## Radon Testing Disparities: Minnesota

Radon and Radon Testing in the State of Minnesota

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### 1 Introduction

The U.S. Environmental Protection Agency (EPA) estimates that radon exposure is responsible for 21,000 lung cancer deaths each year in the United States (U.S.) [1]. Radon is the leading cause of lung cancer among individuals who have never smoked and the second leading cause of lung cancer overall in the U.S.

The EPA recommends that all homes be tested for radon and mitigated if the radon concentration is 4 picocuries per liter (pCi/L) or higher. Because protracted radon exposure at concentrations less than 4 pCi/L also poses a risk, the EPA also recommends homeowners consider reducing the radon concentrations for homes measuring between 2 pCi/L and 4 pCi/L [2].

Even though some counties exhibit relatively lower radon averages, it is important that all homes be tested since radon concentrations greatly exceeding the EPA's Radon Action Level have been reported in homes and other buildings in many of these "lower" radon counties.

Indoor radon concentrations vary substantially, both within and between counties, in the U.S. The primary cause of the geographic variation in radon is the geologic radon source strength and soil permeability within a geographic area. Some of the secondary causes of geographic radon variation include differences in home

construction, HVAC type, and occupant behavior (e.g., opening windows) [3]. The rate of residential radon testing also varies widely within and between U.S. counties.

This report is one of a set of state-by-state reports that attempts to provide a basic summary of U.S. publicly available radon testing data, provided by the Centers for Disease Control and Prevention (CDC), to illustrate the testing rate in U.S. counties, the average radon concentration reported, and a combined "Radon Testing Disparity" measure developed by the American Lung Association to highlight areas with both higher radon concentrations and lower testing rates within each state.

There is clearly no singular way to prioritize these multifaceted aspects of radon testing, but we hope the Testing Disparity presented here provides a meaningful summary for policymakers, and the public alike. In addition, publicly available data on radon testing are often sparse, with some areas reporting few to no radon tests during the period over which data are available. To provide meaningful maps, we apply a smoothing model to borrow strength from neighboring counties within the same state. As radon levels can vary widely at finer geographic scales, we denote counties which had no data, or those which had fewer than 10 tests during the data availability period.

The study period for Minnesota was from 2008-2017.

## 2 Using This Document

Public health professionals interested primarily in the large scale distribution of radon levels in their state should focus on Figure 1. Those interested in testing rates should focus on Figure 2. For a combined measure that highlights relatively fewer tests and also higher radon levels, Figure 3 gives a summary. In all cases, caution is required in interpreting the results due to the issues highlighted in Section 5.

### 3 Quick Facts: Radon in Minnesota

- Among counties with at least 10 reported tests, the highest average radon concentration was observed in Lincoln County with an estimated mean radon level of 10.3 pCi/L.
- Among counties with at least 10 reported tests, the lowest mean radon level was observed in Lake County with an estimated mean radon level of 2.5 pCi/L.
- Testing rates per housing unit vary, with the lowest estimated rates in Lake of the Woods County (2 per 1k housing units), and the highest estimated rates in Brown County (125 per 1k housing units).
- The county with the most tests is Hennepin County with 35,213 premitigation tests and an estimated mean radon level of 4 pCi/L.
- Minnesota has an estimated 2,477,753 total housing units with 130,912 tests during the study period. Overall, Minnesota has an estimated mean radon level of 4.7 pCi/L.

## 4 Mapping Radon in Minnesota

Radon levels vary geographically, both at large scales (state to state, county to county) and at even finer scales. In Figure 1 we see an illustration of this distribution for Minnesota. Specifically, this figure shows the mean radon level across all the tests reported during the period for which data are available. This map shows a general, overall level of risk in an area without specifically considering the housing environment. The counties that are marked with a circle have less than 10 total radon tests.

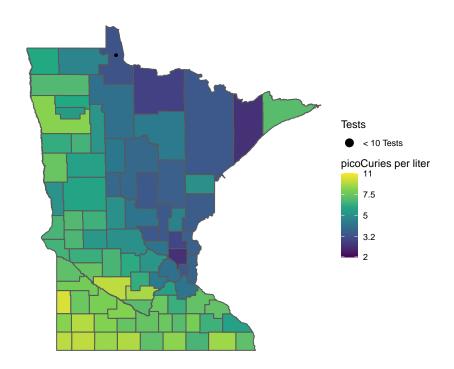


Figure 1: Smoothed mean radon level by county over all reported tests.

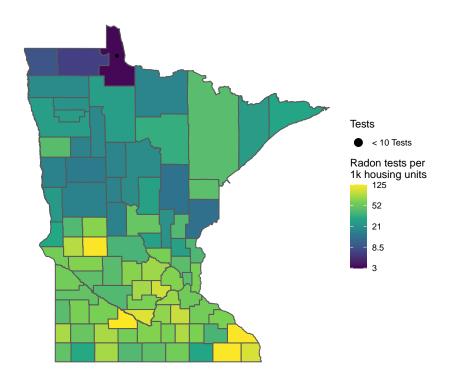
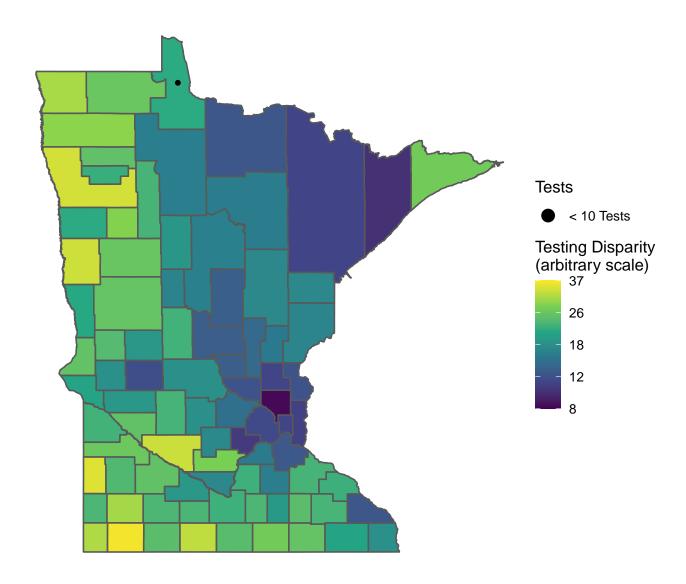


Figure 2: Smoothed number of radon tests per 1,000 housing units by county.

In addition to radon levels, radon testing rates vary widely throughout the state. Figure 2 shows an estimated testing rate, comparing the number of reported tests to the number of housing units estimated by the U.S. Census. Given the variety of radon testing approaches and the complexity of determining what proportion of radon tests end up being reported to the CDC database, the absolute units here are of less interest and relevance than the relative rates between counties.



All homes and buildings should be tested for radon. The counties shown on the high end of the Testing Disparity scale call for increased attention, but radon testing in all counties remains an ongoing need. Indoor radon levels vary widely, and elevated concentrations have been reported in many counties with low radon averages.

Figure 3: Smoothed Testing Disparity metric by county.

Finally, Figure 3 shows a combined measure - a more nuanced view than considering mean radon level and radon testing rates separately - that attempts to capture which counties might be likelier to benefit from increased attention to radon testing. This Testing Disparity metric is designed to show higher values for areas with high radon concentration, as well as low testing rates. The highest values are observed in areas with both - indicating that more tests are especially needed. It is also important to consider the radon concentrations and testing rates separately, but the Testing Disparity metric offers a quick

visual way to highlight the areas where more attention to testing might be the most beneficial.

#### 5 Technical Notes

Data on radon tests and mean concentrations was obtained from the CDC National Public Health Environmental Tracking Network via the Tracking API [4, 5]. Census data for housin-unit adjusted comparisons were obtained from the U.S. census via the tidycensus package for R version 4.1.2 [6, 7]. Full code and tabular versions of the data are available at GitHub.

Radon data were collected from 2008-2017 for the measures: Mean premitigation radon level in tested buildings and Number of pre-mitigation radon tests by radon level over 10 years. Data was accessed on 2022-07-29.

In general, data used were those as reported by testing laboratories voluntarily participating in the CDC's radon data collection and mapping effort. Where laboratory data were unavailable, data as reported by states to CDC were used for this analysis.

To deal with sparsity, smoothing was applied to Figures 1, 2, and 3, so these maps illustrate large, regional variation in testing rates and radon levels. The model used for smoothing is a Bayesian Intrinsic Conditional Autoregressive (ICAR) spatial model, implemented with Nimble [8].

The selected Testing Disparity metric is  $R * log_{10}(\frac{H}{N})$  where R is the mean radon level, H is the number of housing units, and N is the number of Radon tests, adjusted to reflect the expected number of tests per 10 year period. The lower the testing rate,  $\frac{N}{H}$ , and the higher the mean radon level, the higher this metric will be, suggesting that increased attention to testing could be valuable in such counties. However, radon testing in other counties, even those at the bottom of the scale, remains much in need. The values shown in Figure 3 are scaled so that the lowest value of the Testing Disparity metric in the U.S. is 0 and the largest value is 100, with values above 25% of the national maximum capped at 100 to prevent outliers from dominating the scale. This approach can help highlight areas which may benefit more from attention to testing than others, but there are substantial limitations, and policy should not be based on this document in isolation. In addition to the presence of unaccounted-for smallscale variability within states, comparisons between states may be affected by differential data availability. In addition, the Testing Disparity metric presented here describes one of many possible prioritization schemes for trading off radon levels and testing rates. Alternative approaches may strike a different balance between these two measures, or prioritize high or low population areas. Direct interpretation of the units presented here is also limited, and is intended to support relative comparisons within each respective state.

# 6 State Rankings

Table 1: State-level summary data. Note: Hawaii and Mississippi are excluded due to lack of data.

South Dakota	tate	Rank	Weighted Average Smoothed Testing Disparity	Estimated Mean Radon Level	Housing Units	Radon Tests (10 years)	Radon Tests per 1,000 Housing Units
Montana	outh Dalzota	1	9 - 0		401.869	( 0 )	15.6
North Dakota   3   12.5   6.9   380.173   6.607							19.0
Ohio         4         11.5         6.5         5.232.869         98.840           Pennsylvania         5         10.8         7.3         5.732.628         203.045           Maine         6         10.4         5.6         750.939         11,825           Kentucky         7         10.2         5.4         2.006.358         28.793           Indiana         8         9.9         5.0         2.921.032         43,148           Alaska         9         9.5         3.3         319.854         830           New Mexico         10         9.3         3.5         948.473         3.721           Idaho         11         9.3         5.4         751.105         12.961           Wisconsin         12         9.2         5.7         2,725.296         68.104           New Hampshire         13         9.1         5.5         642.315         15.608           Texas         14         9.0         2.8         11,283.33         4.615           Wyoming         15         9.0         5.6         280.291         7,638           Utah         16         8.8         5.3         1,133.521         28.342           <							17.4
Pennsylvania							18.9
Maine         6         10.4         5.6         750,939         11,825           Kentucky         7         10.2         5.4         2,006,358         28,793           Indiana         8         9.9         5.0         2,921,032         43,148           Alaska         9         9.5         3.3         319,854         830           New Mexico         10         9.3         3.5         948,473         3,721           Idaho         11         9.3         5.4         751,105         12,961           Wisconsin         12         9.2         5.7         2,725,296         68,104           New Hampshire         13         9.1         5.5         642,315         15,608           Texas         14         9.0         2.8         11,283,353         4,615           Wyoning         15         9.0         5.6         280,291         7,638           Utah         16         8.8         5.3         1,133,521         2,8342           Iowa         17         8.6         7.1         1,418,626         95,245           Colorado         18         8.4         5.8         2,464,164         96,367           V	· · ·				5,232,009	,	35.4
Rentucky							15.7
Indiana							13.7
Alaska   9   9.5   3.3   319.854   830     New Mexico   10   9.3   3.5   948.473   3.721     Idaho   11   9.3   5.4   751.105   12.961     Wisconsin   12   9.2   5.7   2.725.296   68.104     New Hampshire   13   9.1   5.5   642.315   15.608     Texas   14   9.0   2.8   11.283.353   4.615     Wyoming   15   9.0   5.6   280.291   7.638     Utah   16   8.8   5.3   1.133.521   28.342     Lowa   17   8.6   6.7.1   1.418.626   95.245     Colorado   18   8.4   5.8   2.464.164   96.367     West Virginia   19   8.3   3.9   894.956   10.061     Tennessee   20   8.0   3.9   3.028.213   31.066     Nebraska   21   7.8   6.0   851.227   42.782     Arkansas   22   7.8   2.4   1.389.129   668     Missouri   23   7.4   4.0   2.819.383   58.525     Illinois   24   7.2   4.1   5.388.066   108.909     Oklahoma   25   7.0   2.1   1.749.464   814     Arizona   26   7.0   2.4   3.075.981   3.589     Virginia   27   6.9   3.4   3.562.143   53.199     Connecticut   28   6.8   3.8   1.524.992   25.572     Alabama   30   5.9   2.3   2.248.47   12.569     Georgia   31   5.9   2.6   4.378.391   30.152     Maryland   35   5.7   2.6   8.404.381   97.145     New York   34   5.7   2.6   8.404.381   97.145     New York   34   5.7   2.6   8.404.381   97.145     New York   34   5.7   2.6   8.404.381   97.145     New York   38   5.7   3.2   2.470.316   47.941     Florida   36   5.6   2.8   1.808.465   23.951     Vermont   38   5.1   3.1   4.629.611   114.407     Nevada   40   4.6   2.1   1.285.684   10.930     District of Columbia   41   4.1   1.9   322.793   2.126     North Carolina   42   4.1   2.2   4.47.943   73.139							
New Mexico         10         9.3         3.5         948,473         3,721           Idaho         11         9.3         5.4         751,105         12,961           Wisconsin         12         9.2         5.7         2,725,296         68,104           New Hampshire         13         9.1         5.5         642,315         15,608           Texas         14         9.0         2.8         11,283,353         4,615           Wyoming         15         9.0         5.6         280,291         7,638           Utah         16         8.8         5.3         1,133,521         28,342           Iowa         17         8.6         7.1         1,418,626         95,245           Colorado         18         8.4         5.8         2,464,164         96,367           West Virginia         19         8.3         3.9         894,956         10,061           Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668							14.8 2.6
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Wisconsin         12         9.2         5.7         2,725,296         68,104           New Hampshire         13         9.1         5.5         642,315         15,608           Texas         14         9.0         2.8         11,283,353         4,615           Wyoming         15         9.0         5.6         280,291         7,638           Utah         16         8.8         5.3         1,133,521         28,342           Iowa         17         8.6         7.1         1,418,626         95,245           Colorado         18         8.4         5.8         2,464,164         96,367           West Virginia         19         8.3         3.9         894,956         10,061           Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909						,	17.3
New Hampshire         13         9.1         5.5         642,315         15,608           Texas         14         9.0         2.8         11,283,353         4,615           Wyoming         15         9.0         5.6         280,291         7,638           Utah         16         8.8         5.3         1,133,521         28,342           Iowa         17         8.6         7.1         1,418,626         95,245           Colorado         18         8.4         5.8         2,464,164         96,367           West Virginia         19         8.3         3.9         894,956         10,061           Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         55,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814      <			l .			,	
Texas         14         9.0         2.8         11,283,353         4,615           Wyoming         15         9.0         5.6         280,291         7,638           Utah         16         8.8         5.3         1,133,521         28,342           Lowa         17         8.6         7.1         1,448,626         95,245           Colorado         18         8.4         5.8         2,464,164         96,367           West Virginia         19         8.3         3.9         894,956         10,061           Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,333         55,255           Illinois         24         7.2         4.1         5,386,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589						,	25.0
Wyoming         15         9.0         5.6         280,291         7,638           Utah         16         8.8         5.3         1,133,521         28,342           Iowa         17         8.6         7.1         1,418,626         95,245           Colorado         18         8.4         5.8         2,464,164         96,367           West Virginia         19         8.3         3.9         894,956         10,061           Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.1         1,749,464         814						,	24.3
Utah         16         8.8         5.3         1,133,521         28,342           Iowa         17         8.6         7.1         1,418,626         95,245           Colorado         18         8.4         5.8         2,464,164         96,367           West Virginia         19         8.3         3.9         894,956         10,061           Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572							0.4
Iowa         17         8.6         7.1         1,418,626         95,245           Colorado         18         8.4         5.8         2,464,164         96,367           West Virginia         19         8.3         3.9         894,956         10,061           Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912							27.3
Colorado         18         8.4         5.8         2,464,164         96,367           West Virginia         19         8.3         3.9         894,956         10,061           Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,447,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569							25.0
West Virginia         19         8.3         3.9         894,956         10,061           Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152					, ,		67.1
Tennessee         20         8.0         3.9         3,028,213         31,066           Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201							39.1
Nebraska         21         7.8         6.0         851,227         42,782           Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415							11.2
Arkansas         22         7.8         2.4         1,389,129         668           Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145							10.3
Missouri         23         7.4         4.0         2,819,383         58,525           Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>50.3</td>							50.3
Illinois         24         7.2         4.1         5,388,066         108,909           Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794							0.5
Oklahoma         25         7.0         2.1         1,749,464         814           Arizona         26         7.0         2.4         3,075,981         3,589           Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951							20.8
Arizona       26       7.0       2.4       3,075,981       3,589         Virginia       27       6.9       3.4       3,562,143       53,199         Connecticut       28       6.8       3.8       1,524,992       25,572         Minnesota       29       6.1       4.7       2,477,753       130,912         Alabama       30       5.9       2.3       2,284,847       12,569         Georgia       31       5.9       2.6       4,378,391       30,152         Washington       32       5.8       2.2       3,195,004       8,201         California       33       5.7       1.8       14,366,336       9,415         New York       34       5.7       2.6       8,404,381       97,145         Maryland       35       5.7       3.2       2,470,316       47,941         Florida       36       5.6       2.1       9,673,682       53,794         Oregon       37       5.6       2.8       1,808,465       23,951         Vermont       38       5.4       3.4       339,439       10,600         Michigan       39       5.1       3.1       4,629,611       114,407			l .		, ,	,	20.2
Virginia         27         6.9         3.4         3,562,143         53,199           Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407							0.5
Connecticut         28         6.8         3.8         1,524,992         25,572           Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930							1.2
Minnesota         29         6.1         4.7         2,477,753         130,912           Alabama         30         5.9         2.3         2,284,847         12,569           Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126<							14.9
Alabama       30       5.9       2.3       2,284,847       12,569         Georgia       31       5.9       2.6       4,378,391       30,152         Washington       32       5.8       2.2       3,195,004       8,201         California       33       5.7       1.8       14,366,336       9,415         New York       34       5.7       2.6       8,404,381       97,145         Maryland       35       5.7       3.2       2,470,316       47,941         Florida       36       5.6       2.1       9,673,682       53,794         Oregon       37       5.6       2.8       1,808,465       23,951         Vermont       38       5.4       3.4       339,439       10,600         Michigan       39       5.1       3.1       4,629,611       114,407         Nevada       40       4.6       2.1       1,285,684       10,930         District of Columbia       41       4.1       1.9       322,793       2,126         North Carolina       42       4.1       2.2       4,747,943       73,139							16.8
Georgia         31         5.9         2.6         4,378,391         30,152           Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139							52.8
Washington         32         5.8         2.2         3,195,004         8,201           California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139							5.5
California         33         5.7         1.8         14,366,336         9,415           New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139						,	6.9
New York         34         5.7         2.6         8,404,381         97,145           Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139							2.6
Maryland         35         5.7         3.2         2,470,316         47,941           Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139							0.7
Florida         36         5.6         2.1         9,673,682         53,794           Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139							11.6
Oregon         37         5.6         2.8         1,808,465         23,951           Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139							19.4
Vermont         38         5.4         3.4         339,439         10,600           Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139							5.6
Michigan         39         5.1         3.1         4,629,611         114,407           Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139			l .				13.2
Nevada         40         4.6         2.1         1,285,684         10,930           District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139							31.2
District of Columbia         41         4.1         1.9         322,793         2,126           North Carolina         42         4.1         2.2         4,747,943         73,139			5.1			,	24.7
North Carolina 42 4.1 2.2 4,747,943 73,139		40			, ,		8.5
	District of Columbia	41	4.1	1.9	322,793	2,126	6.6
D 1 49 49 49 49 49 49 49 49 49 49 49 49 49						,	15.4
	Delaware	43	3.8	2.2	443,781	12,214	27.5
Kansas 44 3.7 4.1 1,288,401 88,584							68.8
Louisiana 45 3.7 1.0 2,089,777 499							0.2
Rhode Island 46 3.6 3.4 470,168 37,874							80.6
Massachusetts 47 3.6 3.2 2,928,732 234,152							79.9
South Carolina 48 3.5 1.7 2,351,286 26,481		48		1.7		26,481	11.3
New Jersey 49 1.2 1.8 3,641,812 1,234,094	lew Jersey	49	1.2	1.8	3,641,812	1,234,094	338.9

# 7 Appendix: Supplemental Figures

This section contains additional maps which may be of interest, including raw (non-smoothed) maps of radon levels, estimated number of housing units, and testing rates. For mapping of raw data, counties with no data during the study period are shaded in gray.

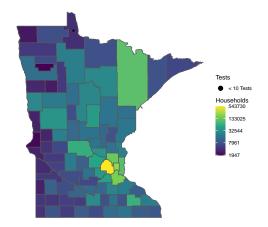


Figure 4: Raw Number of housing units by county.

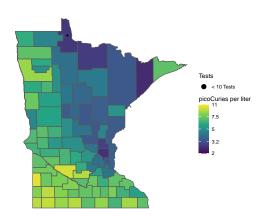


Figure 6: Raw Mean radon level by county.

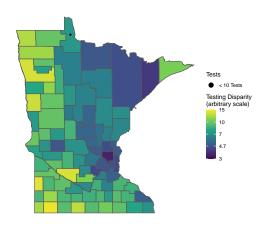


Figure 8: Raw Testing Disparity metric (unscaled) by county.\*

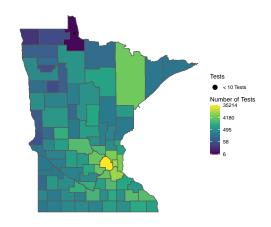


Figure 5: Raw number of radon tests by county.

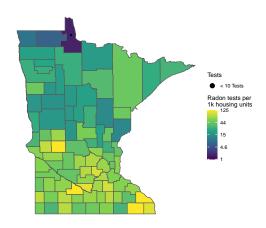


Figure 7: Raw number of radon tests per 100,000 housing units by county.

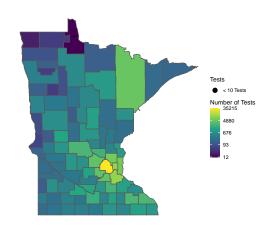


Figure 9: Smoothed number of Radon tests by county.

<sup>\*</sup> All homes and buildings should be tested for radon.

## 8 Disclaimer

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