Chapter 5

The Myth of the Reading Prong

> We have identified an area (in Minnesota and North Dakota) similar in severity to the Reading Prong.
> — Second EPA State Survey, September 1988

In this chapter, we confront two key myths about radon that emerged from the early Watras experience. The myth of the hot house involves the fixation of radon policy on finding and remediating "hot houses," hypercontaminated buildings, such as those found in Colebrookdale Township, Pennsylvania. Radon policy after the Watras case never got past the inconceivable risk faced by the occupants of such hot houses, resolving to attempt their identification by fast and dirty screening tests. The myth of the Reading Prong, also dating from that time, refers to the early association of the high radon levels in Colebrookdale Township with the granite/gneiss rock formation stretching east along the Appalachian chain from Reading, Pennsylvania, up the spine of western New Jersey, along southeastern New York, and into Connecticut (see fig. 5.1). The myth of the Reading Prong triggered a search for other radon hot spots having definable boundaries, for a geological understanding of why these hot spots occurred, and for the means to use geologic and geographic features as a predictive tool for locating hot areas. Along with the myth of the hot house, the myth of the Reading Prong represents a fundamental confusion about how radon is manifested that, in turn, has confounded radon policy.

Fig. 5.1 Reading Prong region [Source: (Middletown, New York) *Times-Herald Record*, file graphic by Lance Theraux]

The Myth of the Hot House

Ever since the Watras house was discovered, there has been an obsession with "hot" houses. While there is no formal definition for a hot house, clearly, houses with radon values in the hundreds or thousands of pCi/l qualify. Here we operationally define a hot house as one having an annual average radon concentration of 20 pCi/l or higher, a level at which home occupants would receive an annual dose equivalent to the maximum level allowed to mine workers. While we save for the next chapter the issue of how we test for these hot houses, here we examine the prevalence and threat from hot houses and question whether hot houses are a sound basis for government policy.

Are There Many Hot Houses Out There?

Shortly after the Watras discovery, a rough idea of the theoretical distribution of radon in U.S. homes was developed. Scientists at Lawrence Berkeley Laboratory (LBL) examined existing data for 817 homes adjusted to show annual averages (Nero et al., 1986), while University of Pittsburgh physicist Bernie Cohen (1986) analyzed one-year average radon measurements collected from the homes of 453 physics professors. The distribution of residential radon from both studies follows a lognormal curve (see fig. 5.2); that is, while most houses have fairly low radon values—the studies show an average radon value in homes of 1.5 pCi/l—there is a long tail on the distribution showing that a significant number of houses have radon values much higher than average.[1]

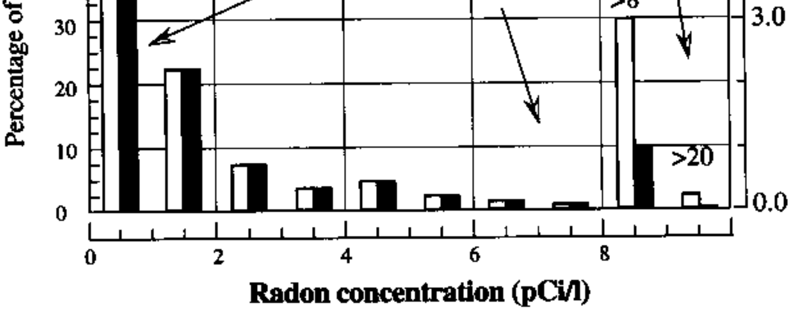


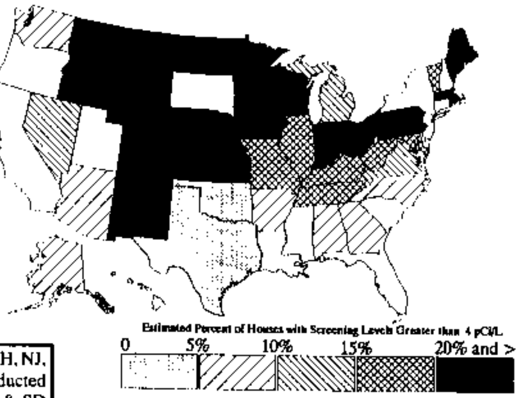
Fig. 5.2 Probability distribution of radon concentrations in 552 U.S. homes. See endnote 1 for discussion of figure
(Source: Data from Nero, 1986, and Cohen, 1986)

Because of the small sample sizes and sample bias, these results were viewed as tentative. The basic problem in determining a valid distribution for radon exposure in homes is getting a representative sample that is large enough. A good representative sample would also reflect all regions of the country, represent different housing types, and consider the full range of geological diversity. Ideally, testing procedures would be standardized so that measurements were made using the same kind of detector, in appropriate locations in the home, and at the same time of the year. If the annual average radon concentration was not measured directly, corrections would be made.

Initial efforts to verify the LBL/Cohen lognormal distribution using existing large data samples were not particularly fruitful. By 1992, more than a million radon measurements had been taken from all over the country and larger testing firms such as Terradex, the Radon Project at the University of Pittsburgh, and Key Technology had collected many tens of thousands of measurements each. Despite the large sample size, however, the data came with severe limitations. Illustrative of such bias was a Terradex survey of ninety-one thousand measurements that found ten times the LBL and a hundred times the Cohen estimate of homes projected to be over 20 pCi/l (Alter and Oswald, 1988).[2] It is likely that the Terradex data exaggerated the number of hot houses. The data set included many confirmatory tests following up on initially high radon levels and a disproportionate number of tests from radon elevated regions of the country. Additionally, many of these tests did not measure annual average radon exposure to occupants and, thus, were unrepresentative. Similar problems affected government research, as well. The joint State/EPA Residential Radon Survey (SRRS) incorporated more than fifty-nine thousand randomly selected measurements from forty-two states in order to avoid geographic, geologic, and housing diversity biases (Philips et al., 1991; Philips and Marcinowski, n.d.). However, the findings, depicted in the summary map shown as figure 5.3, are based on data representing short-term screening measurements made under closed house conditions in the lowest livable area of the house. As explained in the next chapter, these results fail to reflect the homeowners' average annual radon exposure level.[3] As a result, there is no precise definition of the magnitude of the radon health threat. In addition, such test results have sometimes been reported in a misleading way by comparing them to the annual average EPA guideline of 4 pCi/l (see EPA 1987c). This misinterpretation falsely suggests that over 20 percent of homes in many states have annual averages exceeding the guideline. EPA has been rightly criticized for inflating the data to advance the radon issue.

To address the limitations of previous studies, EPA undertook another project, the National Residential Radon Survey (NRRS), to measure annual average concentrations using year-long alpha track detectors on each lived-in floor of the house (EPA 1992c). The survey covered single-family, attached homes, multiunit structures, and mobile homes, ultimately collecting data from a randomly selected sample of 5,694 homes throughout the United States. Results re leased in October 1992 are shown in figure 5.4. The annual average radon con

STATE/EPA RESIDENTIAL RADON
SURVEY SCREENING MEASUREMENTS



The States of DE, FL, NH, NJ, NY, and UT, have conducted their own surveys. OR & SD declined to participate in the SRRS.

These results are based on 2-7 day screening measurements in the lowest livable levels and should not be used to estimate annual averages or health risks.

Fig. 5.3 Estimated percentage of houses with screening levels greater than 4 pCi/l from State/EPA Residential Radon Survey screening measurements (*Source*: EPA, Philips and Marcinowski - undated)

centration in the U.S. housing stock was found to be 1.25 pCi/l (+/- 9 percent), with about 6 percent of homes having annual average radon values greater than 4 pCi/l, 0.7 percent greater than 10 pCi/l, and 0.1 percent greater than 20 pCi/l. These data indicate that about 5.8 million homes (+/- 22 percent) have annual average radon levels greater than 4 pCi/l, while perhaps 72,000 houses (0.1%) have annual averages greater than 20 pCi/l. The black bars in figure 5.4 show how radon risk is distributed across the U.S. housing stock and indicates that the bulk of the risk is in homes below 4 pCi/l. The results confirm the earlier LBL analysis. Based on the NRRS data, EPA estimates that radon is responsible for seven thousand to thirty thousand lung cancer deaths per year in the United States (EPA 1992c).

A Case of the Tail Wagging the Curve: Limits of Hot-House-Based Policy

Using the NRRS data, we can draw a crucial observation about population exposure. Most radon exposure (about 65 percent)—and the bulk of radon health risk—is at levels of radon below the 4 pCi/l guidance. Hot houses (i.e., over 20 pCi/l) account for only 1 percent of the aggregate risk. Even if all hous-

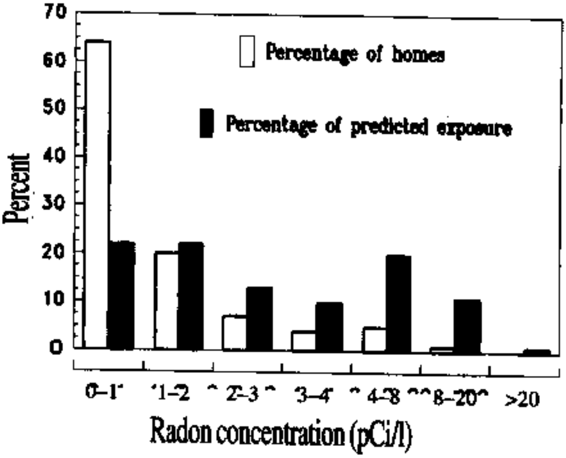


Fig. 5.4 Distribution of homes and total exposure at selected radon levels for all homes (*Source*: EPA, 1992c)

es above 4 pCi/l were identified and remediated to 4 pCi/l, only a third or less of the risk would be addressed.[4] This basic realization has been obscured by the state/EPA radon surveys, designed to screen for hot houses, hot clusters, hot regions, and hot states, discussed further in chapter 6. This concern over hot houses reflects their high individual risk, but ignores the important policy implication (i.e., that the overall aggregate risk from hot houses is small). Furthermore, very hot houses (over 100 pCi/l annual average) are even rarer. Nero and colleagues (1990) estimate that perhaps one in twenty thousand homes in the United States, or a total of four thousand homes, may exceed 100 pCi/l. Beyond representing a small portion of the overall risk, there is difficulty in finding these extreme buildings, discussed later in this chapter.

The Myth of the Reading Prong

Since the Watras experience, federal and state radon policy has rested on the myth of the Reading Prong, the assumption that radon incidence is geographically and geologically bounded. Indeed, certain regions, such as the Reading Prong, are high in radon. However, given the broader geographic distribution of radon, it makes little sense to speak of high-radon versus low-radon regions. Radon is not so readily bounded. This conclusion can be drawn both because high levels of radon are found in significant amounts outside of such hot regions and because low-radon houses and areas exist within these regions. In fact, evidence for rebutting the myth of the Reading Prong was present in the very circumstances that gave birth to this myth.

The Puzzling Geology of Colebrookdale Township, Pennsylvania

The area around the Watras house in Colebrookdale Township, Pennsylvania, became an early "laboratory" for geologist Linda Gunderson and her colleagues from the United States Geological Survey as they sought to discover what geological conditions might account for such extremely elevated indoor radon levels. Colebrookdale was puzzling because it combined a cluster of extremely hot houses with houses with low radon levels. Gunderson discovered that the area around Boyertown consists of the three different types of underlying rock and soil shown in table 5.1. By matching soil and indoor radon data to these bedrock microregions, the Colebrookdale mystery was explained.

Table 5.1 Rock and Soil Types and Characteristics in the Boyertown (Colebrookdale Township) Area

Rock and Soil type	Maximum Uranium Concentration	Soil Permability
hornblende gneiss	less than 5 ppm	low
quartz feldspar and biotite gneiss (QFB)	10–25 ppm	moderate
mylonite	50 ppm	high

Source: Gunderson et al., 1991b.

When we plot indoor radon levels over the local geology of Colebrookdale Township, as shown in figure 5.5, we discover that the hot cluster was located at the boundary of two different types of gneiss bedrock, quartz-feldspar/biotite and hornblende, separated by a sheared fault zone. The "foliated mylonite" rock within this fault zone was created by pressure, temperature, and ductile shear conditions that altered the microstructure, porosity, permeability, and chemical composition of the surrounding parent rock and redistributed and concentrated its component uranium. As a result, radon concentration, emanation, and permeability were all enhanced. Not only are high amounts of radon generated in the rock, creating a high radon source strength, but the conditions for easy movement are present, allowing extremely high volumes of radon to pass easily to the surface and enter homes built atop the shear zone (Gunderson et al., 1987; Gunderson and Wanty, 1991; Agard and Gunderson, 1991).

Comparable local conditions have been documented around the United States (see Gunderson and Wanty, 1991). While the geological details may differ, the outcome is much the same. Smaller areas of very high radon potential can be imbedded even in regions of relatively average potential. And, importantly, knowledge of the higher than average radon potential of the Reading Prong