IEA-EEA Roundtable on Health & Well-being Impacts
Copenhagen April 18-19. 2013

The health impact of poor IAQ &
the need for holistic energy efficiency policies

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Acknowledgement: IAIAQ Funded by DG Sanco EAHC 02 Tender, LOT No 2
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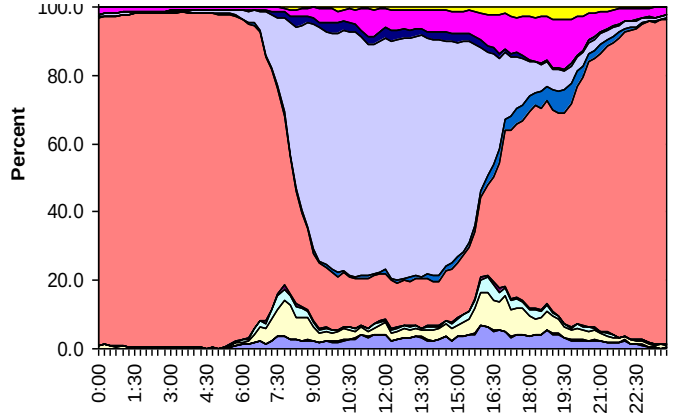
Reality checks: Housing in Europe

- 200 million residences, 700 million rooms, total floor area equal to Flanders
- Constructions, technologies and materials represent local histories, cultures, economies and ecologies of past 65 – 200 years
- Only 2…5 % of the residential building stock is replaced per year
- 300 000 Europeans share one room with 5 or more other occupants
- 5 million Europeans occupy 6 or more rooms only for themselves
- Country averages are meaningless for estimating the IAQ related health and welfare issues in any particular location

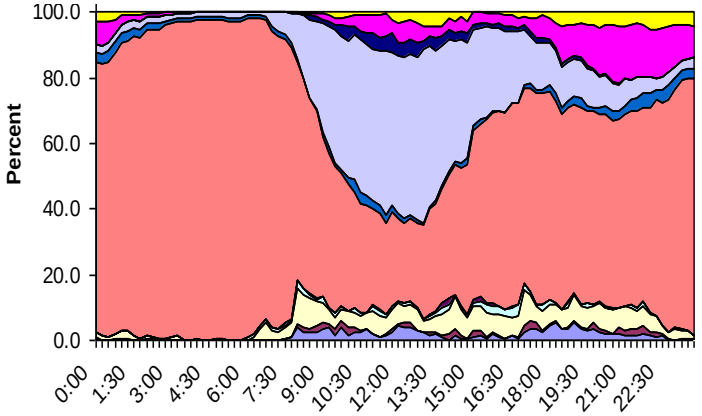
EXPOLIS
Exposure Distributions of Adult Urban Populations

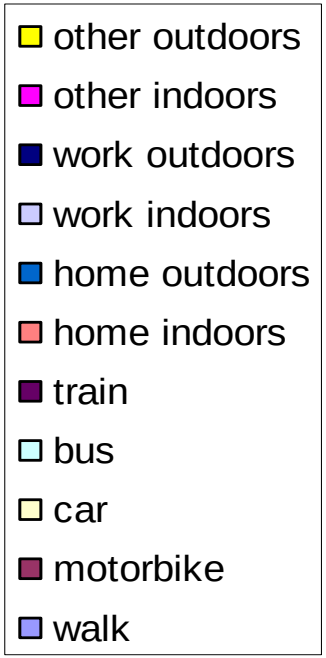
Time use of European adult urban populations in different μenvironments through workdays

Helsinki

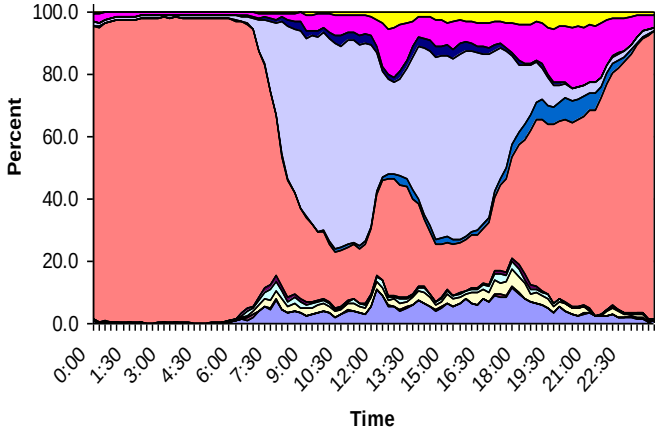


Athens

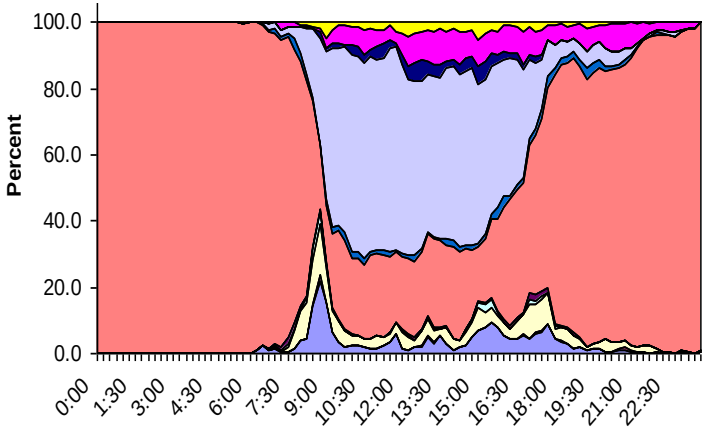


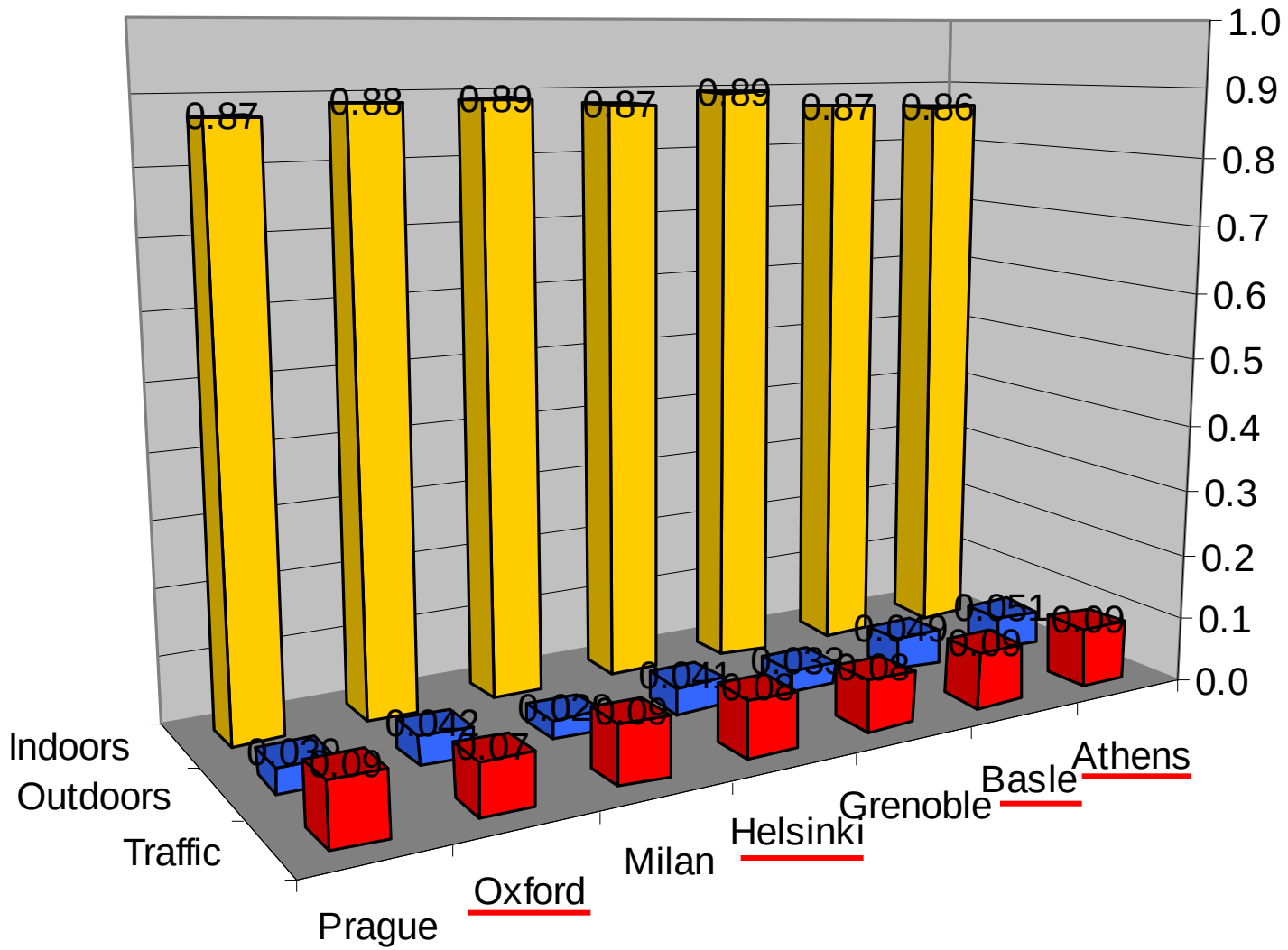


Basel



Oxford





Hänninen et al., 2005

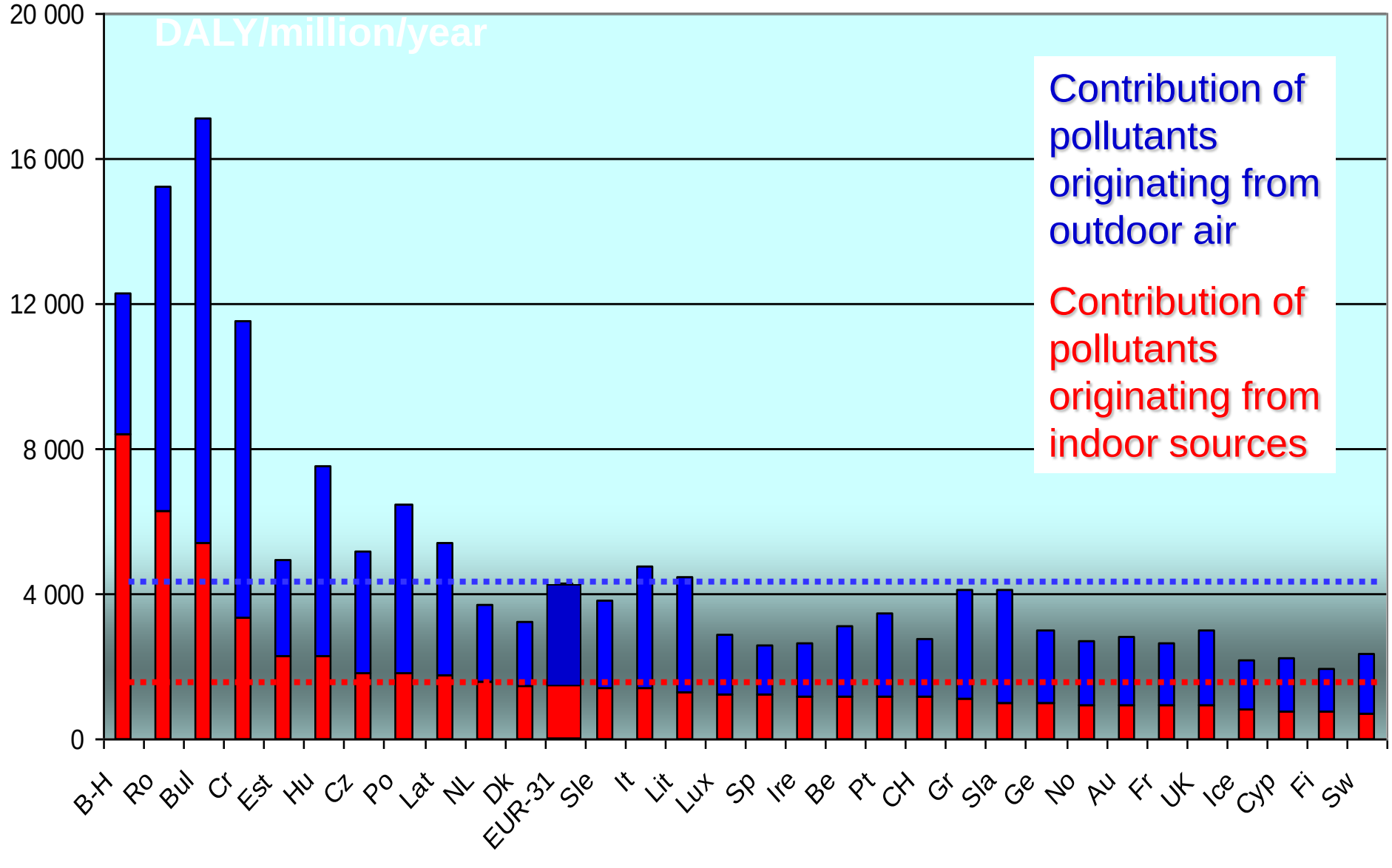
European IAQ related health risk estimates in 3 recent assessments (DALY/100 000)

Study Indoor Exposure	IAIAQ, 2011 (indoor)	EBoDE, 2013 (total exp)	WHO: EBD 2011 (inadeq housing)	note
Countries	Eu-26	BeDeFiFrItNl([1]	Euro-45	[1]) representing EU-26
Fine PM	**300**	**450 - 1000**	**80 ([2]**	[2]) indoor sources only
ETS	**100 - 300([3]**	**60 - 120**	**81**	[3]) with 2010 tobacco policies – without policies
Traffic noise		40 - 150	31	
Lead		10 - 90	79	
Damp & Mould	50		38	
Indoor cold			30 – 70 ([4]	[4]) 11 European countries
Radon	34	45 - 110 ([5]	25 ([6]	[5]) discounted & age adjusted [6]) only Germany
Carbon monox	24		60 ([7]	[7]) 28 European countries acute deaths only - undersestimate
VOC	6	0.2 - 0.6 ([8]		[8]) benzene and formaldehyde

A closer look at three different IAQ issues

- Contributions of indoor and outdoor sources to the overall IAQ burden of disease
- Roles of mechanical ventilation and air conditioning in exposure and risk
- Excess cold and heat – not just a comfort issue

IAQ associated DALY/million*a (2005) in 31 European countries, excl. ETS (total 2.2 MDALY/a)



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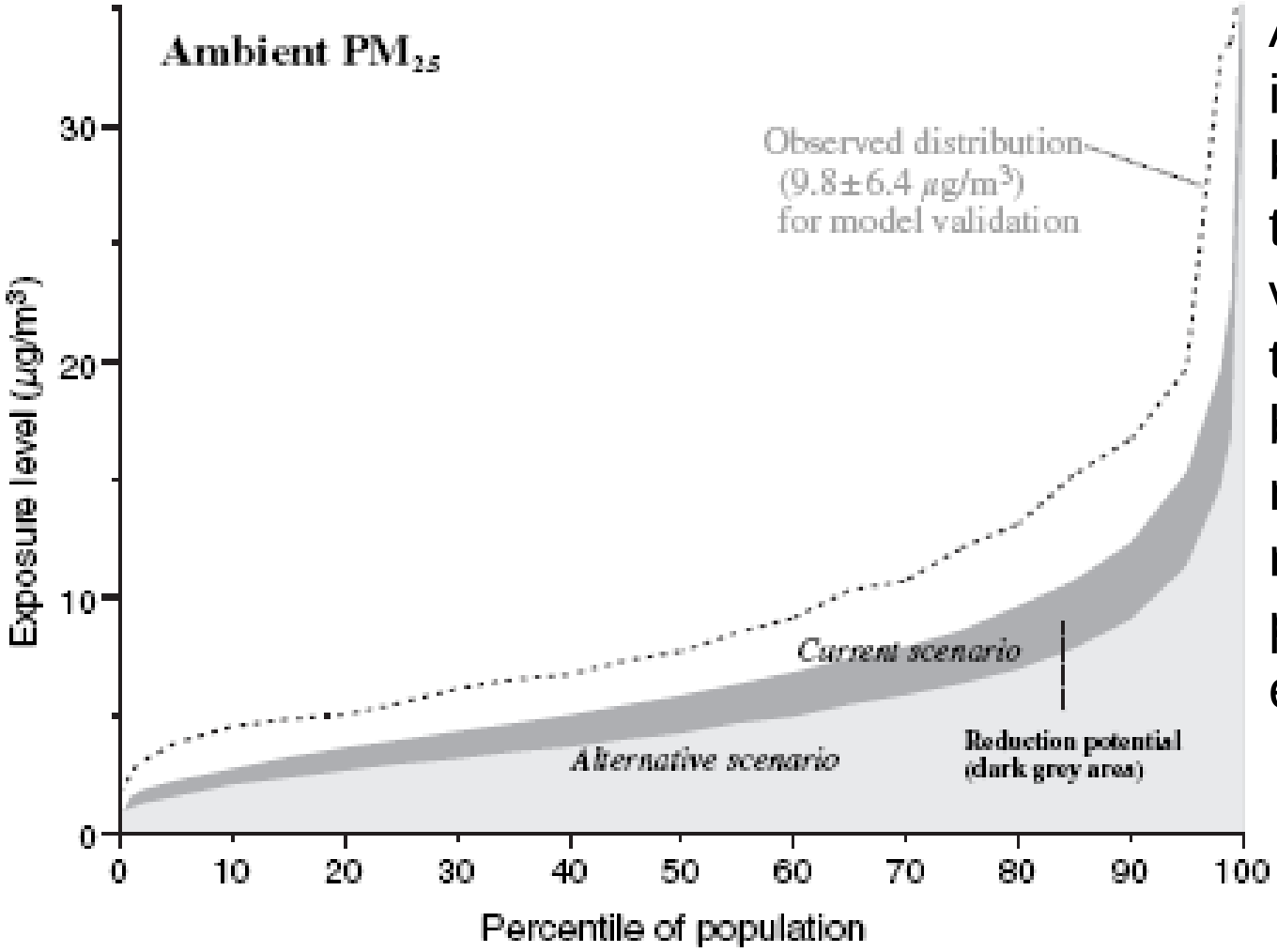
Ventilation policy: $PM_{2.5}$ exposure reduction potential by post- 1990 vs. pre-1990 building technology in Helsinki



A modest improvement in building envelope tightness and ventilation technology (to balanced mechanical) reduced population exposure by 20%.

Hänninen et al. JEA&EE 2005

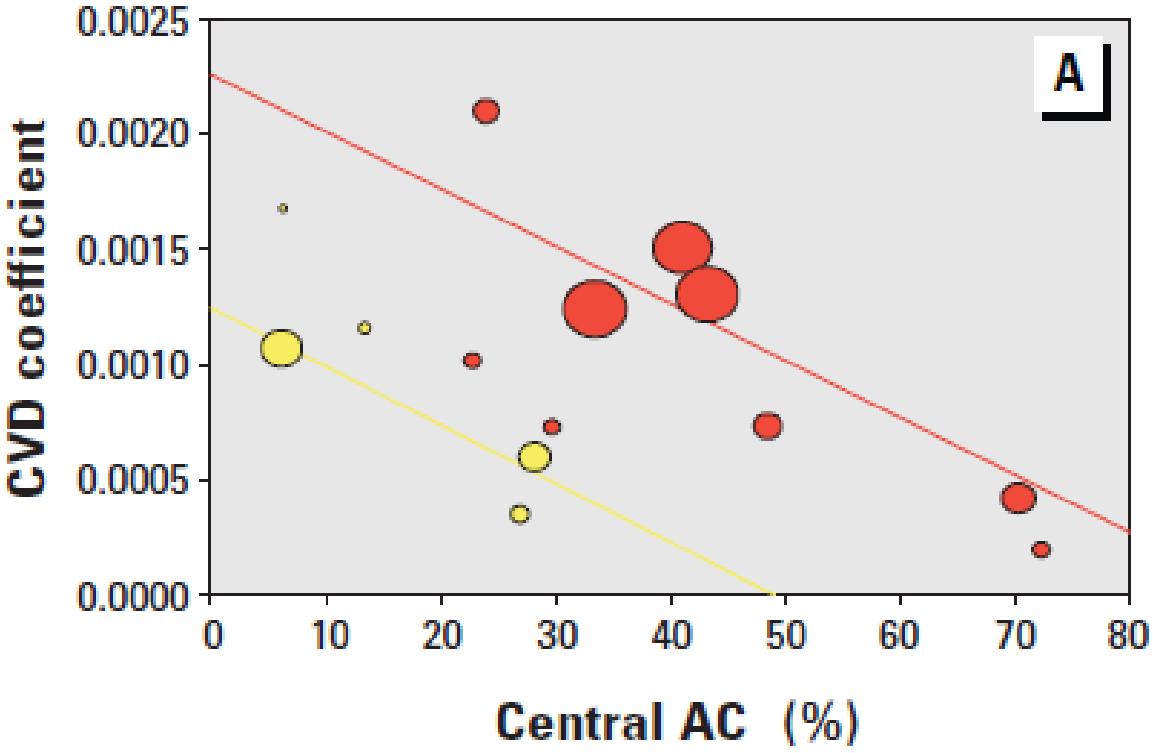
15 US cities: (cardiovascular hospital admissions)/(ambient air PM10) coefficient vs. % housing with central air conditioning.

Janssen et al. EHP 2002

During the cooling season:

In buildings with central AC air is filtered, air exchange rate is low and population exposure to PM10 (and CVD incidence) is poorly related to outdoor air PM10 90% of time

In buildings cooled via open windows air exchange rate is high with no filtration and population exposure to PM10 is close to (and CVD incidence related to) outdoor air PM10



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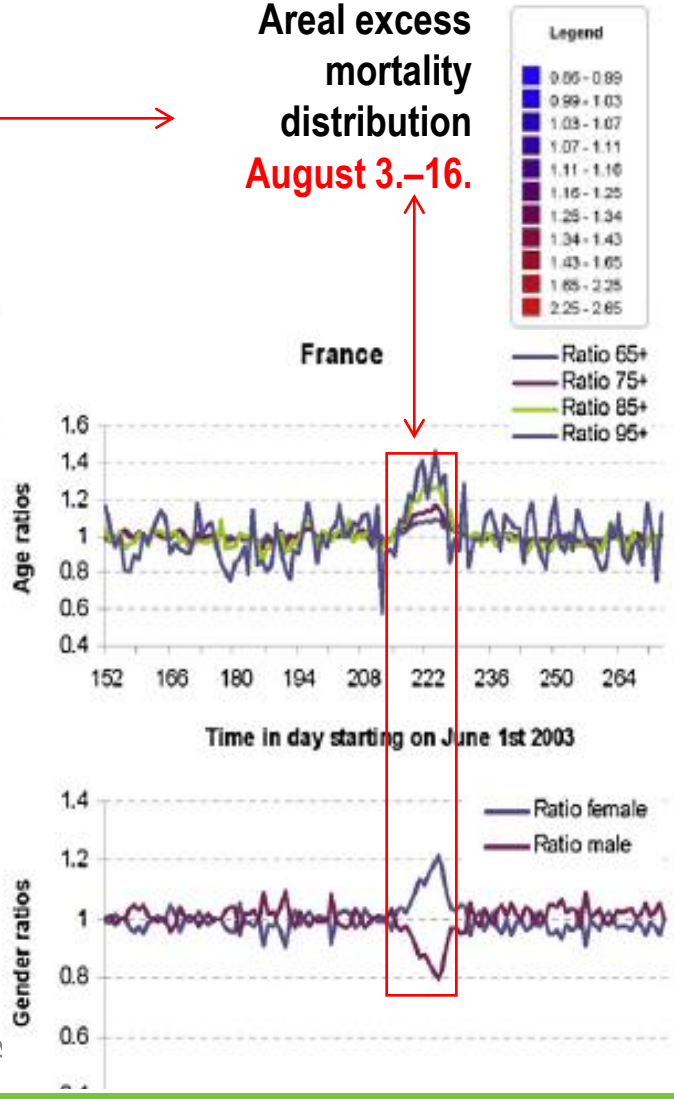
Hot August 2003 & mortality

Excess daily mortality in 16 European Countries. June 1. to Sept. 30. 2003

Robine et al. Comptes Rendus Biologies, 2008

Areal excess mortality distribution August 3.–16.



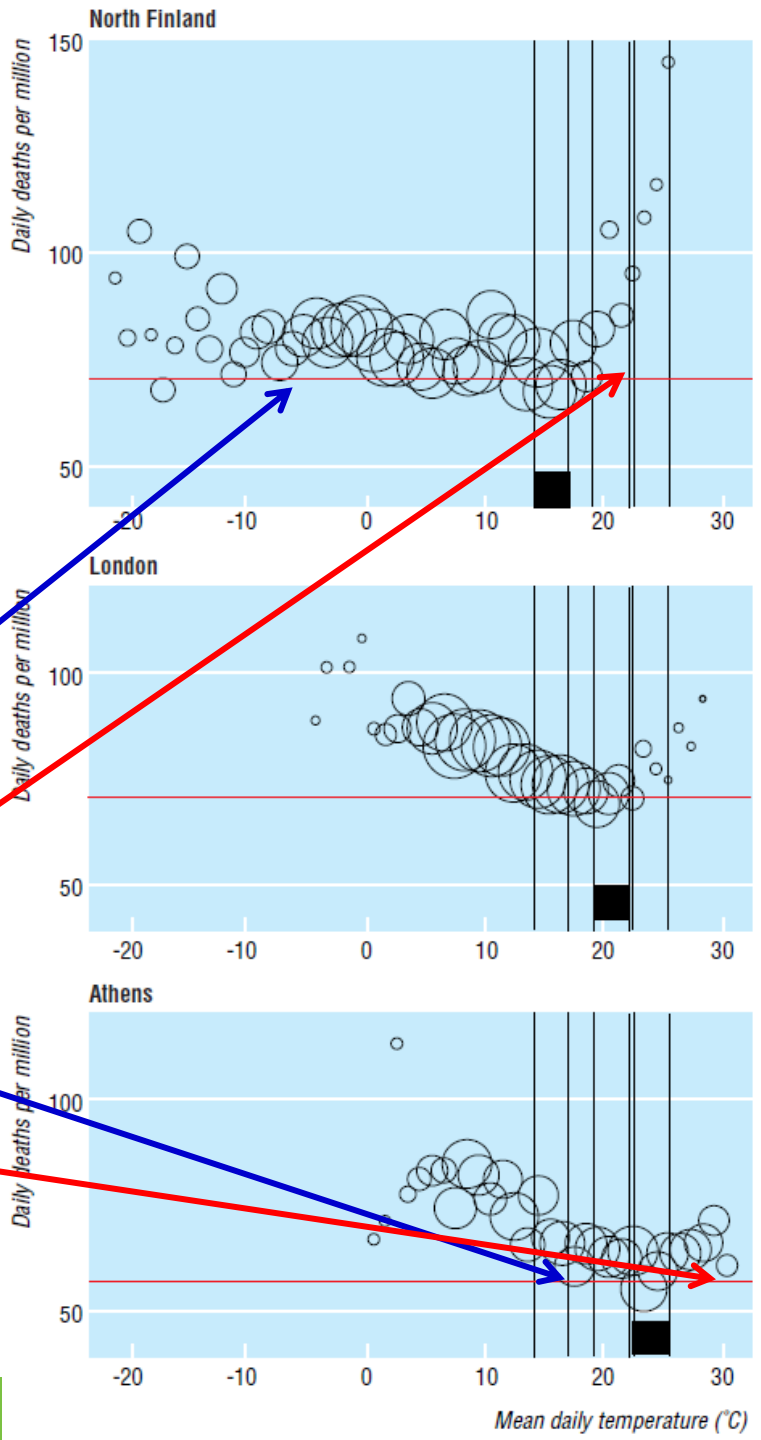
Age and gender distortion of the excess mortality, which increased with age and was 50% higher for females than males.

Back

Daily mortality vs. outdoor T of people aged 65-74

Keating et al. BMJ 2000

- Physiologically people adapt only marginally to ambient temperature.
- Instead people adapt via housing, clothing and behaviour.
- No mortality response to outdoor cold in Northern Finland, but indoor heat increases mortality above 20°C outdoor T. Buildings are poorly designed for cooling.
- In Athens indoor cold increases mortality below 15°C outdoor T but heat only above 30°C. Buildings are poorly designed for heating.



Energy efficiency of buildings vs. IAQ
Energy efficiency ≠ GHG efficiency

- Some energy conservation measures improve some others deteriorate IAQ, yet some do both
- GHG efficiency of a city depends on:
  - energy efficiency of the buildings (kWh/m^3/a),
  - total built volume (m^3/cap),
  - urban structure & transport modes
  - efficiency of the heat and power generating and distributing systems (% losses), and
  - GHG emissions of the primary sources of energy (gCO_2/kWh)

Energy efficiency of buildings

Wasted/used energy	Conservation solution	IAQ issue (+ -)
• Thermal leaks through building envelope	• Tight/sealed building envelope and thick insulation	• isture may migrate thru condense in the ation and promote mold
• Thermal loss via ventilation	• Elimination of ind sources	• mproves IAQ with no sacrifice
	• Reduced a	• Increases risk of poor IAQ and dampness
	• Bala nical v PM d heat from exhaust ake air	• Ensures set air exchange rate, reduces outdoor pollution penetration
• Electric power consumptio	atural ventilation, no air conditioning	• Outdoor air pollution penetrates indoors, air exchange is insufficient and heat builds up during the warm season
	• Maximum utilisation of passive solar heat	• Excessive heat may result from spring to autumn

Neither the conservation nor the IAQ optima are the same across Europe!

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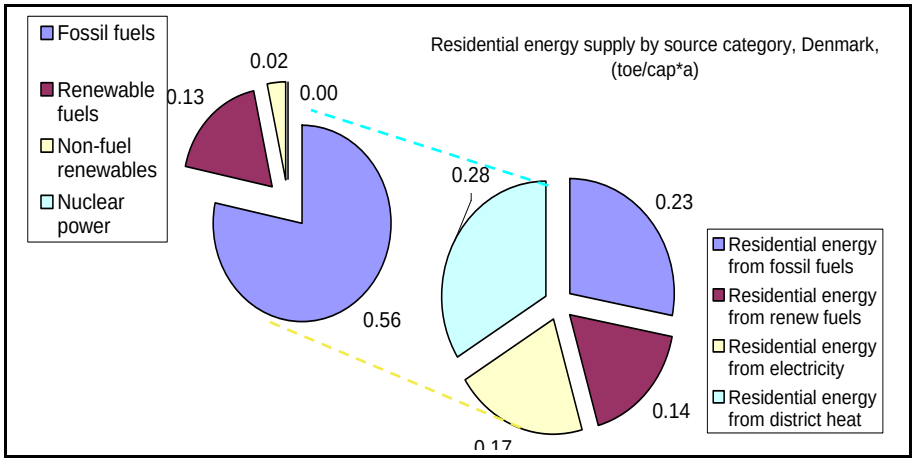
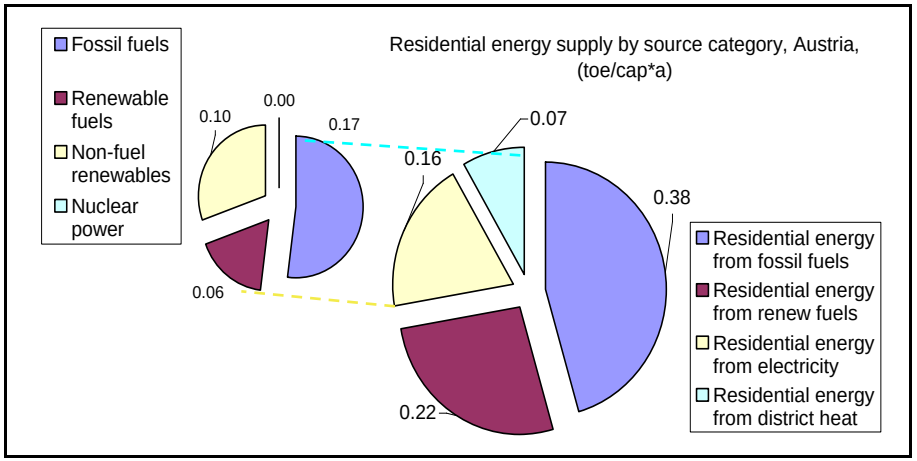
Two ongoing EU-RTD projects, URGENCHE and PURGE, are doing just this.

Residential use of fuels and energy (toe/cap*a), central heat and power generation and total residential GHG contribution (CO_2/cap*a) in four EU countries

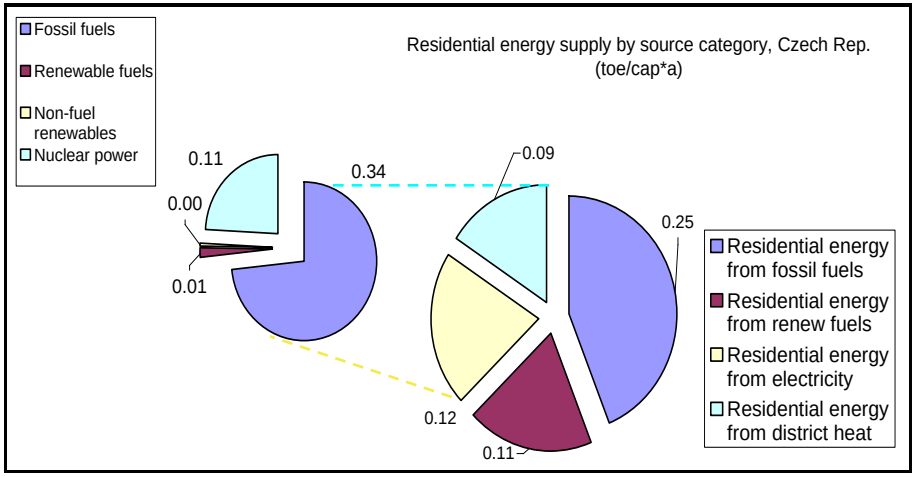


Denmark, 0.82 toe, 3.80 tCO_2/cap*a

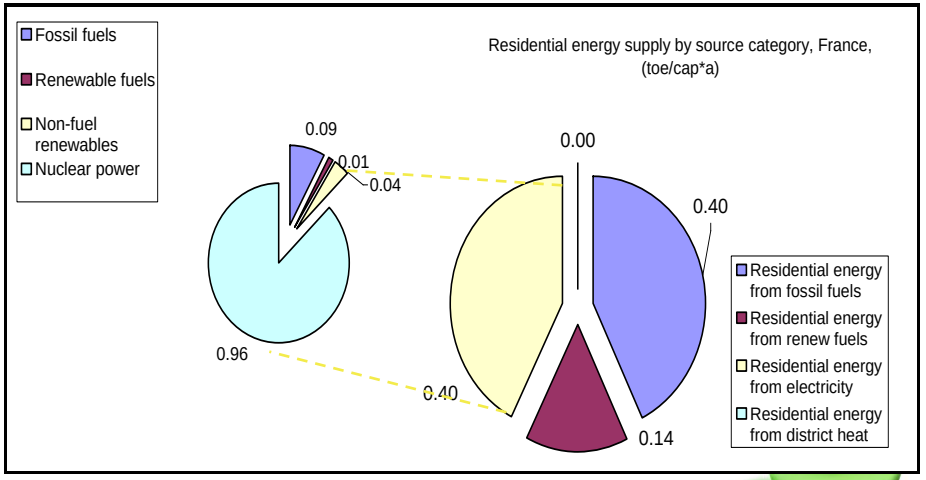


Austria, 0.83 toe, 2.70 tCO_2/cap*a

Czech Rep, 0.57 toe, 2.41 tCO_2/cap*a



France, 0.94 toe, 1.96 tCO_2/cap*a



Data: OECD/IEA, 2009

My home town, Kuopio, FINLAND

Holistic view: in addition to the energy need of each building, the GHG impact of a city is determined by:

- **Sources of heat and power**
  - Sources of power for the national grid
    - *Proportions of fuels, hydro, nuclear, wind, solar*
  - Local heat and power cogeneration
    - *Fuels, thermal power plant or industrial waste heat*
  - Energy generated in buildings
    - *Gas, fuel oil, coal/coke, wood/pellets, solar*
- **Urban planning**
  - Total volume of the building stock
    - *Increasing both transport distances and heat/power demand*
  - Availability of solar heat for buildings in the winter and shading in the summer
  - District heating network
  - Urban density; commuting distances, routes and means
    - *Transport fuel use, congestion, biking, walking, physical activity*

Two ongoing EU-RTD projects, URGENCHE and PURGE, are doing just this.

ETS: CVD impact of the 2005 public smoking ban in Rome

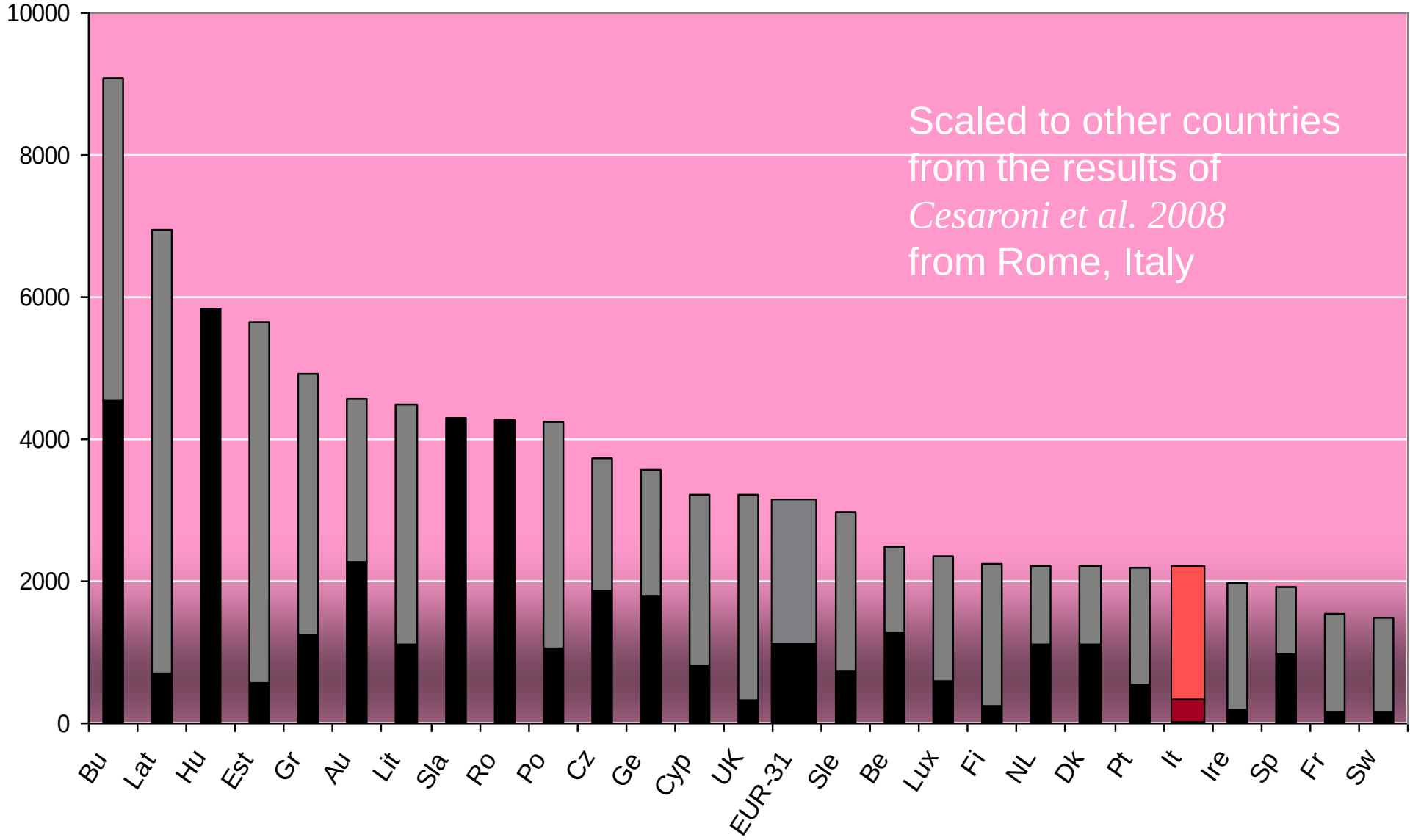
Table 3. Results of Additional Adjusted Analyses and Subgroup Analyses of the Association Between the Italian Smoking Ban and Acute Coronary Events in 35- to 64-Year-Olds and 65- to 74-Year-Olds

Cesaroni et al. Circulation 2008

	35–64 y			65–74 y		
	n	RR*	95% CI	n	RR*	95% CI
All events						
Main analysis	2136	0.89	0.85–0.93	2126	0.92	0.88–0.97
Adjusted for time trend	2136	0.93	0.88–0.99	2126	0.88	0.83–0.94
Adjusted for all-cause hospitalization rates	2136	0.90	0.86–0.95	2126	0.89	0.85–0.94
Adjusted for time trends and all-cause hospitalization rates	2136	0.94	0.88–1.01	2126	0.90	0.84–0.96
By gender						
Only men	1712	0.88	0.84–0.93	1408	0.90	0.85–0.96
Only women	424	0.90	0.81–1.00	718	0.95	0.88–1.04
By socioeconomic position (quintiles)						
1 (High)	340	0.92	0.82–1.03	342	0.97	0.86–1.09
2	383	0.90	0.81–1.01	388	0.90	0.81–1.01
3	408	0.88	0.79–0.98	465	0.97	0.87–1.07
4	470	0.90	0.81–0.99	417	0.83	0.75–0.92
5 (Low)	535	0.85	0.77–0.93	514	0.94	0.86–1.04
By type of event						
Out-of-hospital deaths	224	0.85	0.74–0.99	312	0.84	0.74–0.95
Hospital events	1912	0.89	0.85–0.94	1814	0.94	0.89–0.99
Only incident cases	1680	0.93	0.88–0.98	1528	0.95	0.90–1.01

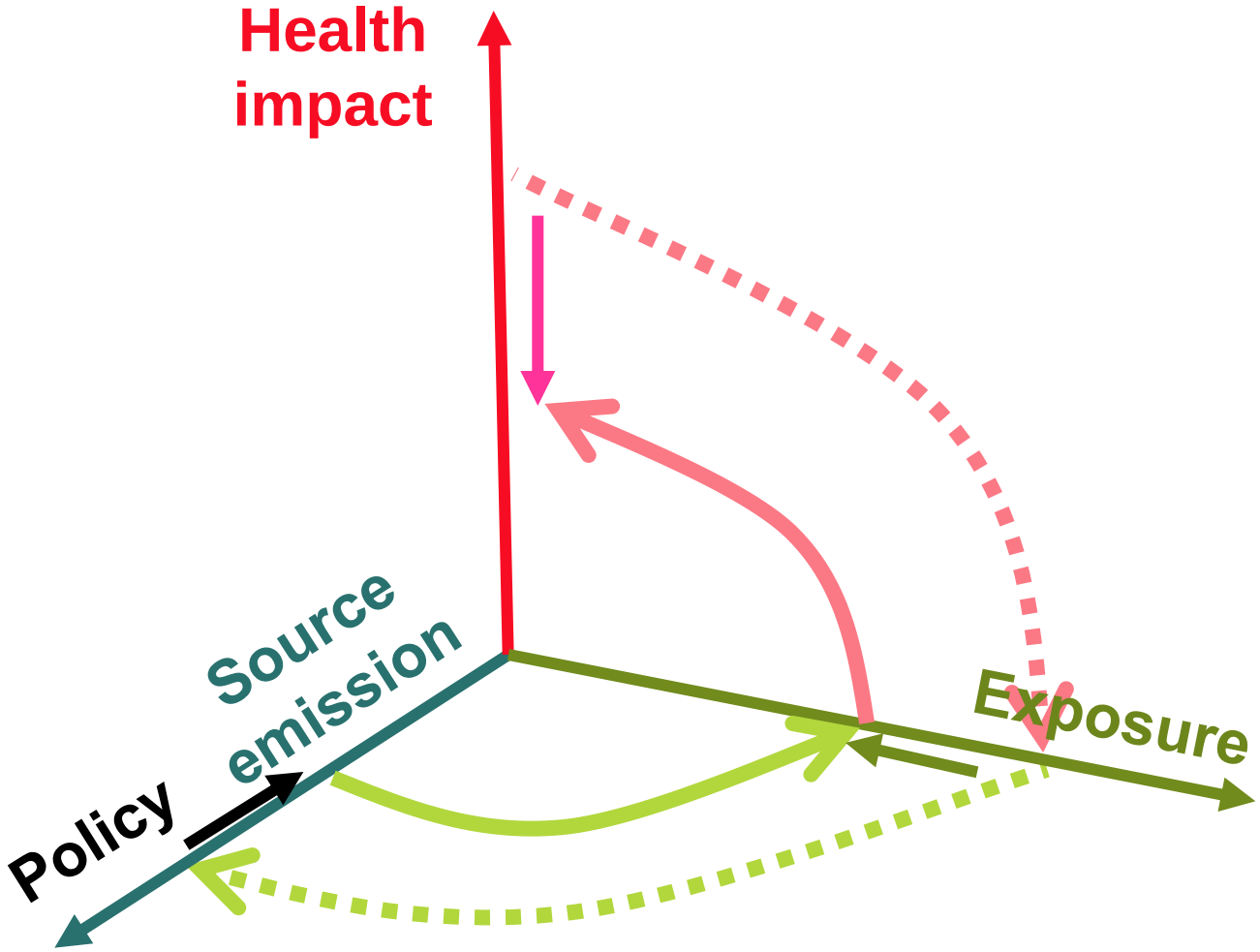
*All rate ratios comparing 2005 vs 2000–2004 are adjusted for PM_{10}, flu epidemics, holidays, and apparent temperature.

Public health impact from ETS exposure with and without the 2010 public and workplace smoking bans (DALY/million*a)



Data quality range: good *** … poor * nil ○	Indoor and common occupational sources for personal air pollution exposure [in addition to tobacco]	Significance for the highest individual exposures	Contribution for population air pollution exposure (%)		
			indoor & occup. origin	commuting exposures	ambient air origin
$PM_{2.5}$ *** $PM_{10-2.5}$ ○	solid fuel combustion, candles	dominant	20…50 …80	…35 …50	40…70 …25
O_3 **	ozonators, electrostatic air cleaners, laser printers	rare or weak	nil	nil	ca. 100
NO_2 **	unvented gas appliances	significant	…50	…20	40…90
CO **	unvented, faulty and/or inproperly operated combustion equipment	dominant	some	some	…90
SO_2 ○	residential coal burning, paraffin heaters & lamps	rare but dominant	nil	nil	…100
C_6H_6 ***	Attached garages and solvents in some domestic chemicals	dominant	…50	…25	…80
BaP * Naphth**	solid fuel combustion - naphthalene also in mothballs and coal tar based waterproofing	dominant rare but dominant	small 40…70	small small	…100 30…60
As ○, Cd ○, Ni ○, Pb*	some old paints & accumulated dust	some	…40	nil	…90
Hg ○	breaking thermometers and fluorescent tubes, amalgam fillings	high	…65	nil	< 100

The EnVIE concept, linking health impact to exposure, source and policy



Daytime cooling in the summer in Europe is possible without refrigeration

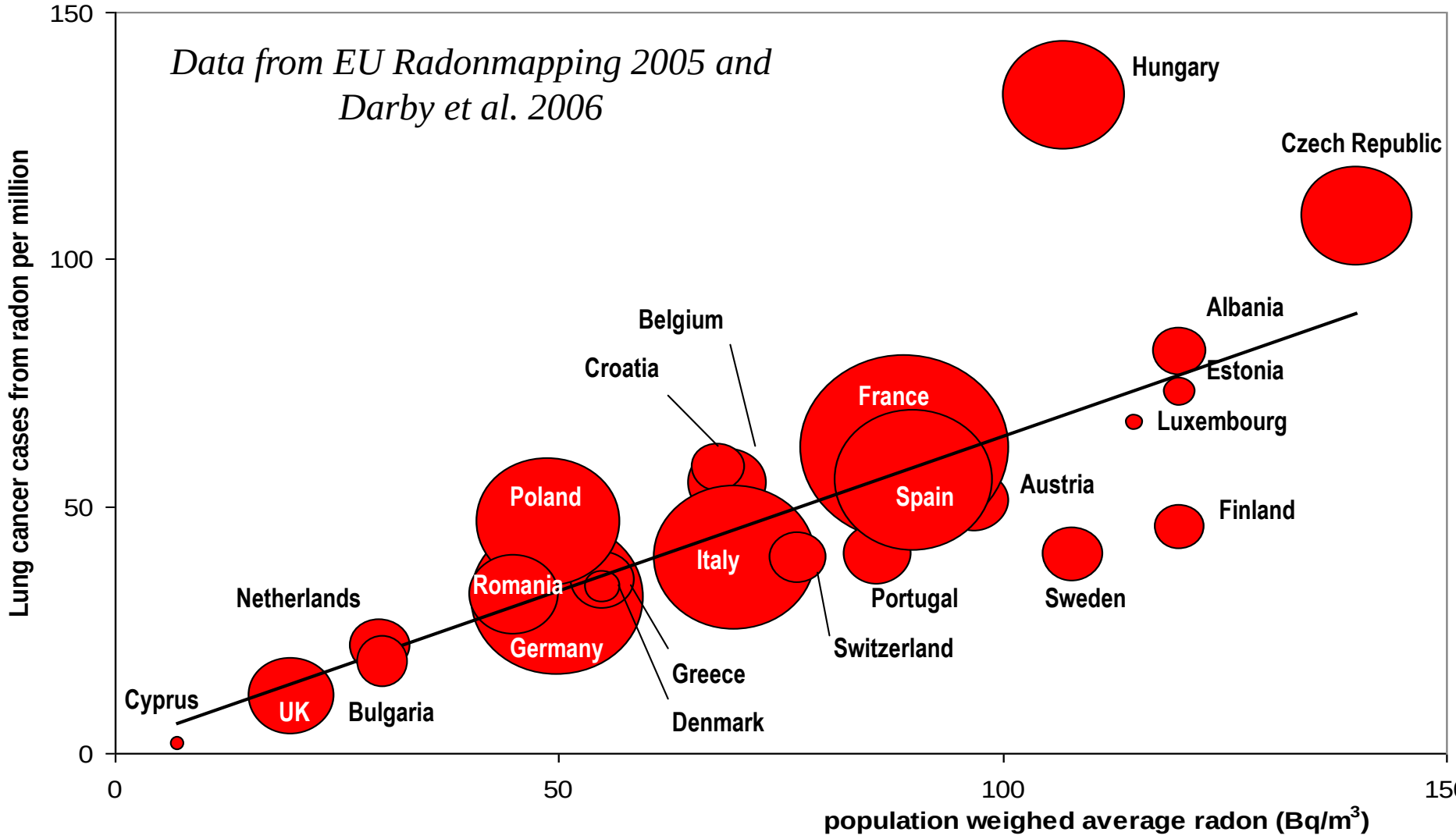
- In the Mediterranean region cooling has been traditionally been carried out by building characteristics and occupant activities

- Narrow building frame allows natural ventilation through all residences
- Wide eaves shade the walls from high midday sun
- Window shutters let through air but not sun or insects
- Walls and floors made of heat buffering mineral materials

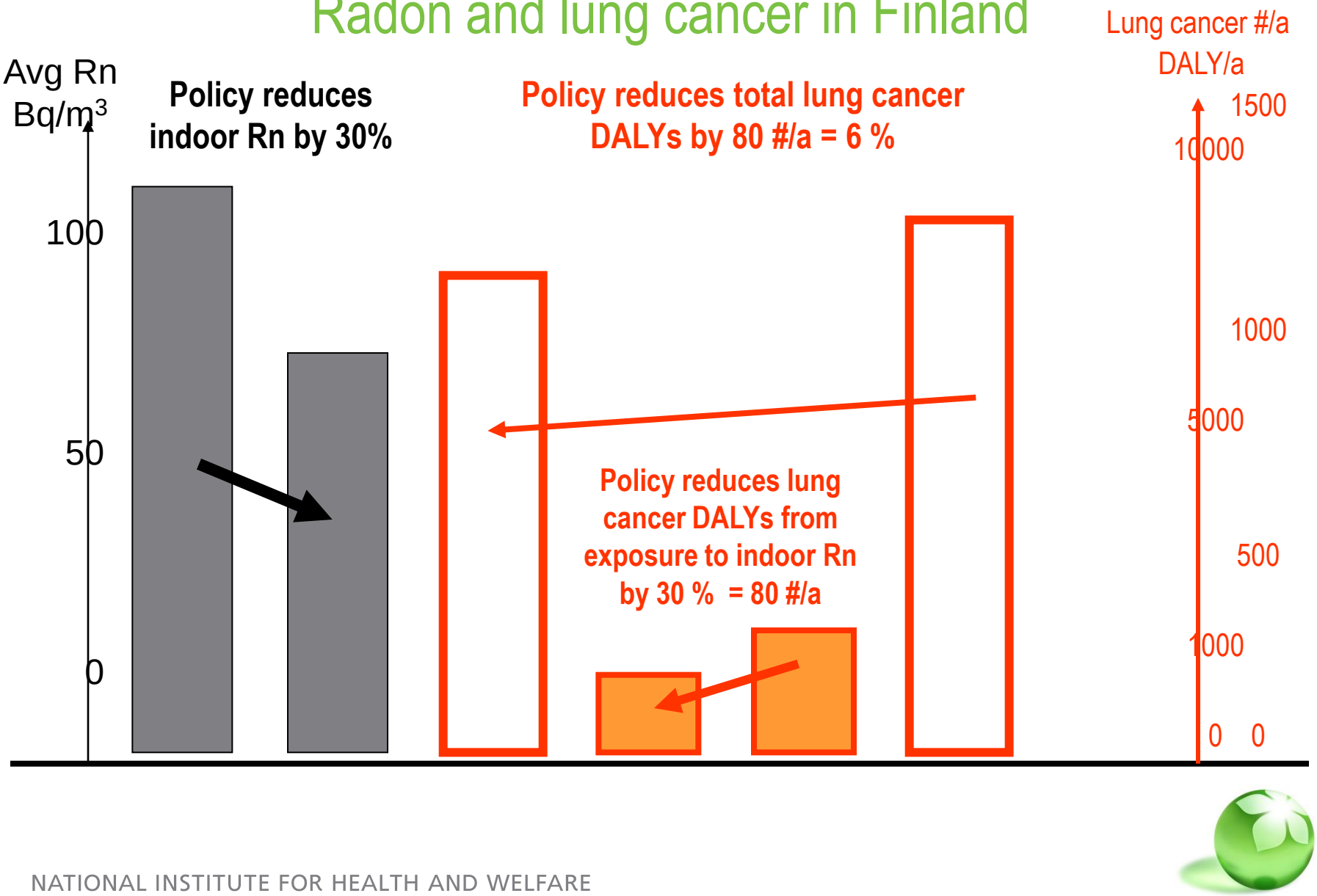
- Shutters are kept closed on the sunny side of the building
- From morning till evening the windows and are kept closed
- Through the nigh the shutters are kept closed but windows open

This way the afternoon peak indoor temperature remains easily 5.. 8 °C below the peak outdoor temperature

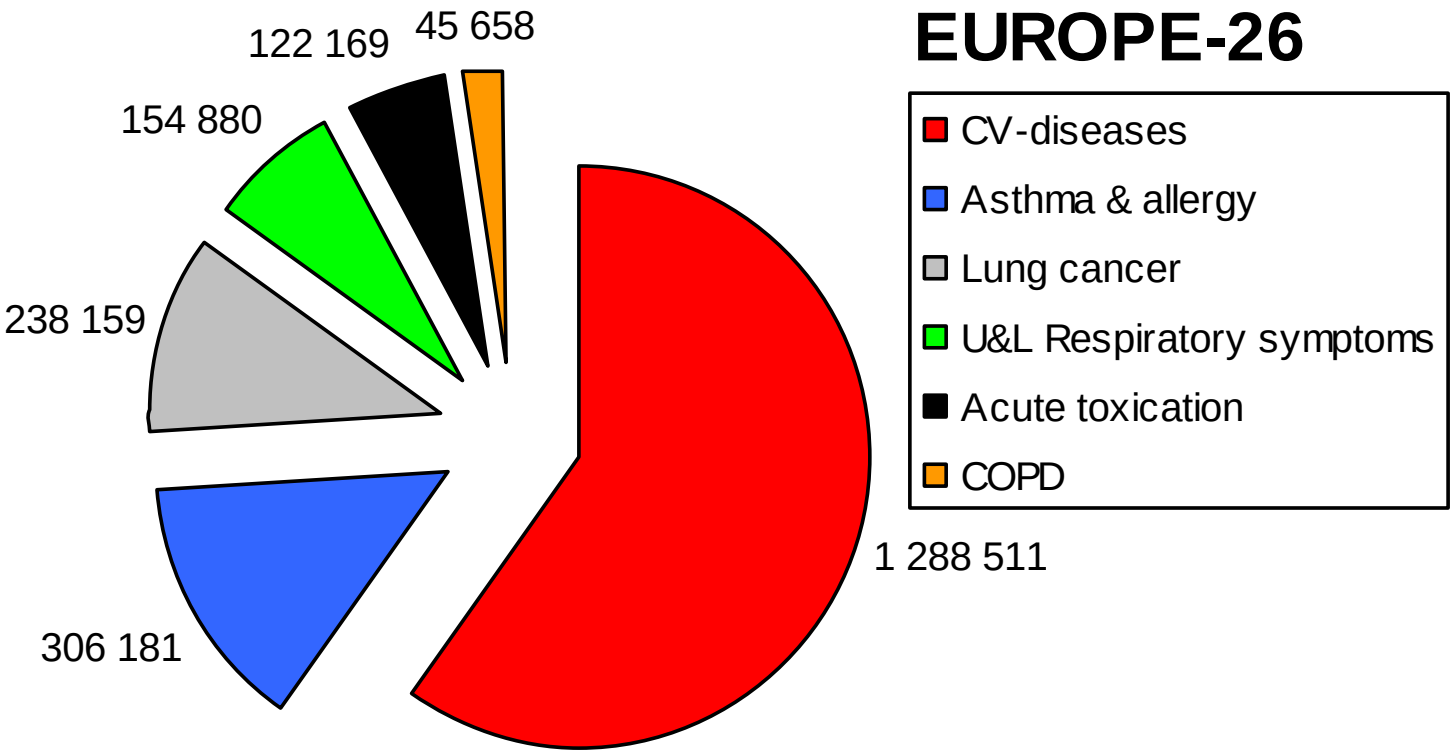
Radon exposure and lung cancer cases estimated by relative risk model across Europe



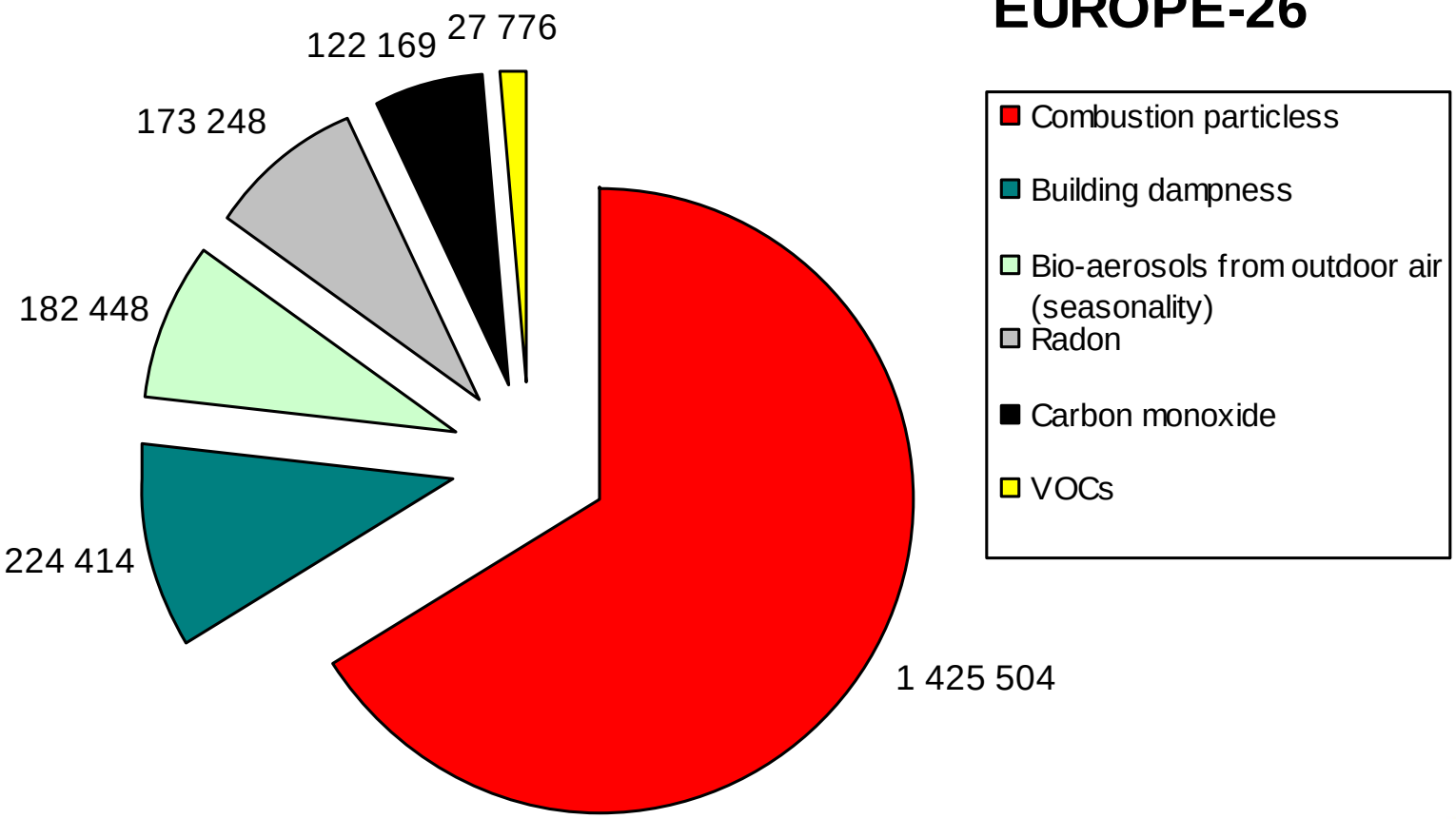
Example of an EnVIE MT IAQ policy impact assessment:
Radon and lung cancer in Finland



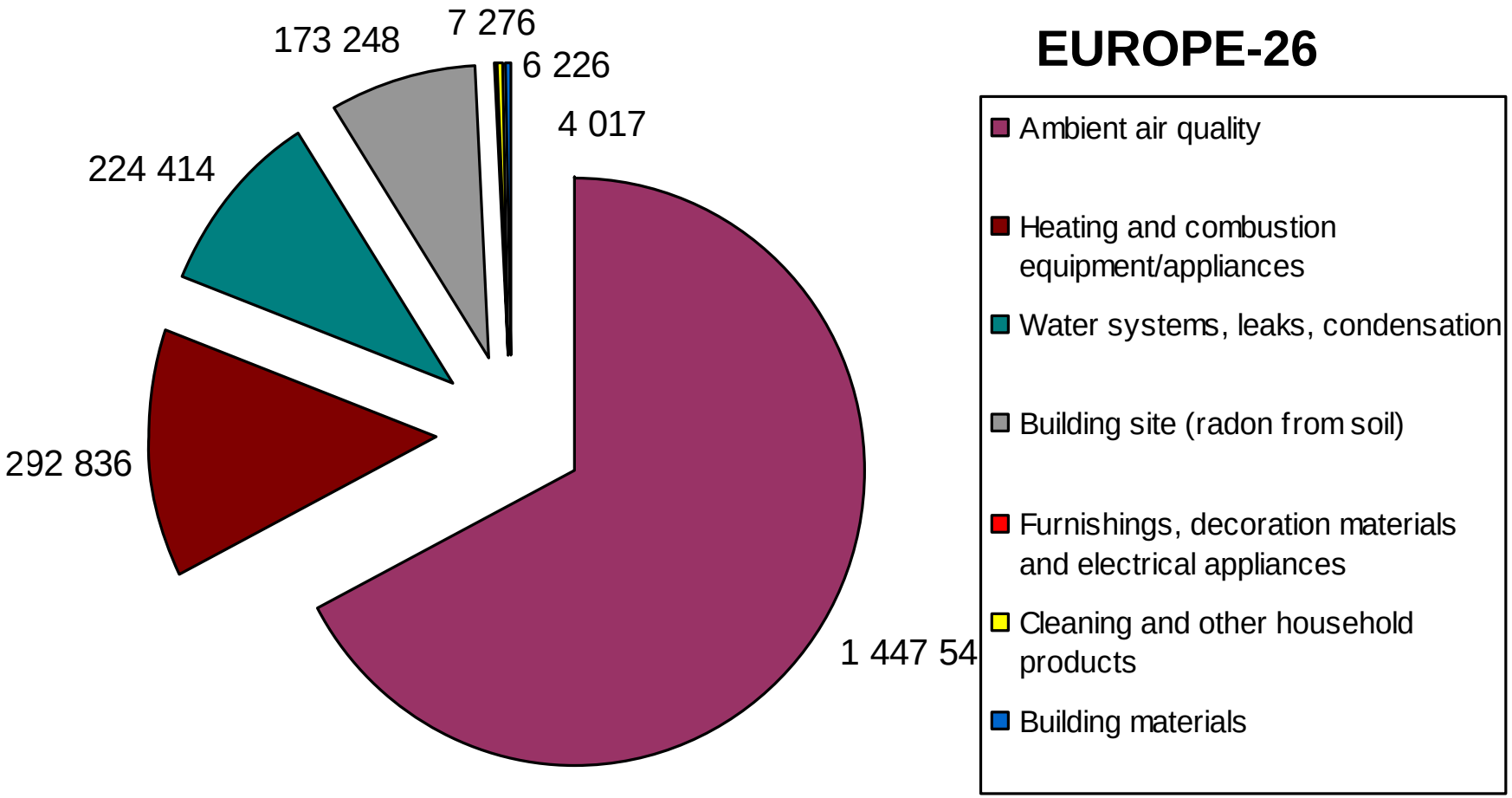
IAQ associated BoD in DALY/a attributed to diseases – in total 2.2 MDALY/a, excluding ETS



IAQ associated BoD in DALY/a attributed to exposure agents

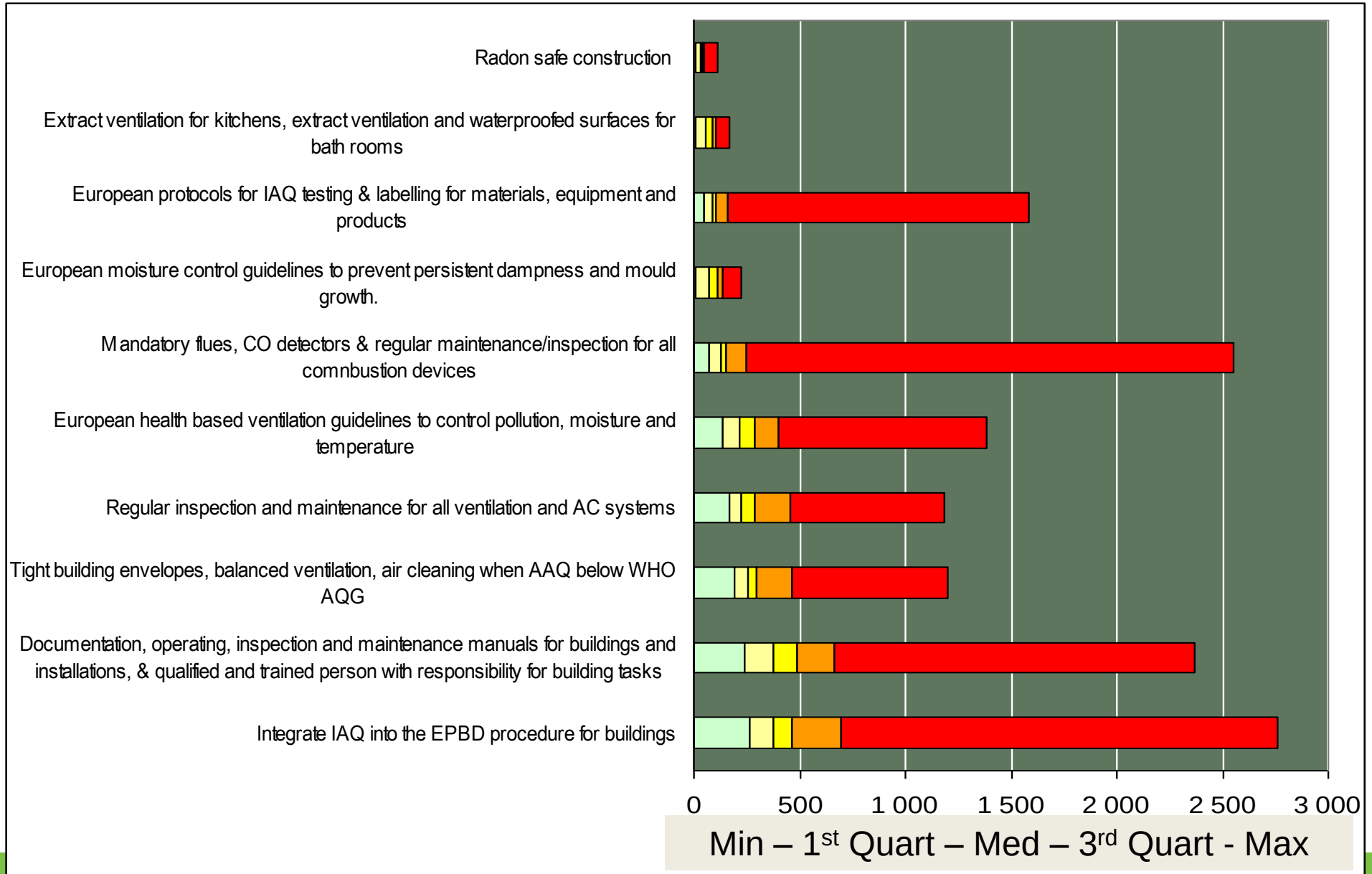


IAQ associated BoD in DALY/a attributed to sources of exposure



Distribution of the public health benefits of IAQ policies within 31 European countries, (DALY/a*million)

IAIAQ



Estimated distribution of the total EU-27 population into households (1 … 6 or more occupants), and residences (1 … 6 or more rooms)

# of persons in residence	Estimated population division into households in the EU-27 residence stock						
	1 Room	2 Rooms	3 Rooms	4 Rooms	5 Rooms	6 or more	Total
1	10 000 000	15 000 000	13 000 000	8 300 000	3 700 000	2 100 000	**53 000 000**
2	3 300 000	18 000 000	33 000 000	32 000 000	19 000 000	12 000 000	**117 000 000**
3	1 100 000	7 700 000	26 000 000	31 000 000	20 000 000	13 000 000	**99 000 000**
4	810 000	6 100 000	22 000 000	39 000 000	32 000 000	21 000 000	**122 000 000**
5	320 000	2 100 000	7 900 000	18 000 000	19 000 000	16 000 000	**63 000 000**
6	130 000	620 000	2 800 000	7 100 000	8 400 000	11 000 000	**30 000 000**
Total	**16 000 000**	**50 000 000**	**105 000 000**	**135 000 000**	**103 000 000**	**75 000 000**	**483 000 000**

Half of the EU population lives in 2..4 person households occupying 3..5 room residences