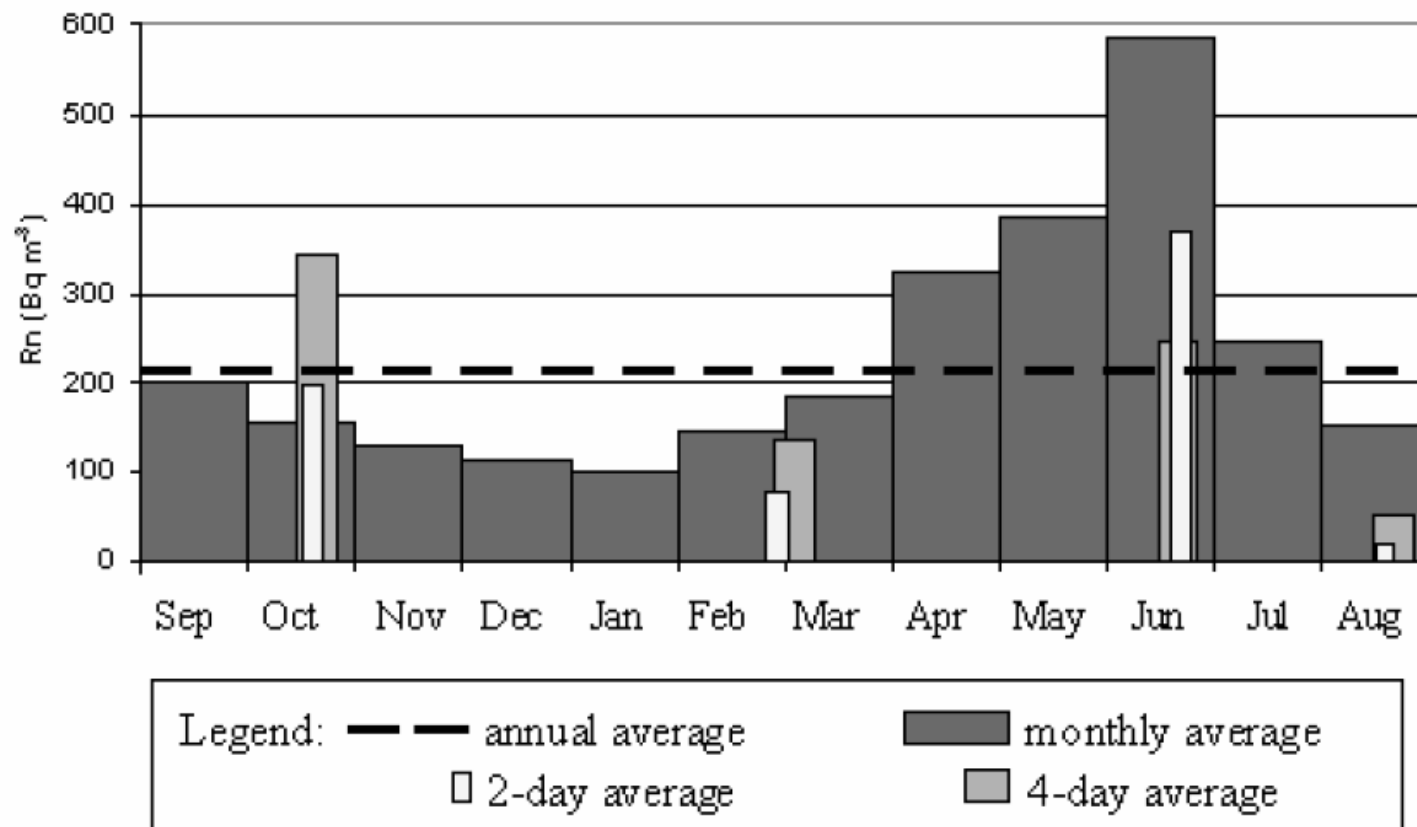


Figure 2. Sample Temporal survey results from measurement site SD3A0.

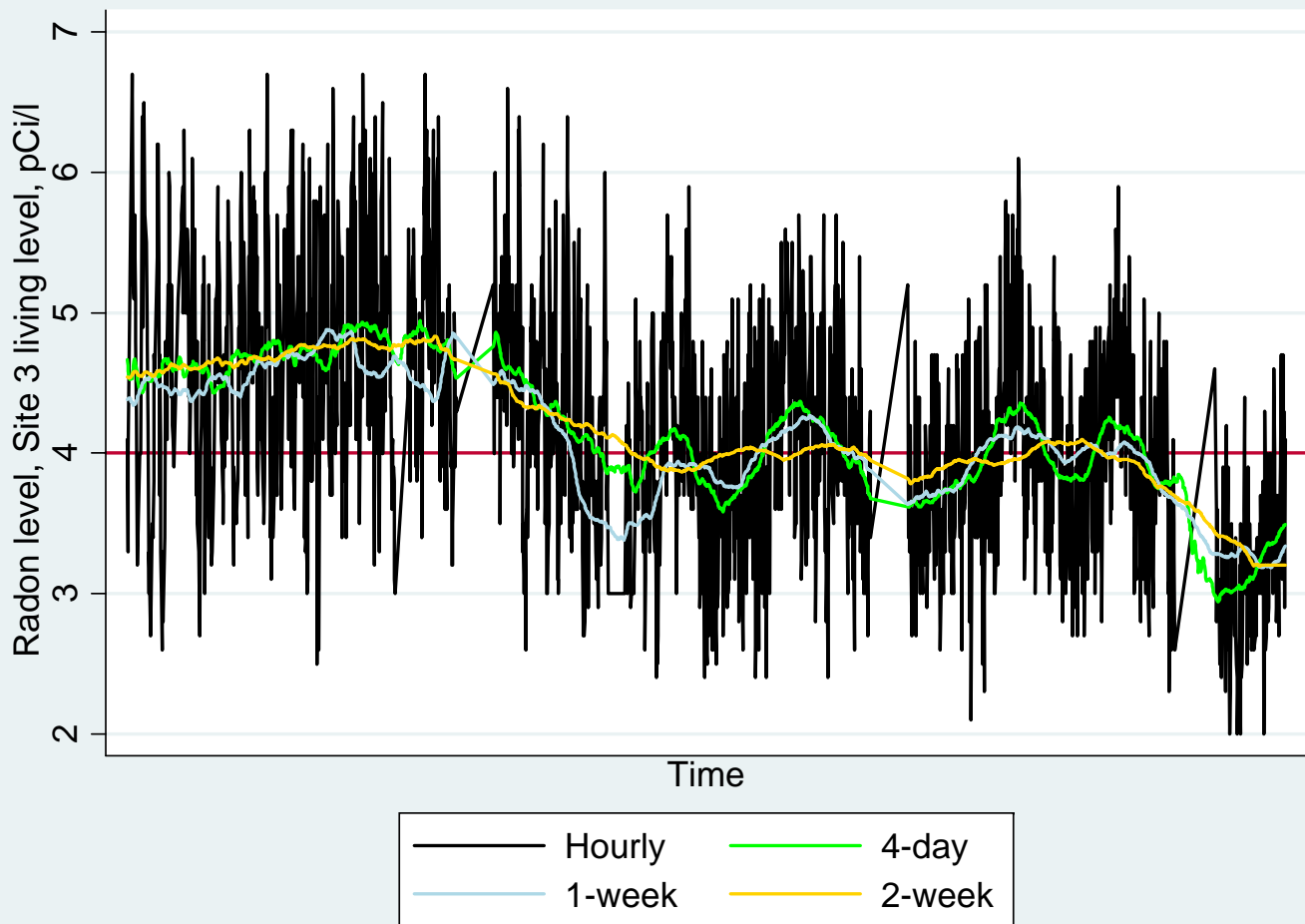
# Steck et al. variability around annual average (Steck 2005)

Table 3. Comparative variations of different averaging periods and operating conditions at the primary measurement site in the Temporal survey

<b>Measurement Type: House conditions</b>	<b>COV about the annual average<sup>1</sup></b>
Two day: closed	76%
Four day: closed	70%
Monthly: normal	40%
Seasonal (90 day) average: normal	25%
Semi-annual average: normal	17%

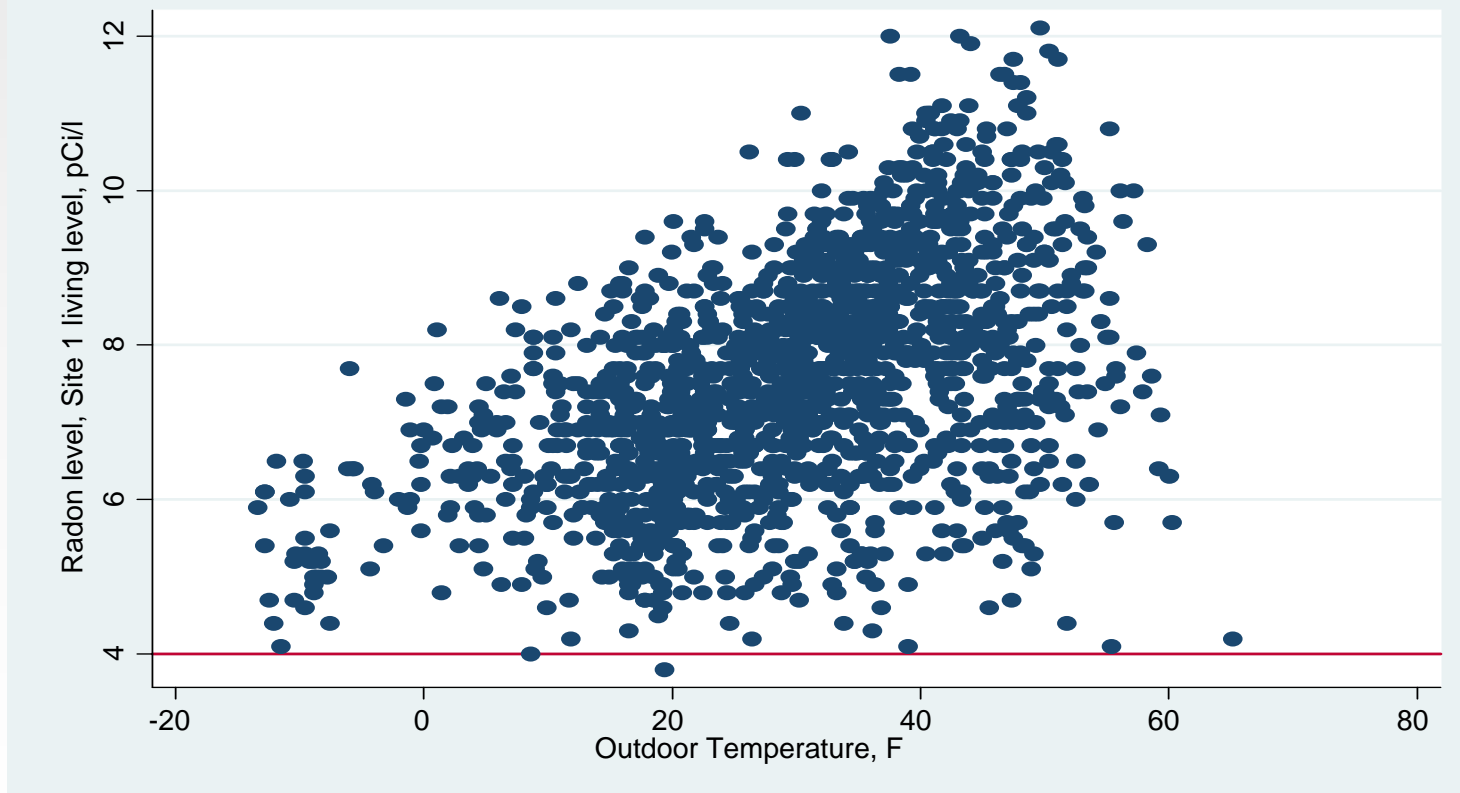
<sup>1</sup> Corrected for instrumental variation

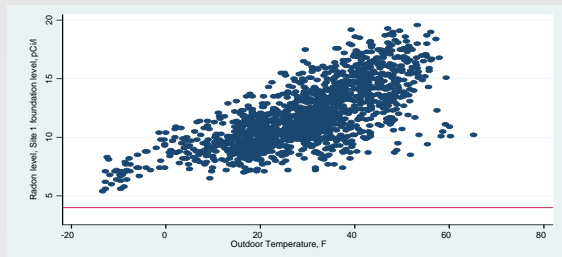
# Building America – Site 3 – Living Level



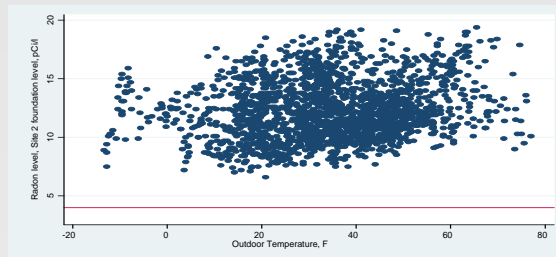
# Weather

- ▶ Radon higher when temperatures are warmer

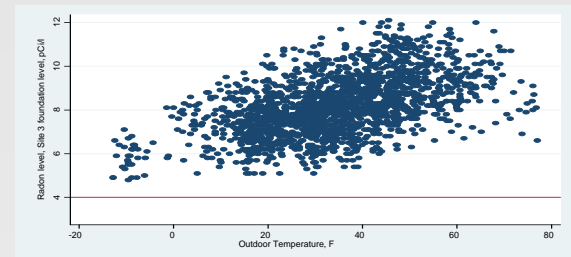




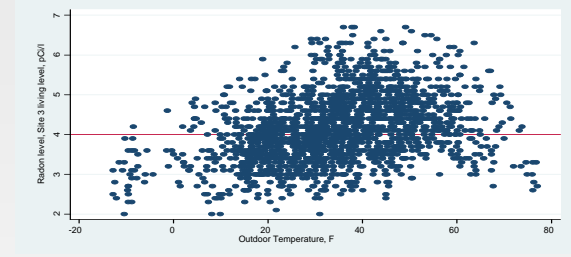
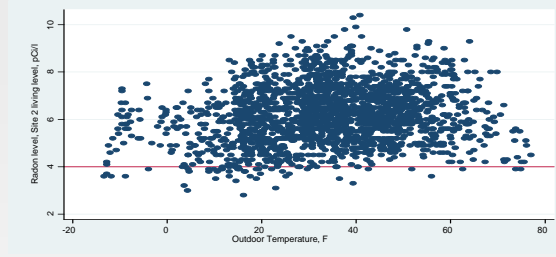
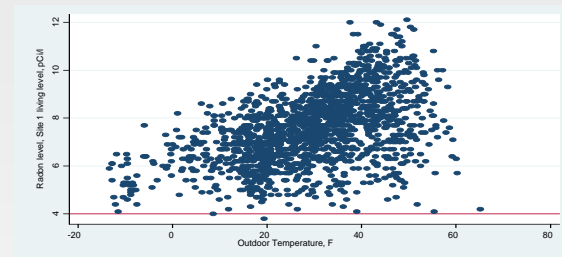
Site 1



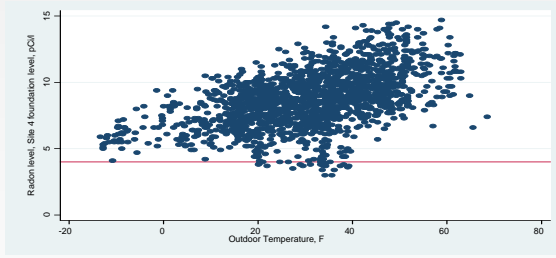
Site 2



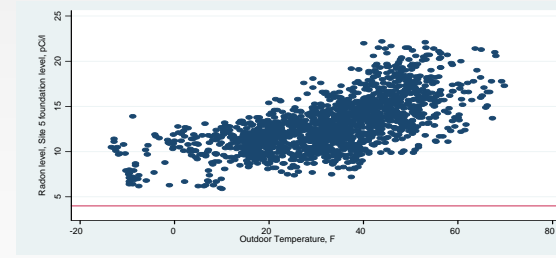
Site 3



Foundation

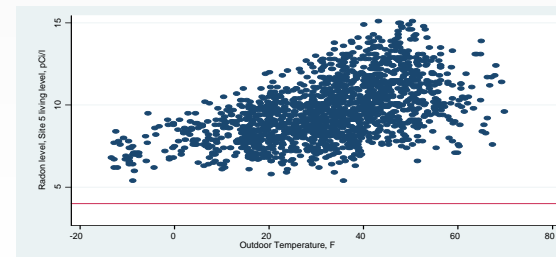
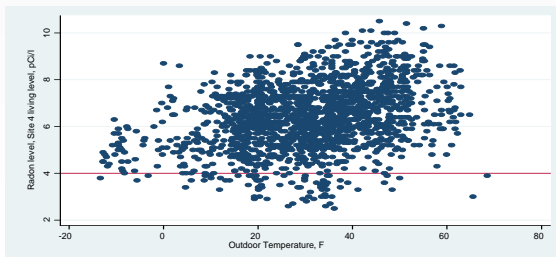


Site 4



Site 5

Living Level





# How good are various test methods?

- ▶ Probably all pretty good at measuring what happened when they were there.
- ▶ Instrumentation itself is not problematic.
- ▶ The problem is that radon is so variable – levels you see this 2 or 4 days may not be the levels you will see 2 or 4 weeks from now.

# Our Research Studies



ILLINOIS SUSTAINABLE  
TECHNOLOGY CENTER  
PRAIRIE RESEARCH INSTITUTE

INDOOR CLIMATE RESEARCH AND TRAINING



# HEALTH-V Study



ILLINOIS SUSTAINABLE  
TECHNOLOGY CENTER  
PRAIRIE RESEARCH INSTITUTE

INDOOR CLIMATE RESEARCH AND TRAINING



# Goals and Methods

- ▶ Compare benefits of differing ventilation standards
  - ASHRAE 62-1989 vs. ASHRAE 62.2
- ▶ Observe changes in IAQ from energy retrofits
  - HCHO, TVOC, Rn, CO<sub>2</sub>, CO, Humidity
- ▶ Conduct preliminary and final health surveys



# Sites Tested

- ▶ Tested 52 homes Chicago area, 35 homes in Indiana
- ▶ Randomly selected
- ▶ Control homes weatherized to ASHRAE 62-1989 (passive infiltration)
- ▶ Treatment homes weatherized to ASHRAE 62.2-2010 (mechanical ventilation)

# Exhaust ventilation

## Radon, basement

Radon	Number (n)	Mean (pCi/l)	Geo-mean (pCi/l)	T-test p-value
Pre-Wx all	51	5.1	2.6	0.330
Post-Wx all		6.0	3.0	
Pre-Wx 62-1989	23	6.3	3.0	0.888
Post-Wx 62-1989		6.7	2.9	
Pre-Wx 62.2-2010	28	4.2	2.4	0.073
Post-Wx 62.2-2010		5.4	3.1	

Green indicates statistical significance at  $p < 0.10$

# Exhaust ventilation

## Radon, 1<sup>st</sup> floor

Radon	Number (n)	Mean (pCi/l)	Geo-mean (pCi/l)	T-test p-value
Pre-Wx all	46	2.7	1.8	0.143
Post-Wx all		2.6	1.4	
Pre-Wx 62-1989	21	2.4	1.7	0.824
Post-Wx 62-1989		2.8	1.6	
Pre-Wx 62.2-2010	25	3.0	1.9	0.067
Post-Wx 62.2-2010		2.4	1.3	

Green indicates statistical significance at  $p < 0.10$

# Building America Study

- ▶ Conducted by researchers at ICRT, homes in Champaign, IL
- ▶ Intended to evaluate potential for air sealing between foundation and first floor to reduce radon migration
- ▶ Principle of “do no harm” as opposed to solving high radon problems



# Objectives

1. Investigate effectiveness of targeted floor air sealing at isolating the living space from the foundation space
2. Monitor effect of air-sealing on radon levels in foundation and living spaces
3. If specific air-sealing targets can be prescribed to address radon levels
4. Discover the role that ductwork plays in the transport of radon to the living space

# Sample House Characteristics

- 3 Groups: Fall 2013, Spring 2014, Summer 2014
- 11 Crawlspace, 4 Basement + Crawlspace(s)
- Average home age: 1966; Newest: 2005; Oldest: 1890
- Average CFM50: 3239; Tightest: 1542; Leakiest: 5896

# Study Design

- ▶ 15 homes monitored in 3 groups of five monitored for ~90 days
  - Monitor for a month
  - Retrofit 2-3 of them, monitor for a month
  - Retrofit the others, monitor for a month
  - Monitoring was continuous in living level, crawlspaces and basements



# Retrofit Measures



Applying mastic and foil tape to duct work



Expanding urethane foam at penetrations beneath the floor

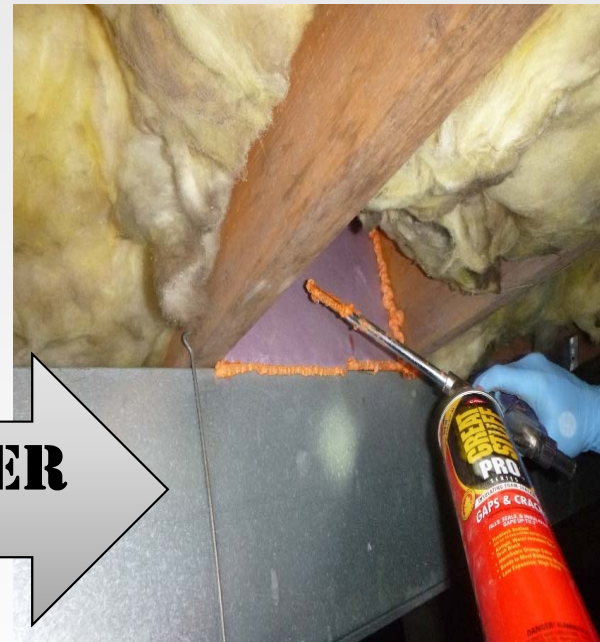


Repairing or replacing degraded missing duct work

# Wide open ducts in crawl space



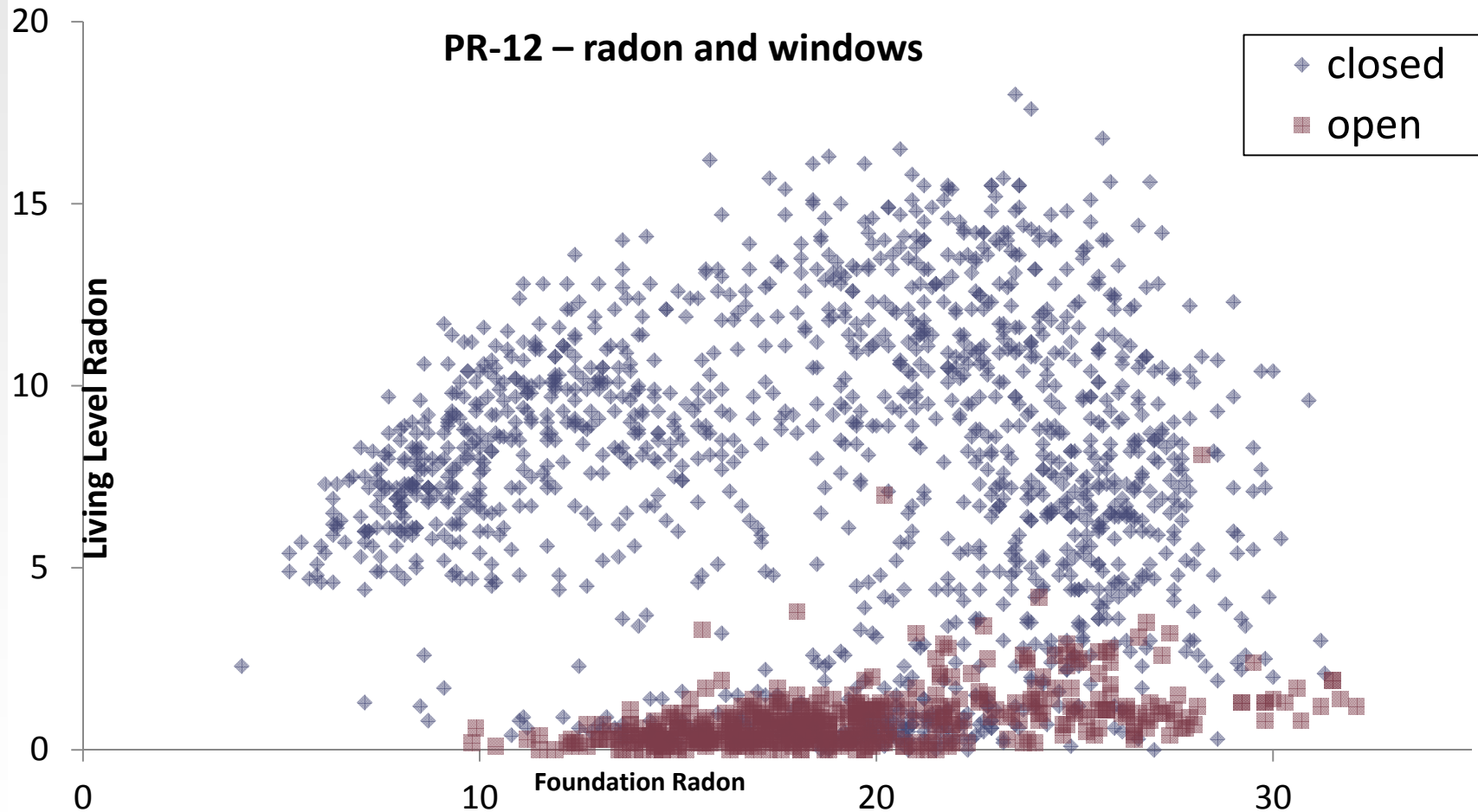
**BEFORE**



**AFTER**

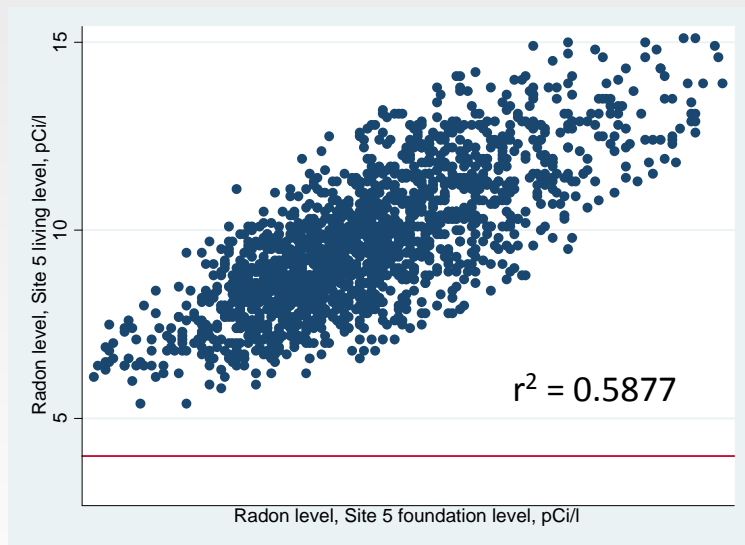


# Windows Open / Closed



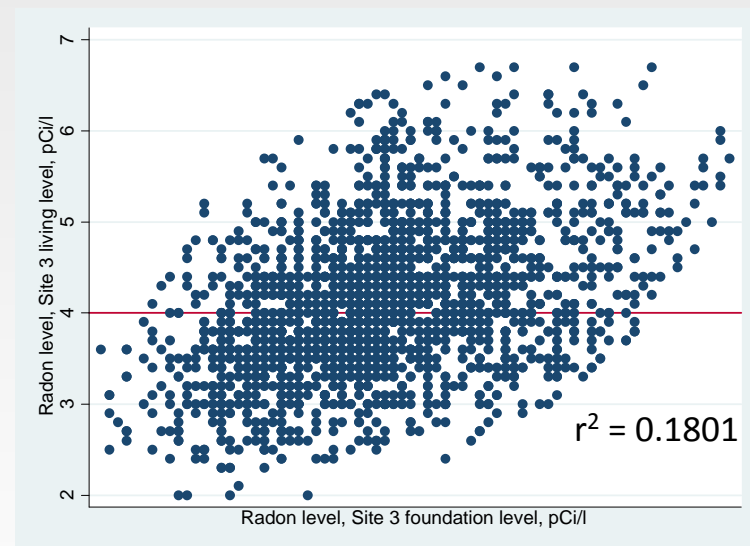
# Basements and First Floors track each other?

Site 5



Greatest agreement

Site 3



Worst agreement

# Results

- ▶ Treatment lead to measureable change in zone pressure measurements with greater isolation of foundation and living space.
- ▶ Improved isolation did not lead to statistically significant change in living level average radon

$\frac{6}{15}$  Reduced;  $\frac{2}{15}$  Even;  $\frac{7}{15}$  Increased

- ▶ No changes could be conclusively attributed to the treatments.



# Case Studies

- ▶ Air handler fan ran continuously – living level and crawl radon were within 10%
- ▶ Very large return duct leaks – after sealing radon noticeably dropped

# National Weatherization Evaluation

Report released 2015

## Weatherization and Indoor Air Quality: Measured Impacts in Single-Family Homes Under the Weatherization Assistance Program

Scott Pigg, Energy Center of Wisconsin

Dan Cautley, Energy Center of Wisconsin

Paul Francisco, University of Illinois

Beth Hawkins, Oak Ridge National Laboratory

Terry Brennan, Camroden Associates

# Sites Tested

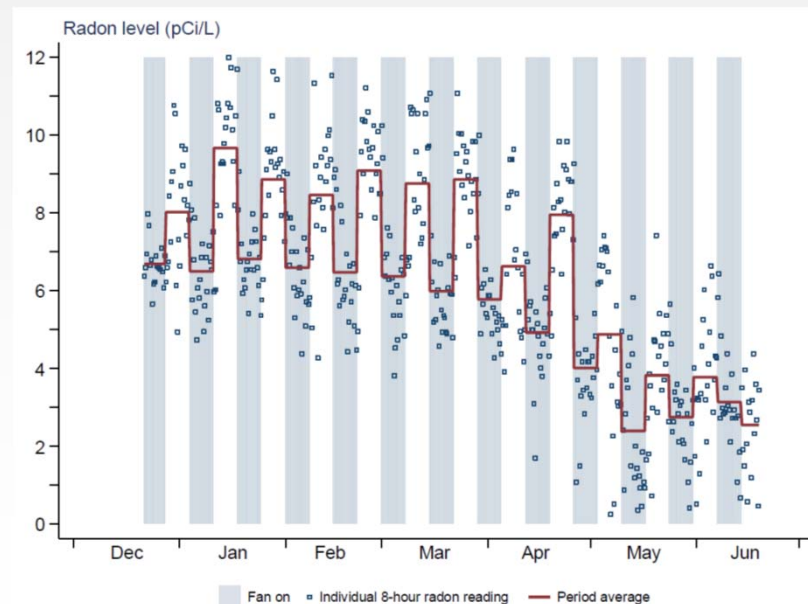
- ▶ 514 single-family homes
- ▶ 35 states
- ▶ 88 weatherization agencies participated
- ▶ 2010/2011 heating season
- ▶ Over sampled in high – radon areas
- ▶ Tested radon using activated charcoal canisters
  - 7 day test before and after Wx

# Key Take Aways

- ▶ Average single-family home had heating-season indoor radon levels of  $1.9 \pm 0.1$  pCi/L
- ▶ Tighter homes tend to have higher radon levels
- ▶ Data suggest Wx results in small, statistically significant increase in radon levels.
- ▶ Average increase of  $0.4 \pm 0.2$  pCi/L
- ▶ Most states Wx programs used ASHRAE 62-1989 (BTL)
- ▶ Follow on study evaluated 62.2 compliant exhaust ventilation. Toggled on/off ventilation and results suggest that 62.2 compliant exhaust ventilation can reduce radon levels.

# National Weatherization Evaluation

- ▶ Follow on study evaluated 62.2 compliant exhaust ventilation. Toggled on/off ventilation and results suggest that 62.2 compliant exhaust ventilation can reduce radon levels.



# **Building Assessment of Radon/Moisture Reduction w/ Energy Retrofits (The BARRIER Study)**

*University of Illinois at Urbana-Champaign  
National Center for Healthy Housing  
Tohn Environmental Strategies*

# Need for the Study

## ▶ Questions:

- Can low-cost, passive measures that are aligned with normal weatherization measures keep radon levels from increasing as a result of WAP activities?
- Are there also moisture benefits?



# Enhanced Measures

- ▶ Crawl spaces
  - Plastic groundcovers carefully installed such that all seams are sealed and the plastic is sealed to the perimeter walls and any foundation supports
  - Air sealing of ducts located in the crawl space
  - Air sealing of the floor between the living space and the crawl space
  - Air sealing around any interior crawl space accesses



# Enhanced Measures

- ▶ Basements
  - Plastic groundcovers over any exposed earth, carefully installed such that seams are the plastic is sealed to concrete
  - Installation of sealed sump pump covers
  - Caulking of cracks in below grade concrete
  - Air sealing of the floor between the basement and first floor, if the basement is not the lowest living level
  - Air sealing of return ducts located in the basement



# Discussion & Conclusions