

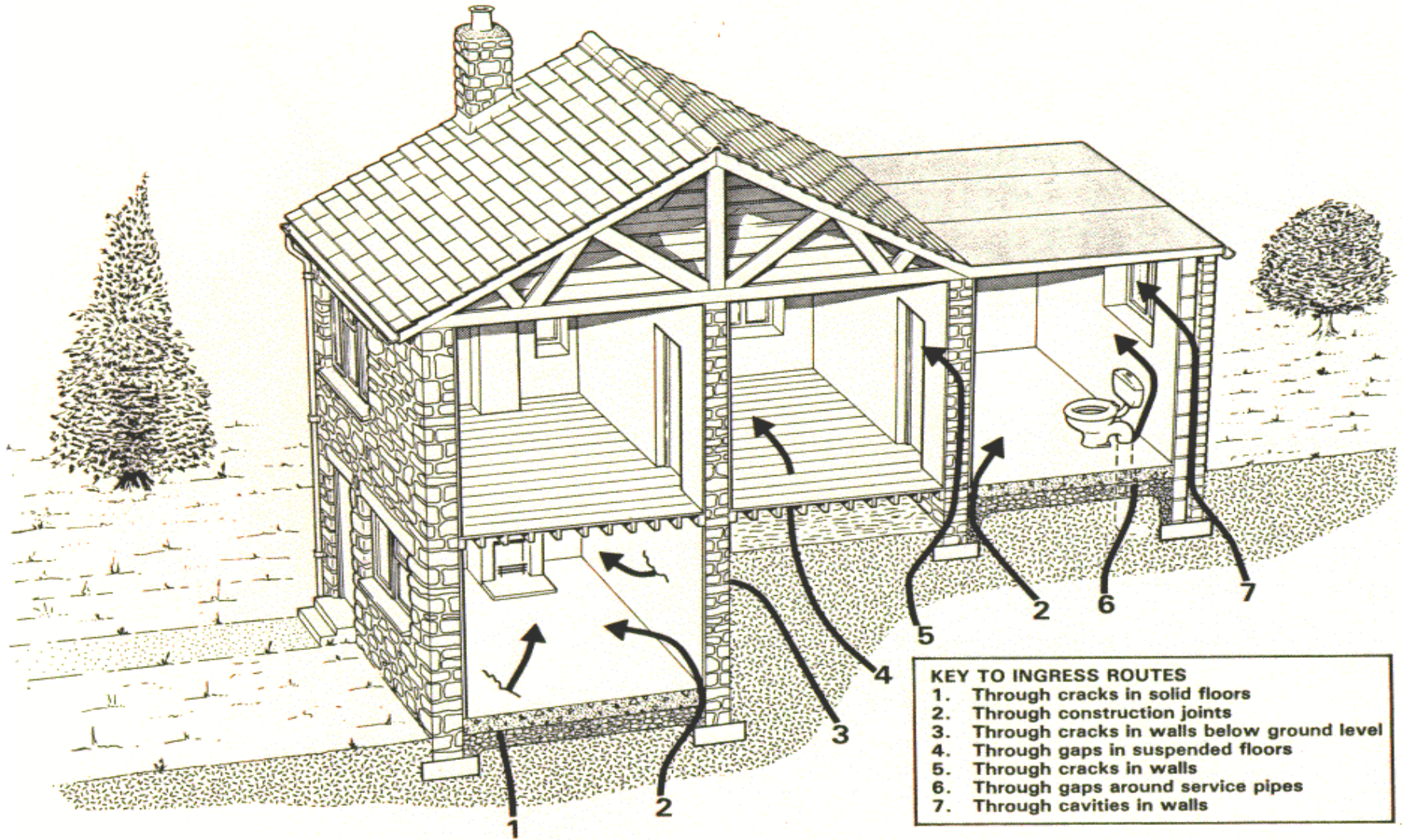
# **Residential Radon, Smoking and Lung Cancer**

**Sarah C Darby  
University of Oxford**

# Plan of talk

- **Most radon exposure occurs indoors in ordinary homes**
- **Lung cancer risk increases with indoor radon concentration**
- **Smokers have bigger risks than lifelong non-smokers**
- **Most radon-related cancers occur after moderate exposures**
- **Most radon-related cancers occur in smokers/ex-smokers**
- **Measuring radon does not reduce radon-related lung cancer**
- **Radon prevention in new homes is cost-effective**
- **Radon remediation in existing homes rarely effective**

# Routes by Which Radon Enters a Dwelling



**Average concentration of radon gas in UK homes: 21 Bq/m<sup>3</sup>**

# Plan of talk

- **Most radon exposure occurs indoors in ordinary homes**
- **Lung cancer risk increases with indoor radon concentration**
- **Smokers have bigger risks than lifelong non-smokers**
- **Most radon-related cancers occur after moderate exposures**
- **Most radon-related cancers occur in smokers/ex-smokers**
- **Measuring radon does not reduce radon-related lung cancer**
- **Radon prevention in new homes is cost-effective**
- **Radon remediation in existing homes rarely effective**

# **Radon in Homes and Lung Cancer Risk: Collaborative Analysis of Individual Data from 13 European Case-Control Studies**

**Darby, D Hill, A Auvinen, JM Barros-Dios, H Baysson,  
F Bochicchio, H Deo, R Falk, F Forastiere, S Farchi,  
A Figueiras, M Hakama, I Heid, N Hunter, L Kreienbrock,  
M Kreuzer, F Lagarde, I Mäkeläinen, C Muirhead,  
W Oberaigner, G Pershagen, A Ruano-Ravina,  
E Ruosteenoja, A Schaffrath Rosario, M Tirmarche,  
L Tomášek, E Whitley, HE Wichmann, R Doll**

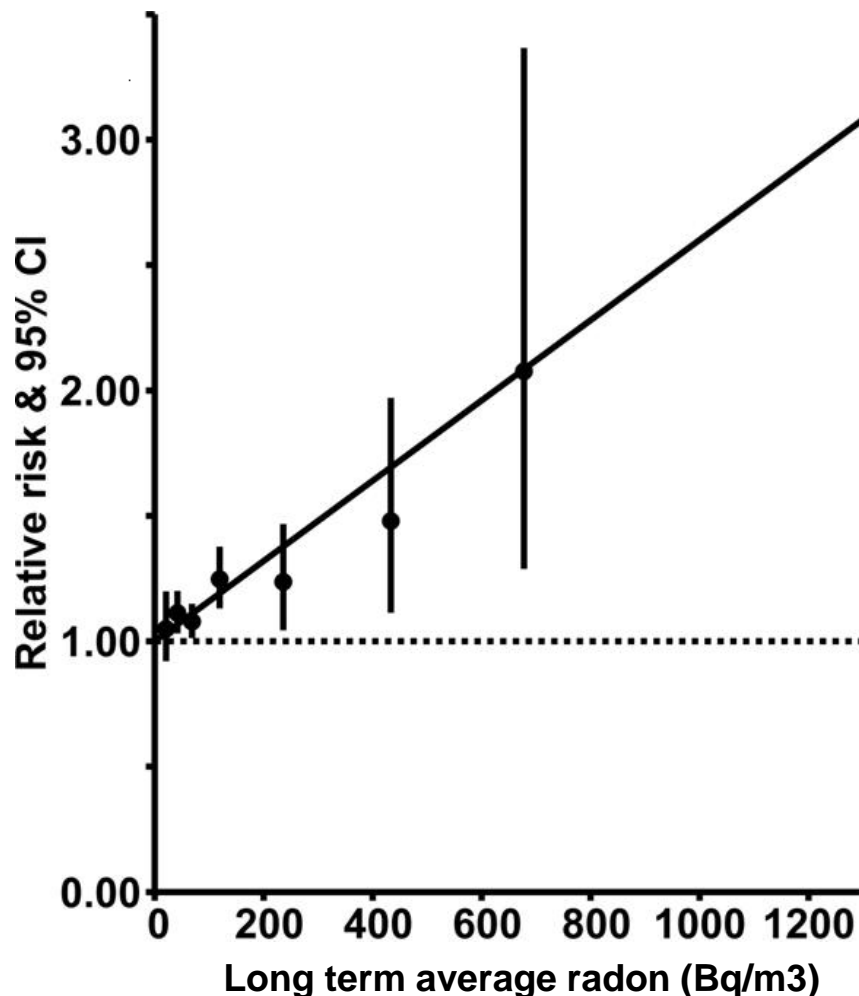
*Br Med J 2005;330:223-7*

*& Scandinavian Journal of Work Environment and Health 2006, Supplement 1*

**Dedicated to Olav Axelson (1937-2004)**

# Relative risk of lung cancer *versus* radon

(with stratification for study, region, age, sex, & 20 categories of smoking, and adjustment for yr-to-yr variation in radon concentrations)



Lung cancer risk  
increases by  
16% per 100 Bq/m<sup>3</sup>

p=0.006

# Estimates of the risk of lung cancer from radon in different data sets

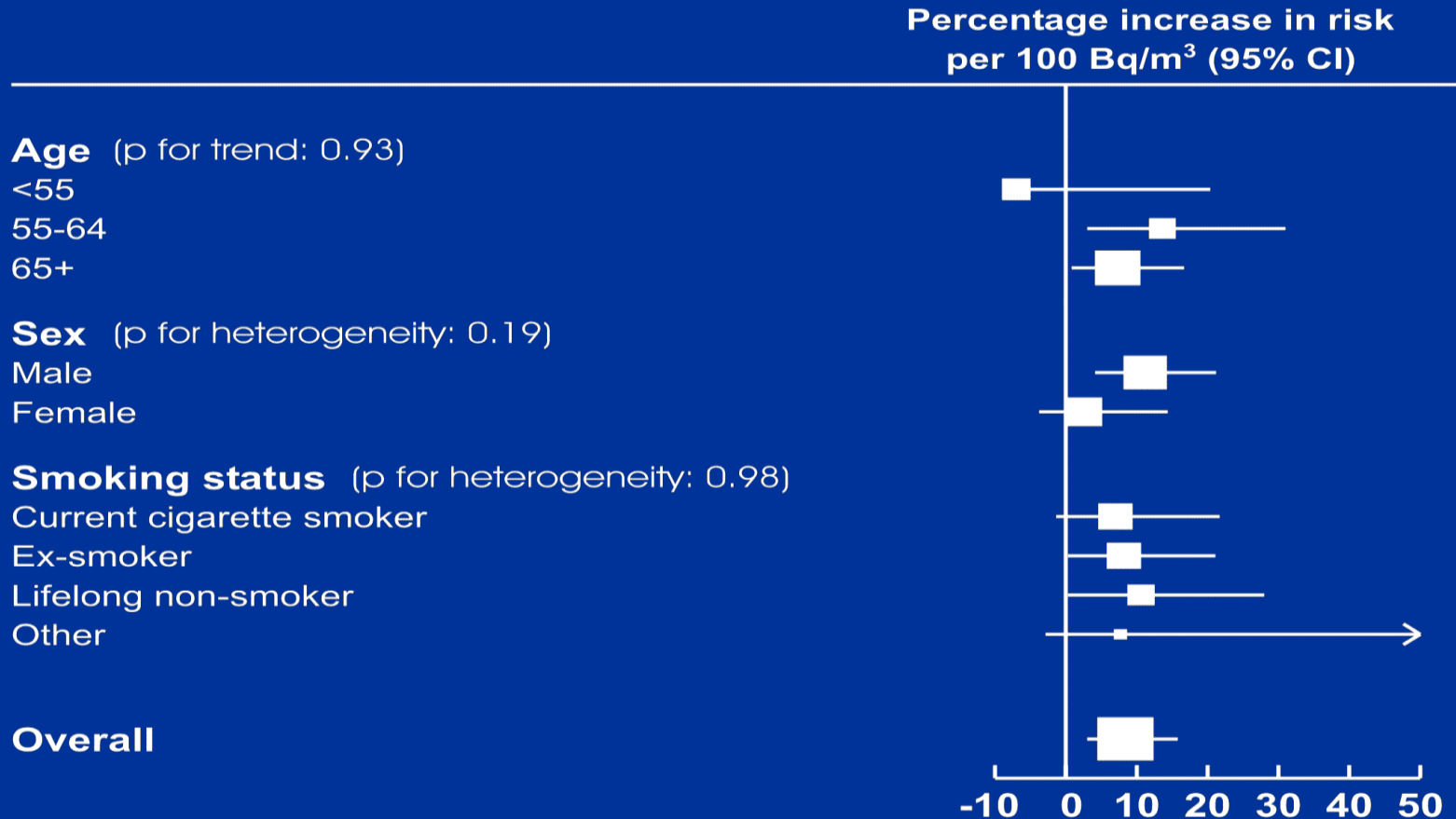
<b>Data</b>	<b>No of lung cancers</b>	<b>% increase per 100 Bq/m<sup>3</sup></b>
<b>European indoor</b>	<b>7148</b> (13 studies)	<b>16%</b> (95% CI 5,31)
<b>North American indoor</b>	<b>3662</b> (7 studies)	<b>11%</b> (95% CI 0,28)
<b>Chinese indoor</b>	<b>1050</b> (2 studies)	<b>13%</b> (95% CI 0,36)
<b>Miners</b>	<b>2787</b> (11 studies)	<b>19%</b>

# Plan of talk

- **Most radon exposure occurs indoors in ordinary homes**
- **Lung cancer risk increases with indoor radon concentration**
- **Smokers have bigger risks than lifelong non-smokers**
- **Most radon-related cancers occur after moderate exposures**
- **Most radon-related cancers occur in smokers/ex-smokers**
- **Measuring radon does not reduce radon-related lung cancer**
- **Radon prevention in new homes is cost-effective**
- **Radon remediation in existing homes rarely effective**



# Variation in risk estimate by age, sex, smoking



## **Risks from smoking (from European pooling study)**

---

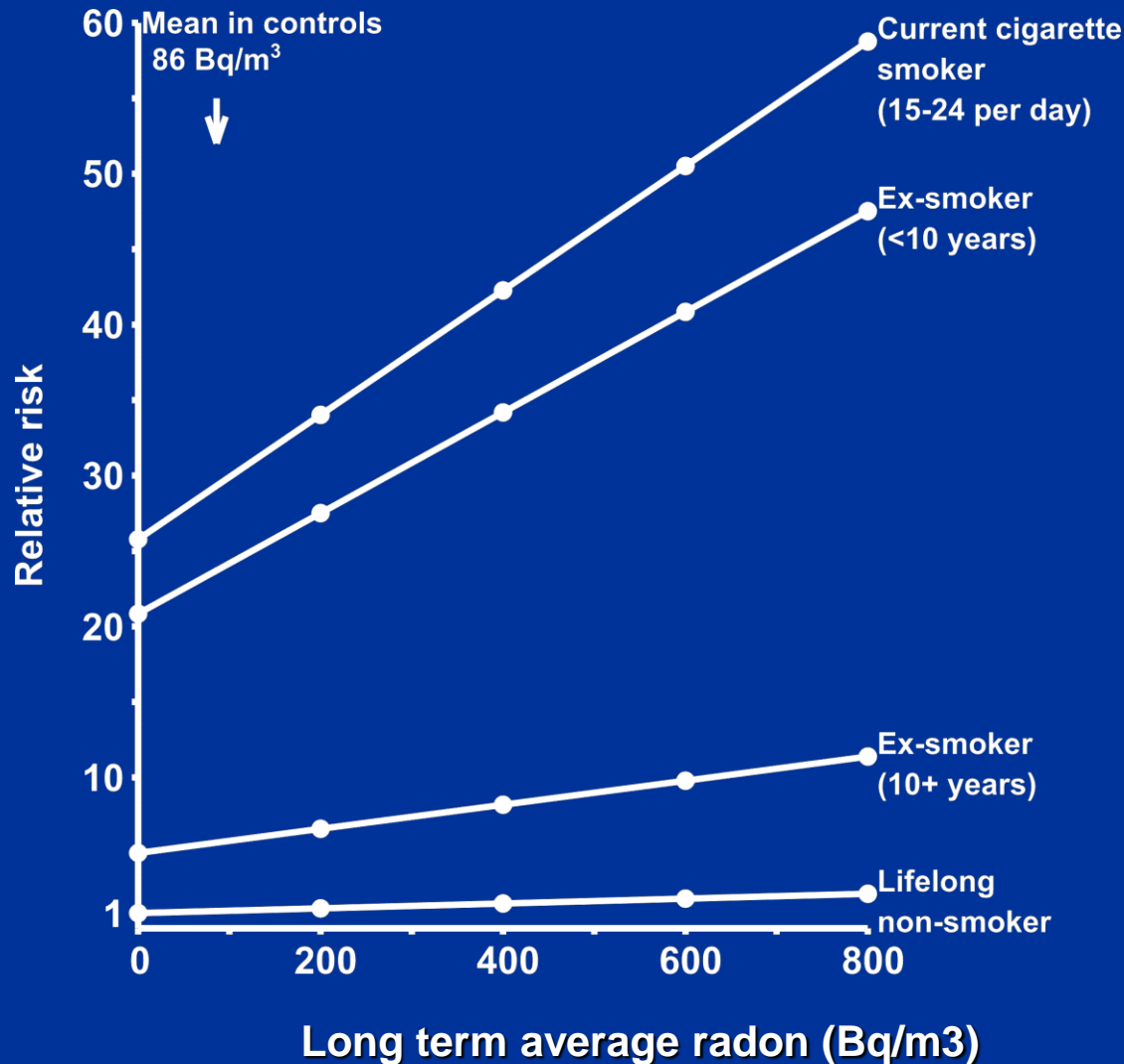
<b>Smoking status</b>	<b>Relative risk (males)*</b>
<b>Lifelong non-smoker</b>	<b>1**</b>
<b>Current cigarette (&lt;15 per day)</b>	<b>13</b>
<b>Current cigarette (15-24 per day)</b>	<b>26</b>
<b>Current cigarette (25+ per day)</b>	<b>40</b>
<b>Ex-smoker (&lt;10 years)</b>	<b>21</b>
<b>Ex-smoker (10+ years)</b>	<b>5</b>
<b>Other</b>	<b>8</b>

---

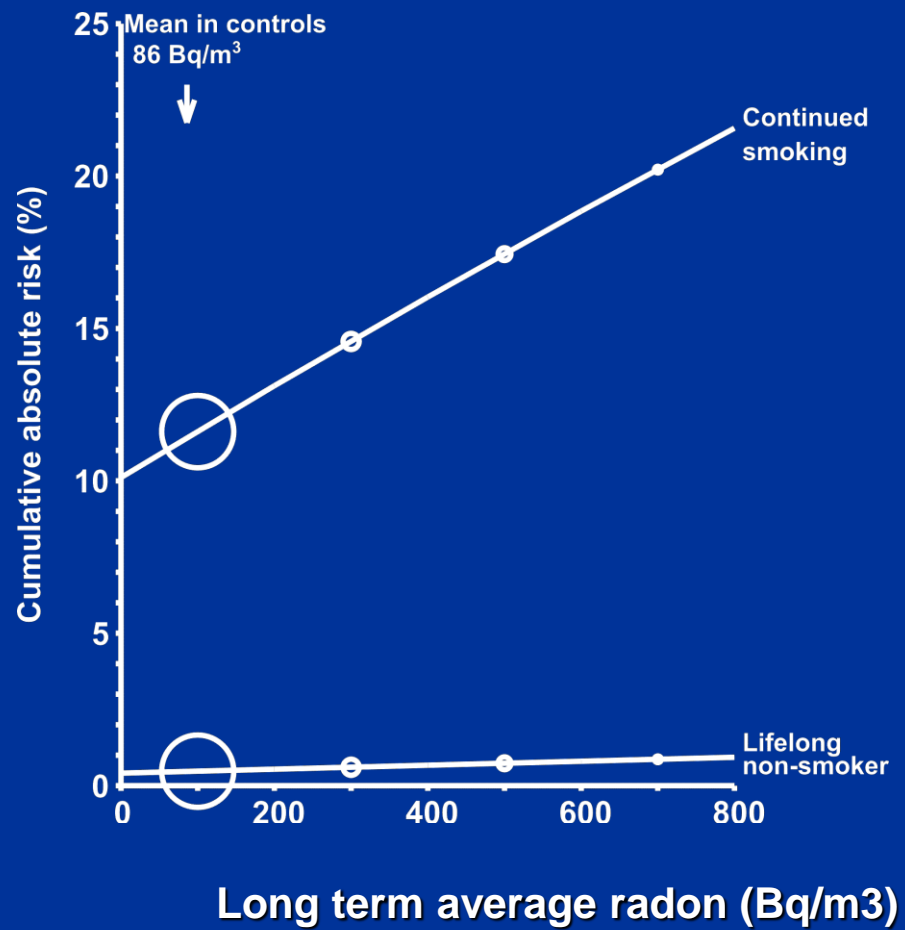
**\*Estimated after stratification by study, age, sex and region**

**\*\*Baseline category**

# Risk of lung cancer relative to lifelong non-smokers



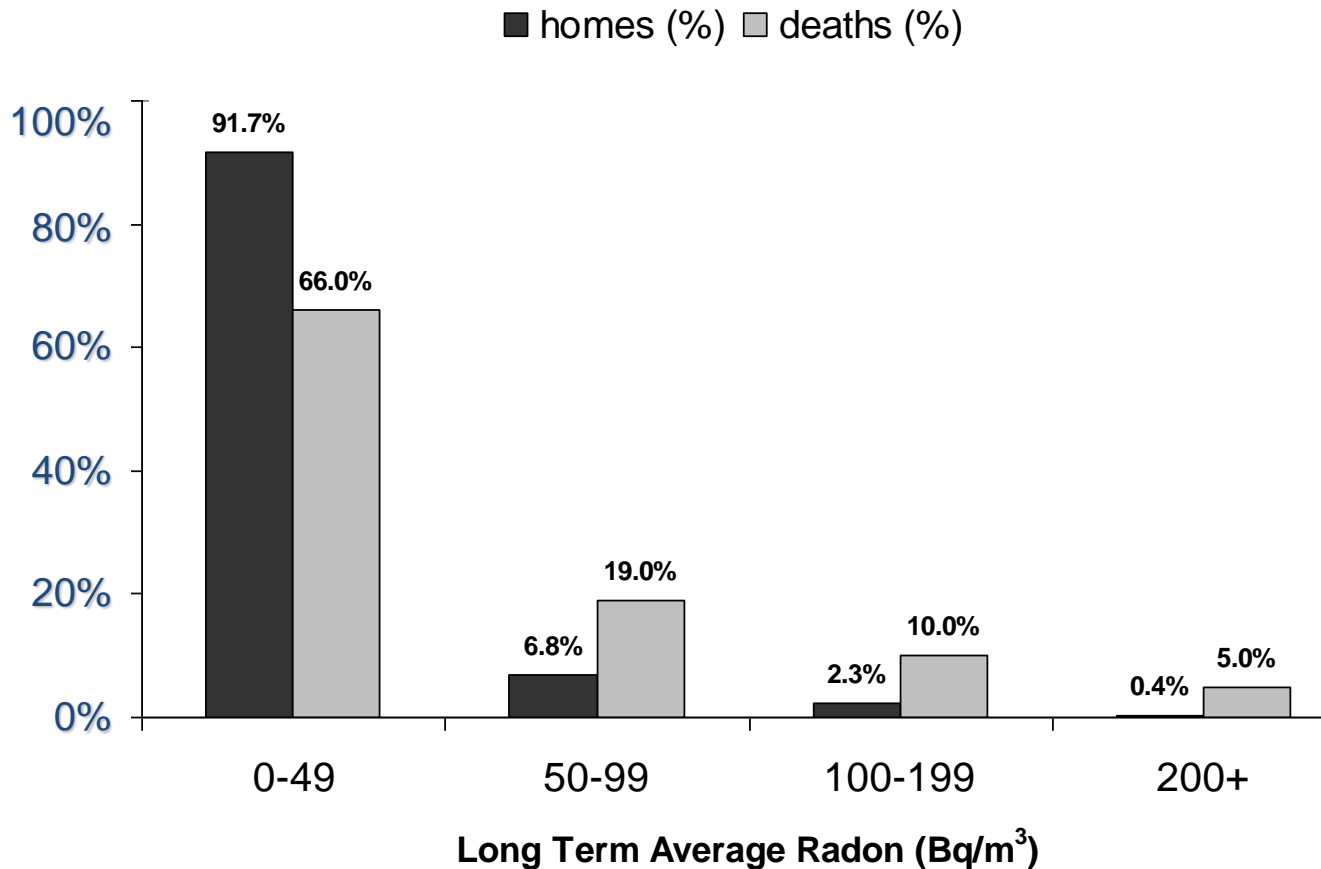
# Cumulative absolute risk of lung cancer death by age 75 (from European pooling study plus ACS lung cancer rates in never smokers)



# Plan of talk

- **Most radon exposure occurs indoors in ordinary homes**
- **Lung cancer risk increases with indoor radon concentration**
- **Smokers have bigger risks than lifelong non-smokers**
- **Most radon-related cancers occur after moderate exposures**
- **Most radon-related cancers occur in smokers/ex-smokers**
- **Measuring radon does not reduce radon-related lung cancer**
- **Radon prevention in new homes is cost-effective**
- **Radon remediation in existing homes rarely effective**

# Numbers of radon-induced lung cancer deaths each year by long-term average radon concentration at home



*Mean radon concentration in all UK homes: 21 Bq/m<sup>3</sup>*

# Plan of talk

- **Most radon exposure occurs indoors in ordinary homes**
- **Lung cancer risk increases with indoor radon concentration**
- **Smokers have bigger risks than lifelong non-smokers**
- **Most radon-related cancers occur after moderate exposures**
- **Most radon-related cancers occur in smokers/ex-smokers**
- **Measuring radon does not reduce radon-related lung cancer**
- **Radon prevention in new homes is cost-effective**
- **Radon remediation in existing homes rarely effective**

## Numbers of lung cancer deaths in the UK each year by cause

Cause	No of lung cancer deaths			
Not caused by active smoking or by residential radon	4664 (13.6%)			
Caused by radon but not by active smoking	157 (0.5%)			
Caused both by active smoking and by radon:				
- in current smokers	532 (1.6%)			
- in ex-smokers	421 (1.2%)			
Caused by active smoking and not by radon	28,376 (83.1%)			
<b>Total UK lung cancer deaths in 2006</b>	<b>34,150 (100.0%)</b>			

***Just over 1000 deaths caused by radon each year, ie 1 in 500 of all deaths***



# Plan of talk

- **Most radon exposure occurs indoors in ordinary homes**
- **Lung cancer risk increases with indoor radon concentration**
- **Smokers have bigger risks than lifelong non-smokers**
- **Most radon-related cancers occur after moderate exposures**
- **Most radon-related cancers occur in smokers/ex-smokers**
- **Measuring radon does not reduce radon-related lung cancer**
- **Radon prevention in new homes is cost-effective**
- **Radon remediation in existing homes rarely effective**

- **Measuring radon does not reduce radon-related lung cancer**
- **Nor does producing radon maps**
- **What is needed is reducing exposure to the whole population in a way that is both effective and cost-effective**

# Plan of talk

- **Most radon exposure occurs indoors in ordinary homes**
- **Lung cancer risk increases with indoor radon concentration**
- **Smokers have bigger risks than lifelong non-smokers**
- **Most radon-related cancers occur after moderate exposures**
- **Most radon-related cancers occur in smokers/ex-smokers**
- **Measuring radon does not reduce radon-related lung cancer**
- **Radon prevention in new homes is cost-effective**
- **Radon remediation in existing homes rarely effective**

## Inputs to cost-effectiveness analysis

---

### **Lung cancer risks pre- and post-preventive action**

Lifetime cumulative lung cancer risk (%) – never/current/ex-smokers

### **Health gain per household**

Lung cancer cases averted

Average life-years gained (per lung cancer case averted)

Average QALYs gained (per lung cancer case averted)

Total QALYs gained (discounted)

### **Resource use and costs per household**

Number of invitations to test & invitation cost

Number of radon tests & radon testing cost

Radon Prevention costs

NHS lung cancer treatment costs averted

Added NHS costs incurred during added life expectancy

Net cost (discounted)

### **Output: Cost-effectiveness**

Cost per Quality Adjusted Life-year (QALY) gained (discounted)

---

**Programmes with cost per QALY gained (discounted) below ~£30k usually accepted by NICE for NHS**

**New homes:** Cost per quality adjusted life year gained (QALY) for basic radon preventive measures (ie membranes) by mean radon concentration in area

Mean radon concentration in area (Bq/m <sup>3</sup> )	% of national housing stock above this value	Cost per QALY (discounted)
90	<1%	£6.6k
<b>52*</b>	<b>5%</b>	<b>£8.0k</b>
40	12%	£8.9k
30	35%	£10.3k
20	67%	£13.1k
<b>Entire country</b>	<b>100%</b>	<b>£11.4k</b>

\*Recent policy requires membrane if mean radon  $\geq 52$  Bq/m<sup>3</sup> (ie 3% of measurements >200)

# Plan of talk

- **Most radon exposure occurs indoors in ordinary homes**
- **Lung cancer risk increases with indoor radon concentration**
- **Smokers have bigger risks than lifelong non-smokers**
- **Most radon-related cancers occur after moderate exposures**
- **Most radon-related cancers occur in smokers/ex-smokers**
- **Measuring radon does not reduce radon-related lung cancer**
- **Radon prevention in new homes is cost-effective**
- **Radon remediation in existing homes is rarely effective**

**Existing homes: Effect on cost per QALY gained (discounted) by Targetted Area and Action Level**

Mean radon concentration in Targetted Area (Bq/m3)	Cost per QALY (discounted)				
	Action Level (Bq/m <sup>3</sup> )*				
	50	100	150	200	400
60	£31.9k	<b>£29.8k</b>	£33.4k	£41.3k	£123.3k
<b>64*</b>	£30.7k	<b>£28.2k</b>	£30.7k	<b>£36.8k*</b>	£101.1k
70	£28.9k	<b>£26.0k</b>	£27.4k	£31.5k	£76.1k
80	£26.6k	<b>£23.5k</b>	£23.7k	£25.9k	£52.5k
90	£24.7k	£21.7k	<b>£21.3k</b>	£22.4k	£39.2k
100	£23.2k	£20.3k	<b>£19.5k</b>	£20.1k	£31.2k

**Minimum value in each row in red.** Line indicates costs <£30k

\*Recent policy targets areas with mean radon  $\geq 64$  Bq/m<sup>3</sup> (ie  $\geq 5\%$  of measurements  $> 200$ ) and has Action Level 200 Bq/m<sup>3</sup>.

# Numbers of lung cancer deaths averted by various radon policies

---

Policy	Total no of lung cancer deaths potentially averted every year
<b>New homes</b>	
*Radon barriers in areas with >3% homes >200 Bq/m <sup>3</sup>	5 after 10 years of policy, increasing by 0.5 each year
†Radon barriers in all new homes	44 after 10 years of policy, increasing by 4.4 each year
<b>Existing homes</b>	
*Targetting areas with >5% of homes >200 Bq/m <sup>3</sup>	0.9 after policy fully implemented
†Most cost-effective choice (ie targetting homes in areas with mean radon at least 60 Bq/m <sup>3</sup> , and recommending remediation at 100 Bq/m <sup>3</sup> or higher)	10.4 after policy fully implemented

---

\*As in recent policy

†Possible new policy



**Existing homes:** Cost per QALY gained (discounted) for Action Level of 100 Bq/m<sup>3</sup> in area with mean radon 60 Bq/m<sup>3</sup> according to smoking status (ie most cost-effective choice)

---

<b>Cost per QALY gained (discounted)</b>		
<b>Household of:</b>		
<b>population prevalence of smoking</b>	<b>never smokers only</b>	<b>current smokers only</b>
<b>£27.9k</b>	<b>£169.1k</b>	<b>£9.6k</b>

---

*Costs per QALY (discounted) for smoking cessation: ~£1000*

# Conclusions re: No of radon-induced deaths & recent policy

- **About 1000 deaths caused each year by radon in the home in the UK**
- **Most radon-induced lung cancers in UK probably occur below currently recommended Action Level and in areas ignored by recent radon policy**

# Conclusions re: Possible future policies

- **A policy requiring basic measures to prevent radon in all new homes across the UK would be highly cost-effective and would contribute (modestly) to reducing lung cancer mortality**
- **Policies to identify and remediate existing homes with high radon concentrations are unlikely to be cost-effective in the UK, and have very limited potential to reduce lung cancer mortality**

**The end**