Intersections of energy efficiency and health and wellbeing: findings from the UK

Leonardo Energy Webinar

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Presentation

The presentation will cover the intersections of energy efficiency and health and wellbeing in the residential housing sector in the UK.

It will provide a summary of findings from recent energy performance and retrofit programme health impact evaluations in the UK and the impact of future retrofit programme to meet the UK's climate change targets in the residential sector.

Biography

Associate Professor at the UCL Energy Institute, University College London, UK.

My research is focused on the nexus between energy demand, energy efficiency, indoor and urban environment and health and climate change.

Co-investigator on the ‘Centre on Research for Energy Demand Solutions’, leading the energy, health and resilience group; and the UK Health Protection Research Unit ‘Healthy and Sustainable Cities under Climate Change’.

Principle Investigator on a project with the UK Government to quantify the health impact of introducing energy efficiency measures in the UK’s housing stock using health surveys and building retrofit programme data.

Lead on energy, climate change mitigation and health on the ‘Lancet Countdown: Tracking Progress on Health and Climate Change’.

Outline

Energy and health – Drivers

Energy efficiency and health – the evidence (it's complicated)

Energy efficiency and health – the impacts (positive and negative)

Next steps – Strengthening the evidence base

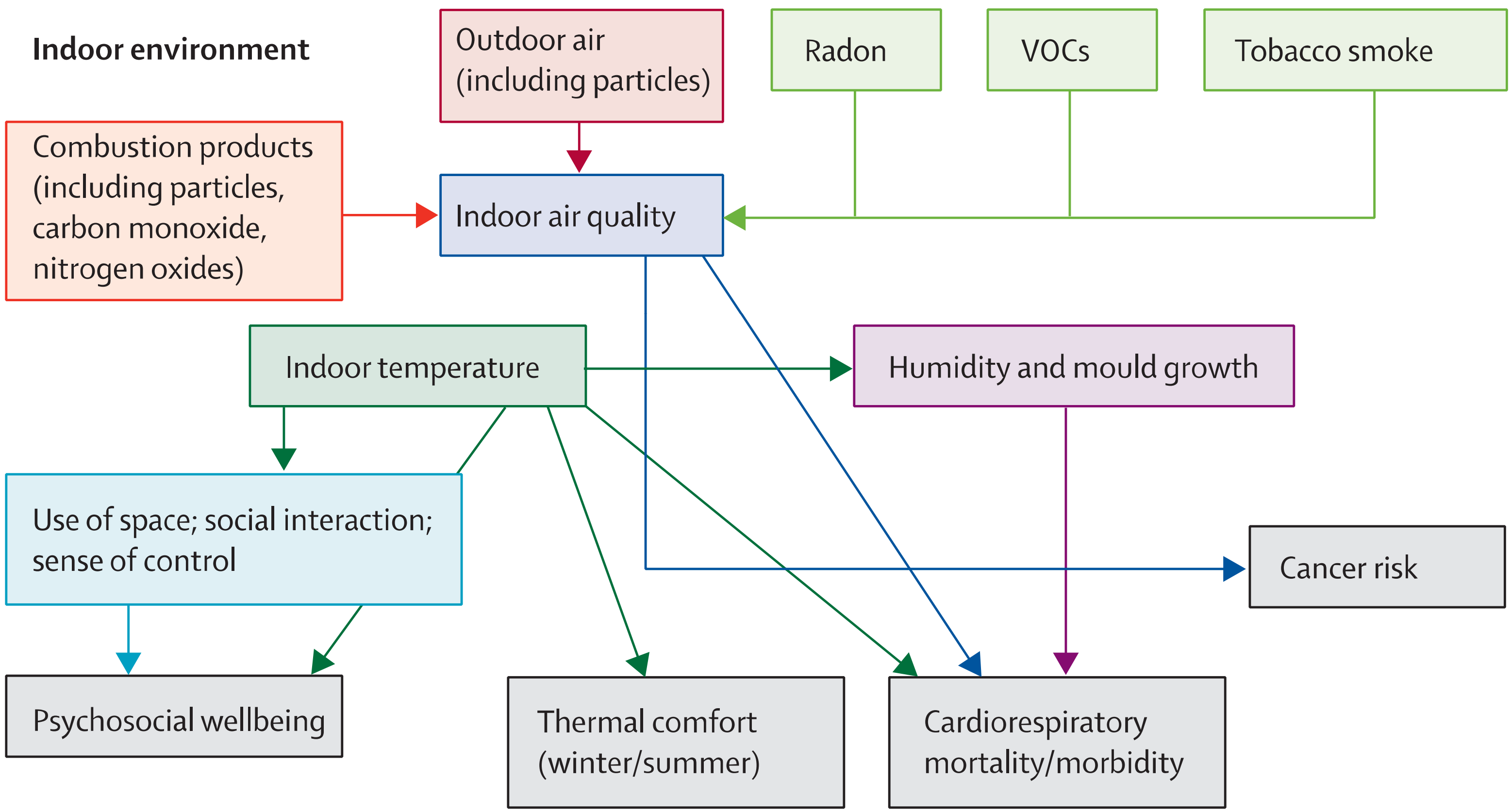
Conclusions

Energy efficiency and health

THE DRIVERS

Buildings quality and health

Connections between building quality, energy and health



Source: Wilkinson, Lancet, 2009

Air pollution and health

Worldwide premature **deaths due to pollution were estimated to be 9 million** in 2015 (16% of the total) with the majority of this burden falling on low to upper middle income countries.

Two thirds of this burden is related to air pollution.

Air pollution and health

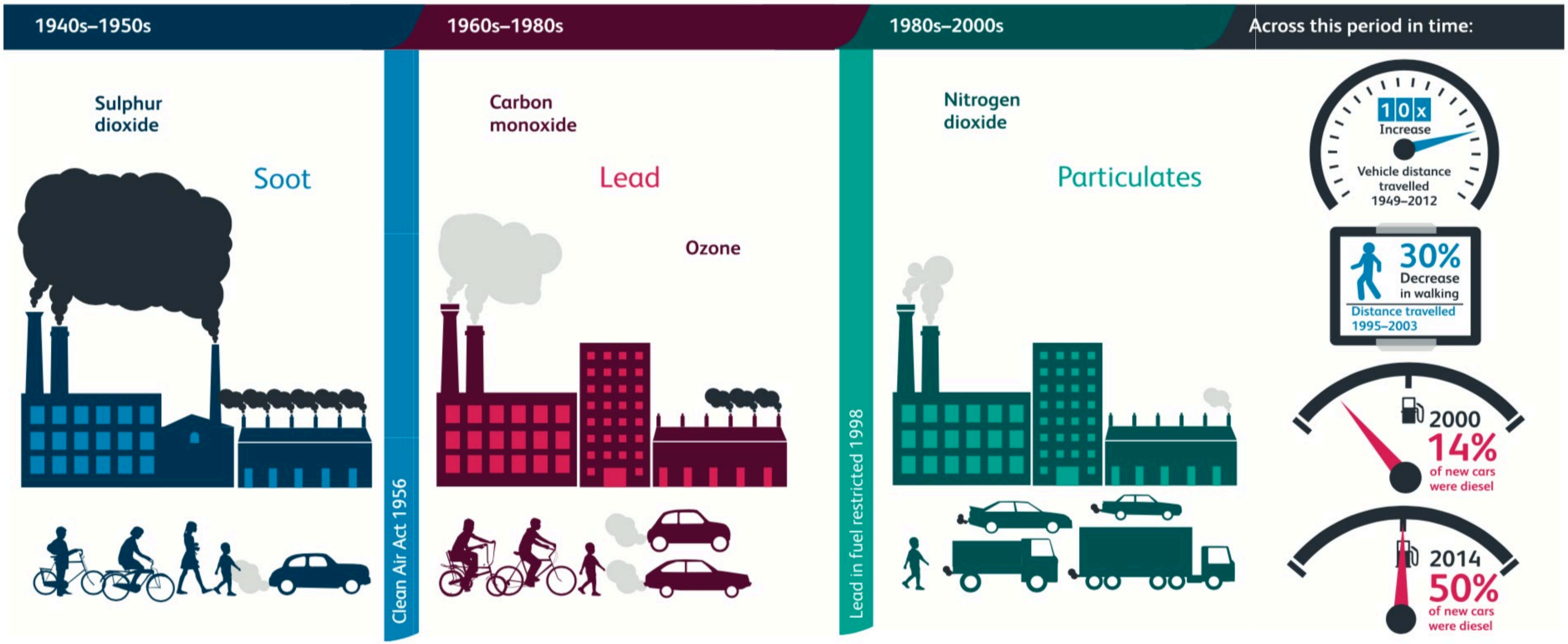
The evidence for adverse effects of urban air pollution clearly shows that **particle pollution in particular is responsible for a large global burden of mortality and morbidity.**

Transport of air masses means that air pollution is not a uniquely urban problem, but it is **predominantly urban because of the density of traffic and stationary sources** in cities.

Street canyons and other buildings in cities can also affect dispersal of pollutants and, thus, local pollutant concentrations.

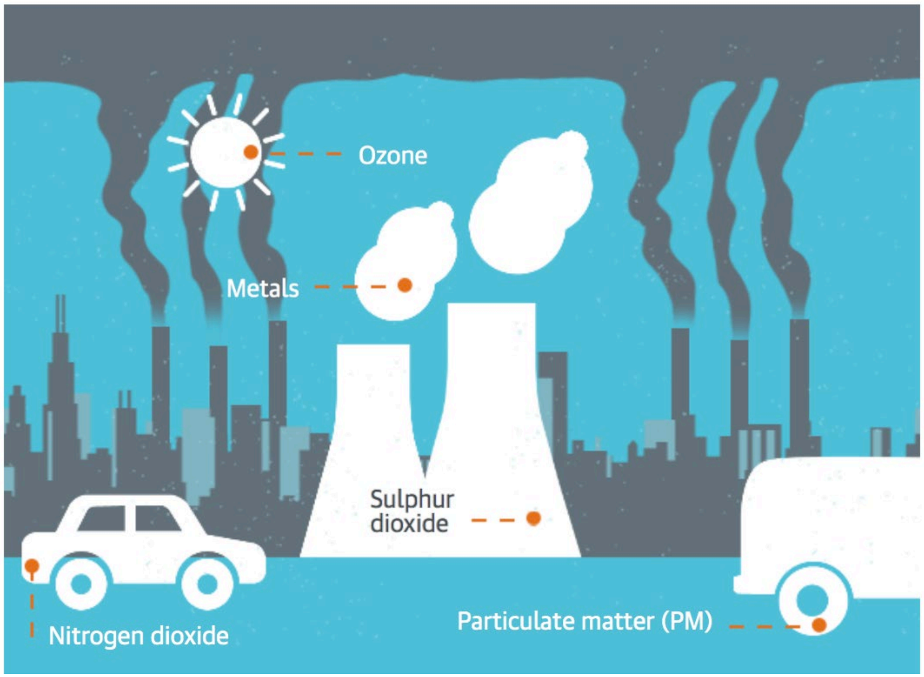
Source: Wilkinson et al, 2007

Air pollution and health



RCP, 2016

Air pollution and health



RCP, 2016

Sulphur dioxide

From the burning of fossil fuels, mostly power stations.

Nitrogen dioxide

Highest levels found close to road traffic or indoor gas cookers.

Ozone (ground-level)

Caused by chemical reactions between natural, traffic and industrial pollution in strong sunlight.

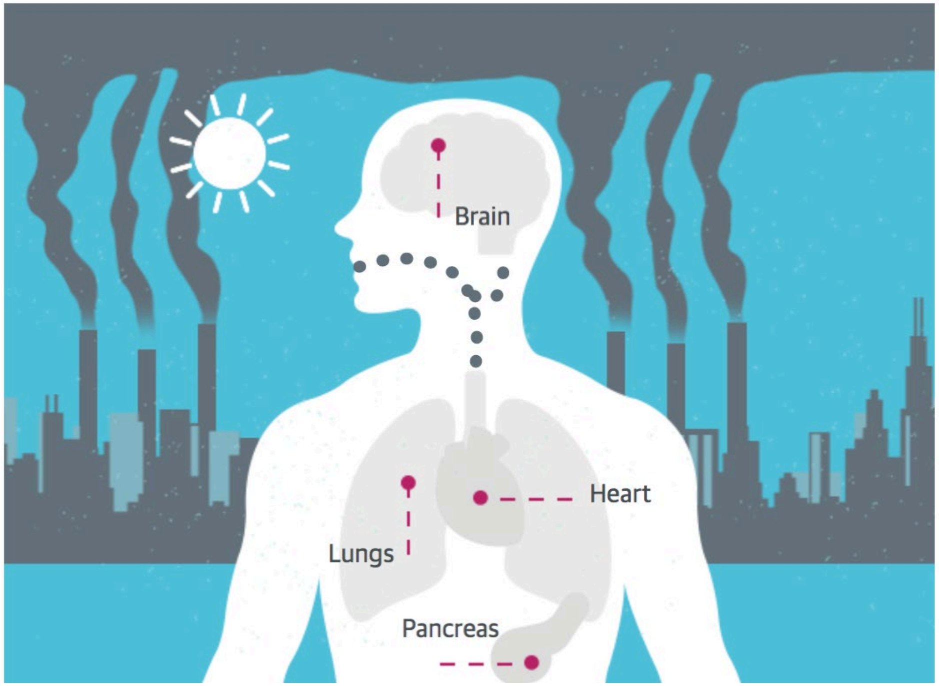
Particulate matter (PM)

Solid particles or liquid droplets in the air, primarily from road traffic. When smaller than 2.5 micrometers (that's 60 times thinner than a human hair), they are known as PM2.5. Larger particles, which could be dirt or dust stirred up from vehicles are known as PM10.

Metals, including lead, mercury, arsenic

Less of a problem in some countries due to controls on emissions. Iron and steel sectors dominate lead emissions, while disposal of treated wood by burning is source of arsenic.

Air pollution and health



RCP, 2016

Lungs

Suppresses normal lung growth in children. Accelerates lung function decline or an ageing lung in adults and a known cause of lung cancer. Also linked to onset of asthma.

Pancreas

Linked to onset of type 2 diabetes in adults.

Heart

Linked to the development of cardiovascular diseases, such as a stroke and heart disease, including atherosclerosis (furring of the arteries). Can also exacerbate existing conditions.

Brain

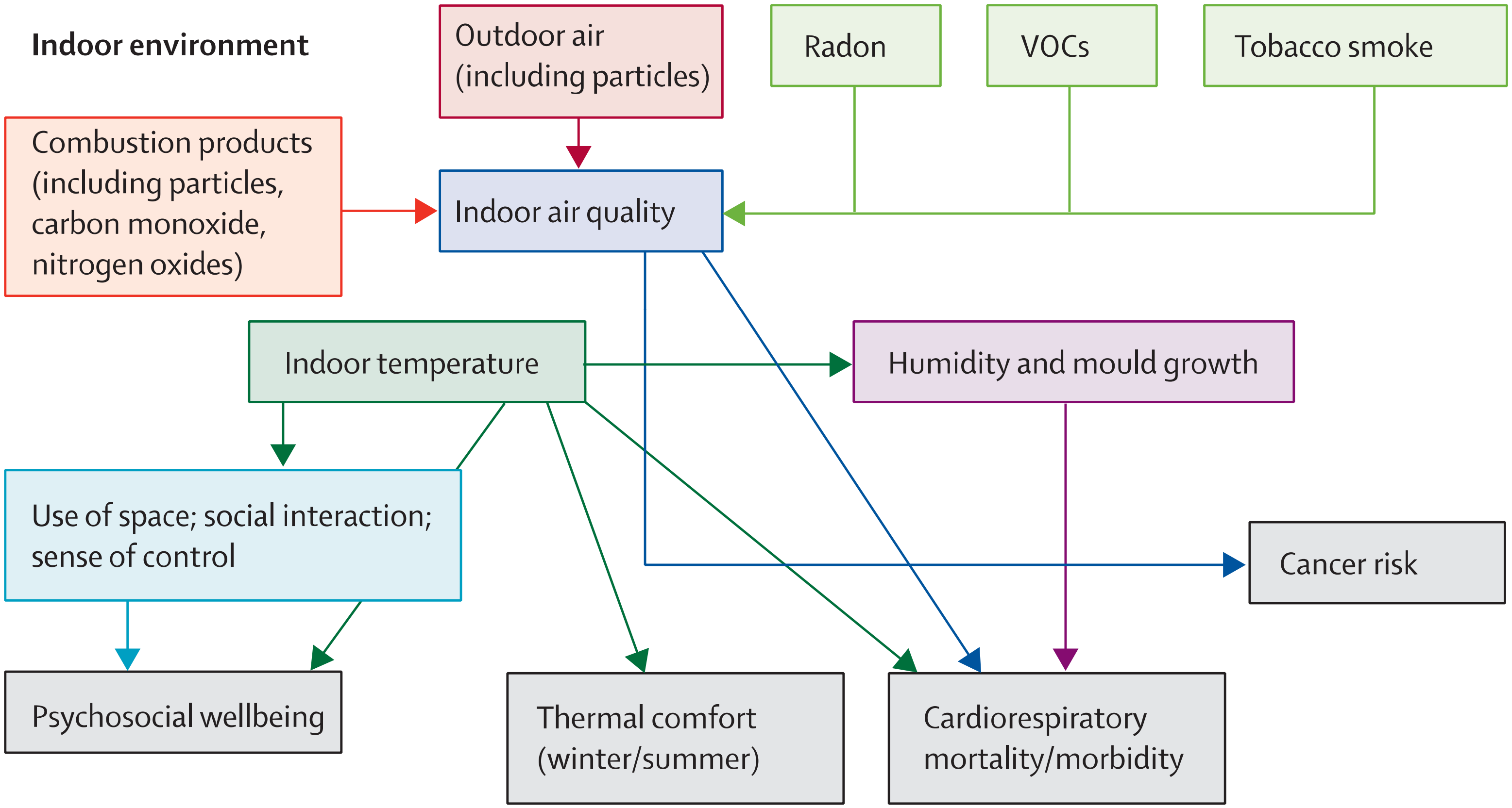
Exposure of pregnant women found to affect to fetal brain growth. Also impacts mental and physical development in children and cognition in adults.

Air pollution and health

Risk Factor	Annual attributable mortality in England	Deaths for which the risk factor is the main cause of death
Long-term exposure to particulate air pollution	25,000	Small number
Alcohol	22,481	6,000
Smoking	79,700	43,400

Buildings quality and health

Connections between building quality, energy and health

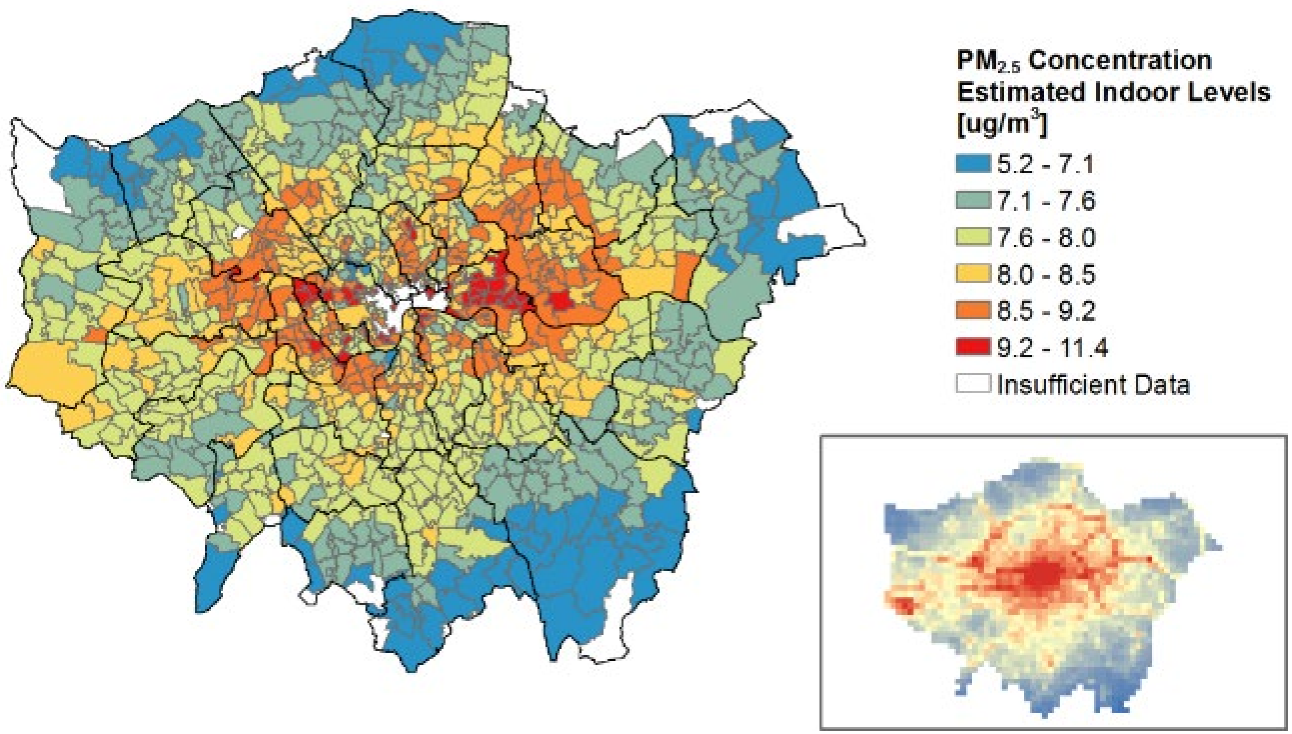


Source: Wilkinson, Lancet, 2009

Buildings and air pollution

Taylor et al 2011

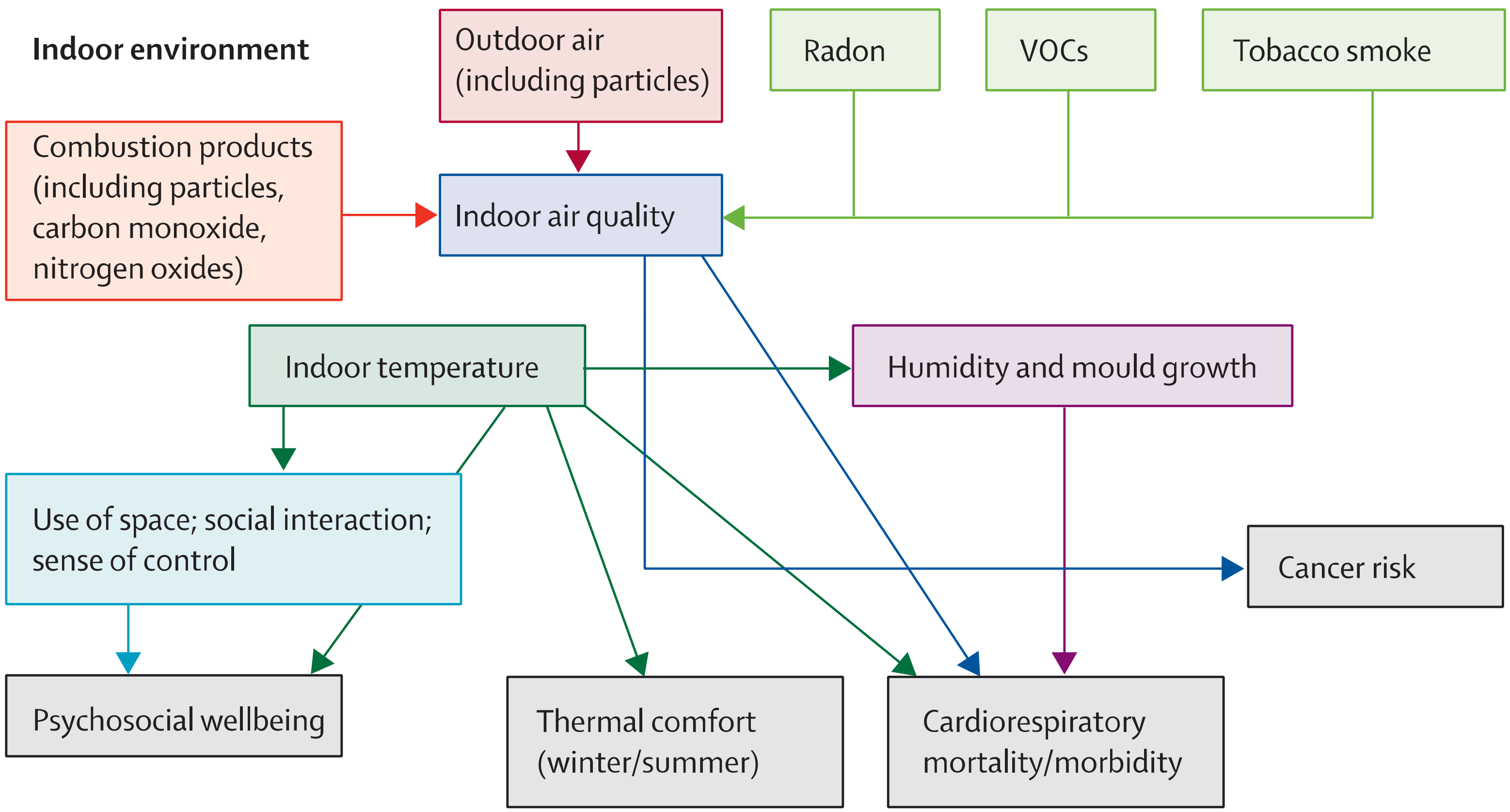
Urban pollution and outdoor air quality



Building stock models simulated for infiltration of outdoor pollutants (PM2.5) into the indoor environment.
Used to estimate the absolute indoor concentrations based on spatial and temporal variations in London background pollution levels.

Buildings quality and health

Connections between building quality, energy and health



Source: Wilkinson, Lancet, 2009

Energy efficiency and health

THE IMPACTS

Buildings and air pollution

Air pollution found inside homes and the workplace makes an important contribution to an **individual's overall exposure** to any given pollutant.

Indoor air pollution can be affected by outdoor concentrations, with air pollutants exchanged readily where buildings have poor insulation and high ventilation rates.

In the UK, **outdoor air quality has improved** over the past 40 years, **buildings have become more energy efficient**, with lower rates of air exchange.

A consequence has been that **indoor air pollution is increasingly decoupled from air quality outdoors**; it is now affected predominately by emissions and **activities occurring within buildings** themselves.

Buildings quality and health

Buildings act as a modifier for health, exacerbating or protecting against exposure to thermal stresses and air pollution.

Indoor environmental quality

- Indoor air quality and exposure to internal & external pollutant sources
- Exposure to heat and cold

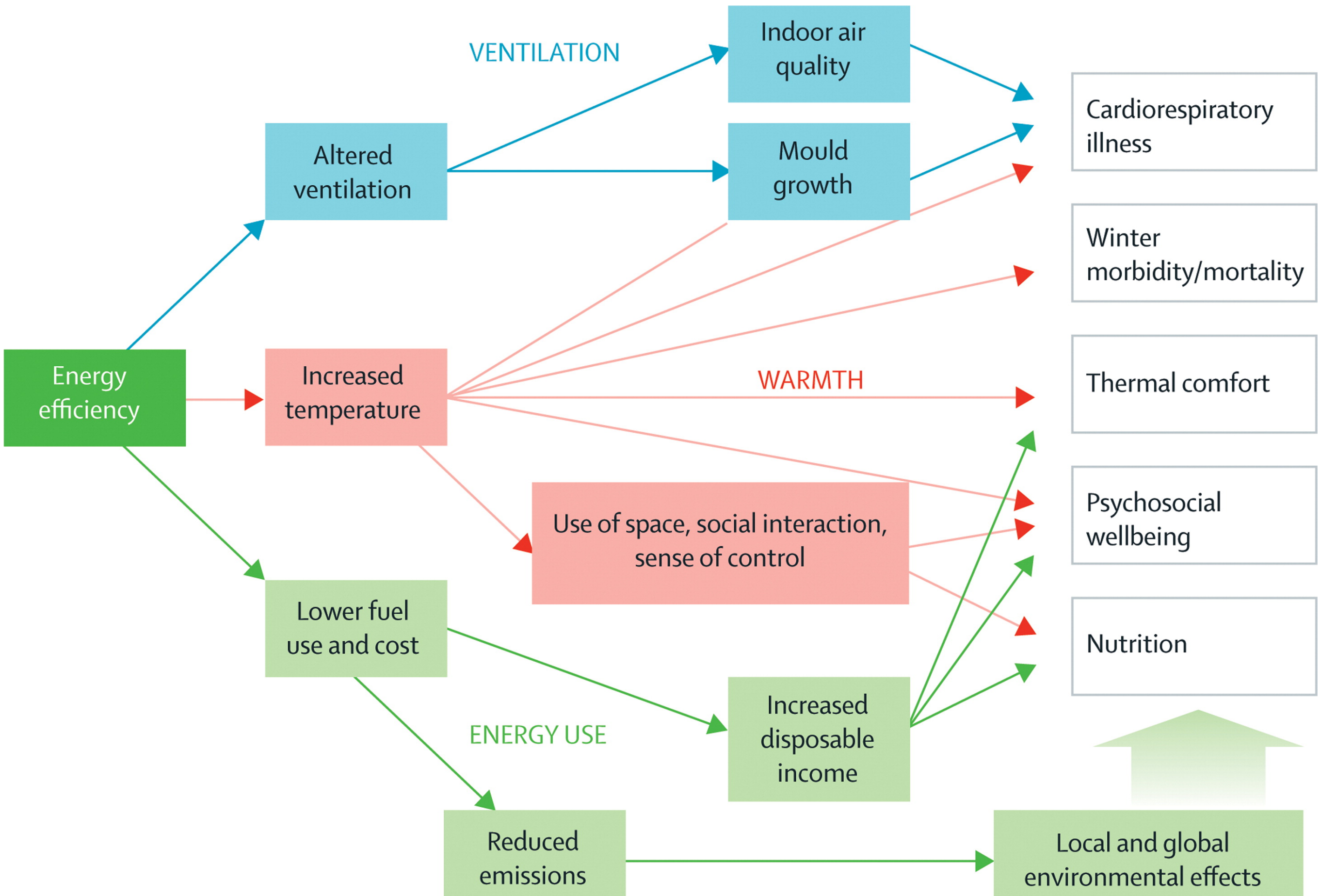
Energy use is a strong feature in modifying the indoor environment

- Energy for maintaining adequate indoor environment (ventilation, heating and cooling)

Population exposure to air pollution is typically evaluated using the outdoor concentration of pollutants and does not account for the fact that people spend a majority of their time indoors.

Buildings quality and health

Connections between building quality, energy and health



Energy, energy efficiency, and the built environment. Wilkinson et al 2007

Buildings quality and health

Category	Description
Thermal retrofit	Isolated measures aimed at improving the thermal performance of the building envelope, such as the installation of ceiling insulation and draught-proofing
Upgrade	Switch to more efficient space conditioning appliances
Refurbishment	Comprehensive strategy that addressed the thermal quality of the building envelope as well as its heating and cooling systems
Purposive refurbishments	Programme included thermal retrofit and upgrade measures in isolation or in combination; results were mostly pooled without differentiation of intervention measures
Low carbon refurbishment	Refurbishment approach that included the use of renewable energies and included mechanical ventilation systems with heat recovery

Sustainability Victoria, 2012

UCL Energy Institute

UCL

Energy efficiency and health

THE EVIDENCE

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...idemiology

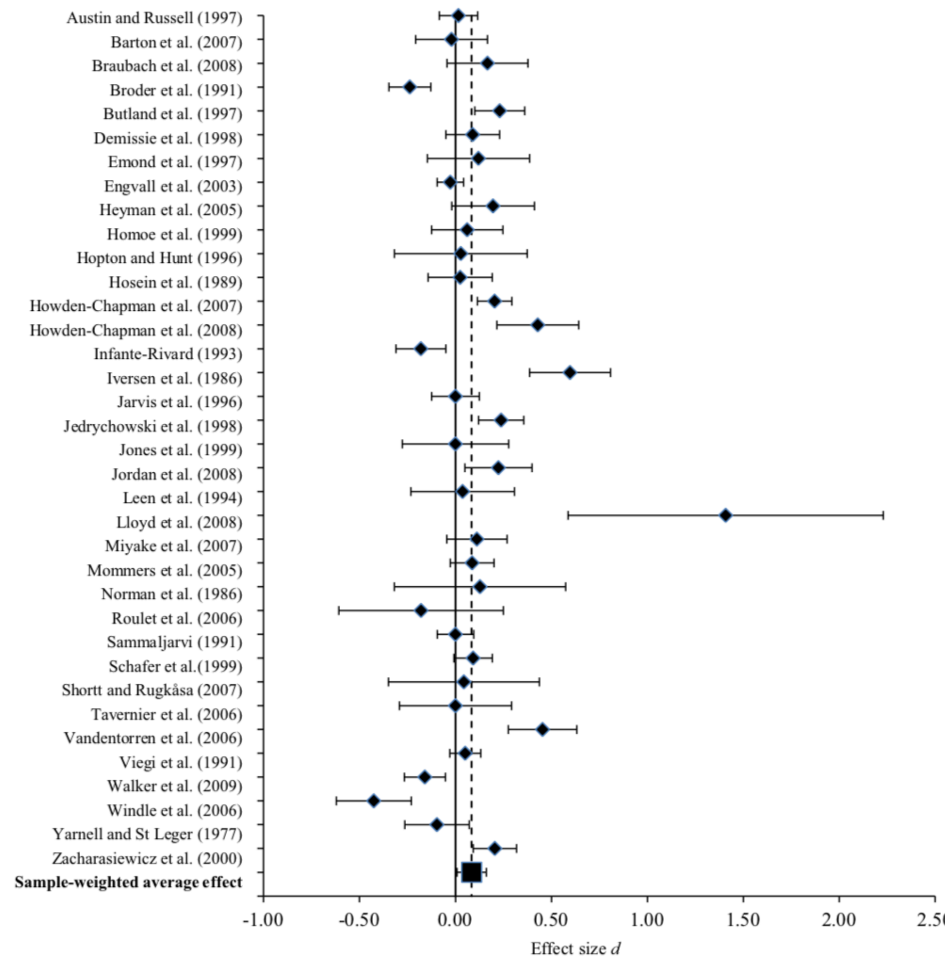
Research Councils UK Energy For a Low Carbon Future

The impact of household energy efficiency measures on health: A meta-analysis, Maidmont, et al 2014

Study systematically **quantify the impact of household energy efficiency measures on health and wellbeing**. Thirty-six studies, involving more than 33,000 participants were meta-analysed.

Effect sizes (d) ranged from -0.43 (a negative impact on health) to 1.41 (a substantial positive impact on health), with an overall sample-weighted average effect size (dþ) of 0.08.

On average, **household energy efficiency interventions led to a small but significant improvement in the health** of residents.



Towards explaining the health impacts of residential energy efficiency interventions: A realist review. Willand et al, 2015

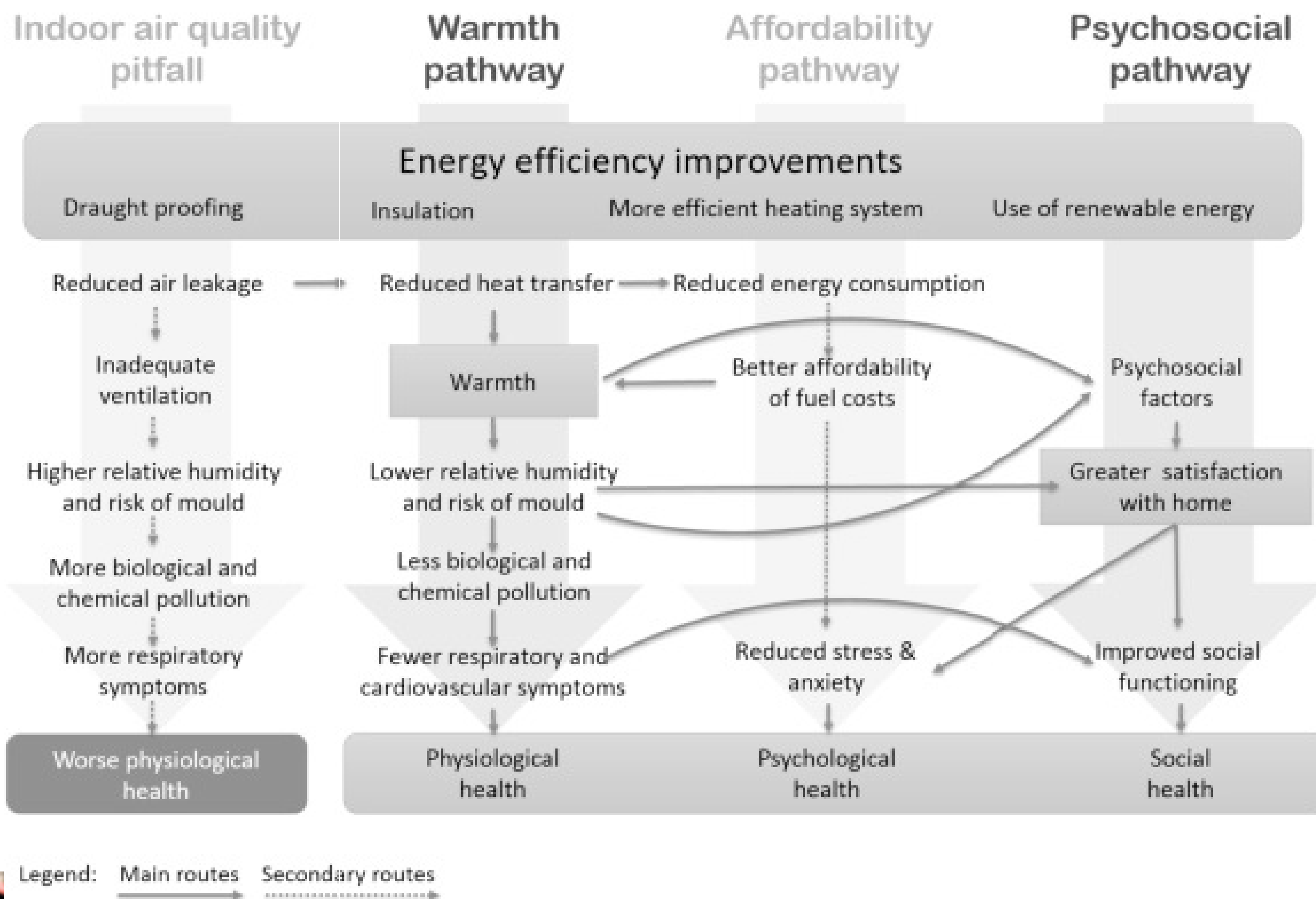
A realist review synthesised the results of 28 energy efficiency improvement programmes.

Reviewed the explanatory factors of three key pathways: **warmth** in the home, affordability of fuel and **psycho-social factors**, and inadequate **indoor air quality**.

The review revealed that residential energy efficiency **interventions improved winter warmth** and **lowered relative humidity** with benefits for **cardiovascular and respiratory health**.

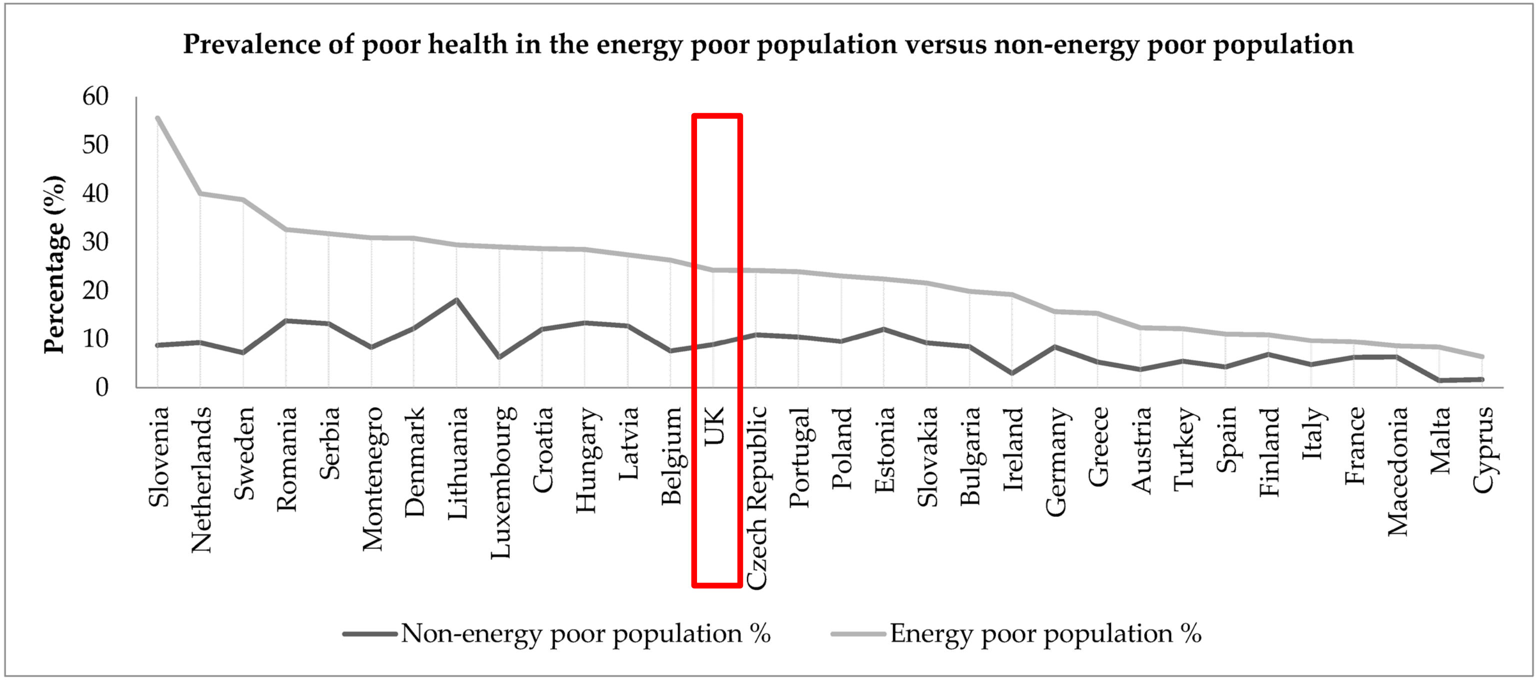
In addition, residential energy efficiency improvements consolidated the meaning of the home as a **safe haven**, strengthened the householder's perceived **autonomy** and enhanced **social status**.

Towards explaining the health impacts of residential energy efficiency interventions: A realist review. Willand et al, 2015



Health, Well-Being and Energy Poverty in Europe: A Comparative Study of 32 European Countries. Thomson et al, 2017

The paper investigates the relationship between energy poverty, health and well-being across 32 European countries, using 2012 data from the European Quality of Life Survey. The results show **uneven concentration of energy poverty, poor health, and poor well-being across Europe**, with Eastern and Central Europe worst affected.

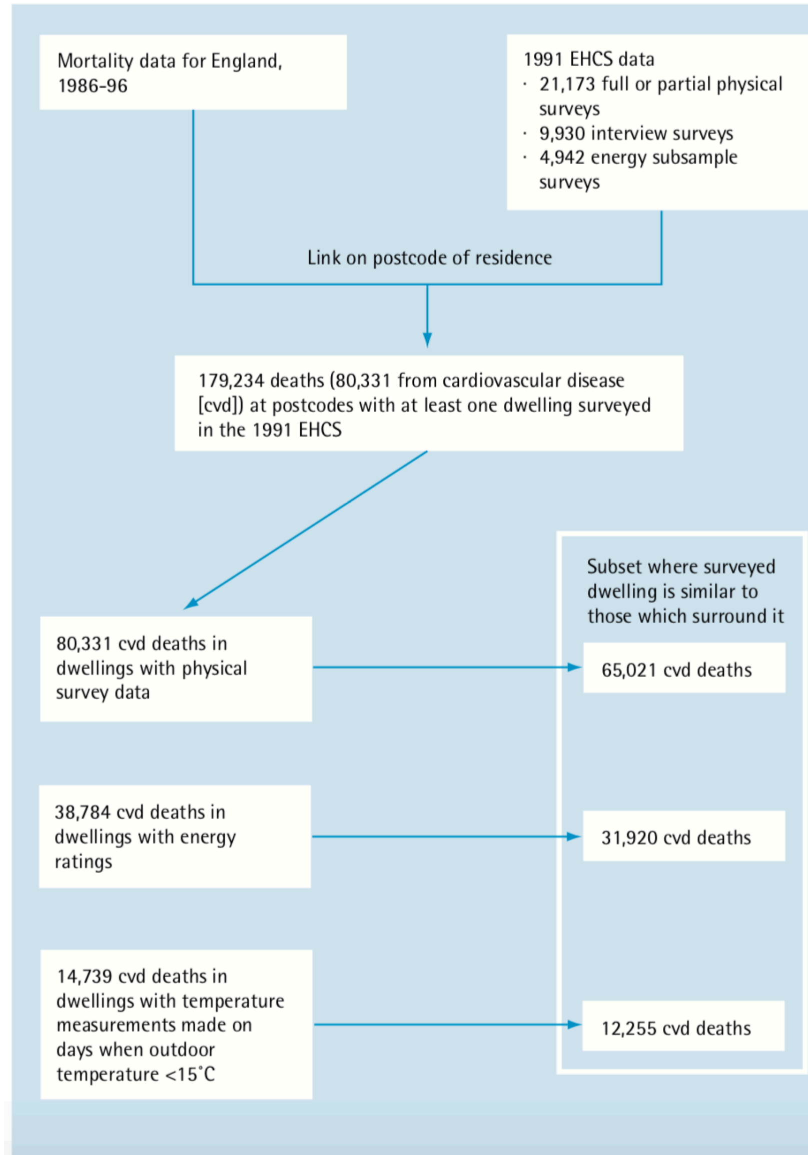


Cold comfort: The social and environmental determinants of excess winter deaths in England, 1986-96

The **winter excess is greater than in most other countries of continental Europe** and Scandinavia, despite the fact that Britain has comparatively mild winters.

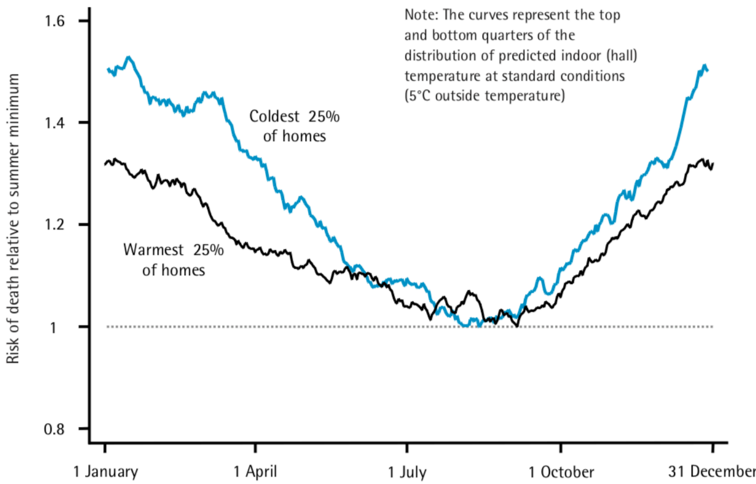
A partial explanation may lie in the **quality of our housing stock**, which is less thermally efficient than that in most other north European countries and hence may afford less protection against the cold.

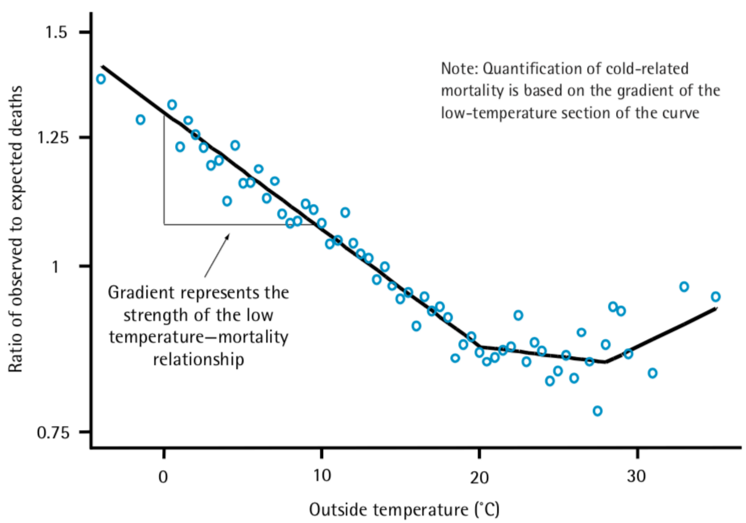
In the study, data on housing conditions from a **large national survey were coupled with routine mortality statistics** to examine whether vulnerability to winter death is related to housing quality and home heating.

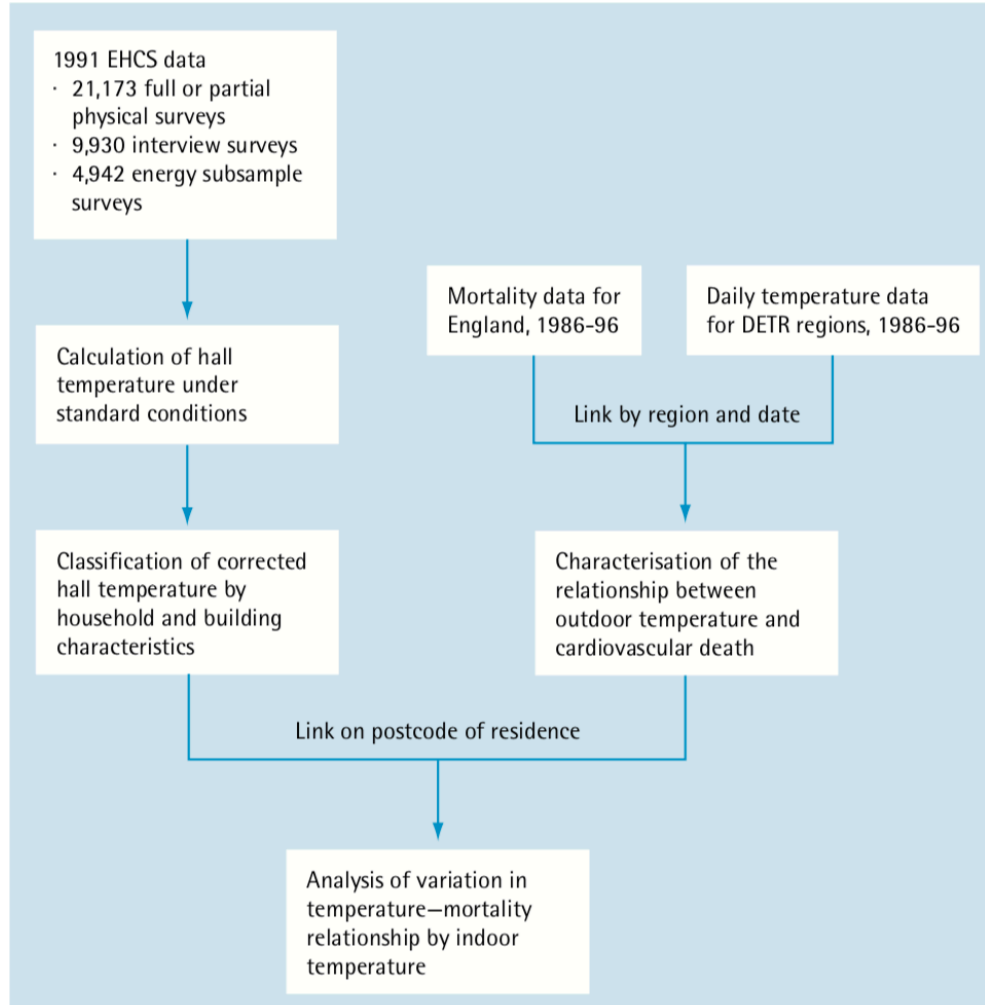


Thermal environment and health: the evidence

Cold comfort: The social and environmental determinants of excess winter deaths in England, 1986-96





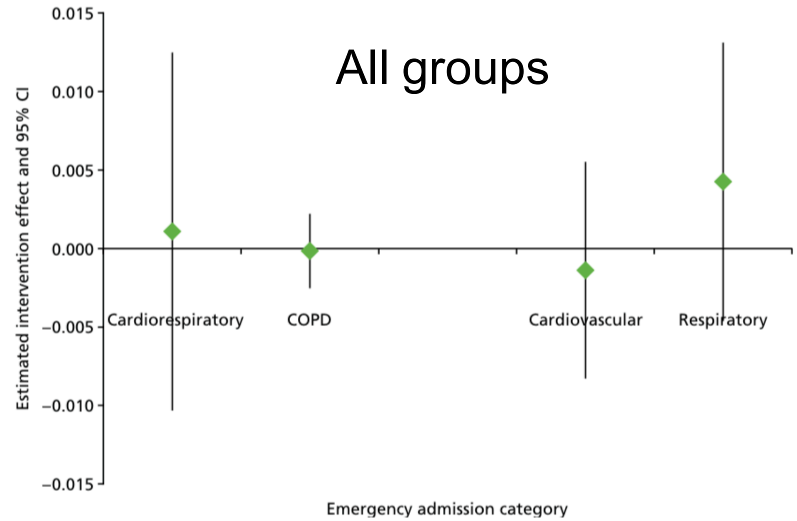


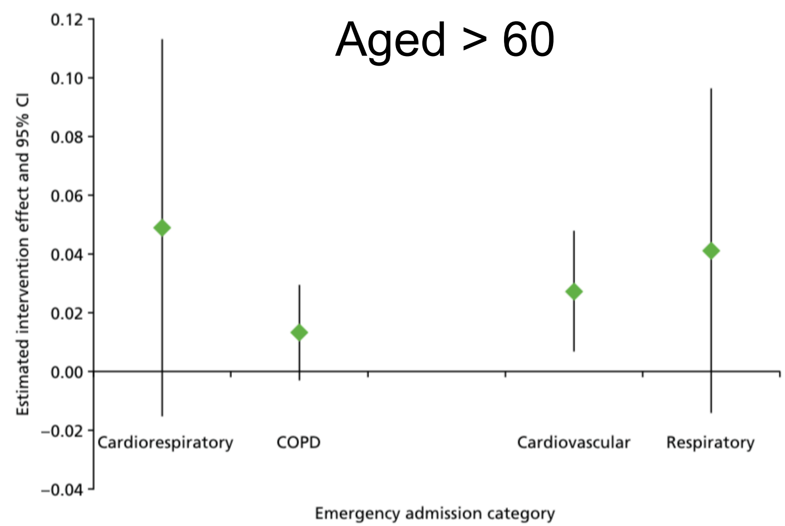
The health impacts of energy performance investments in low-income areas: a mixed-methods approach, Poortinga et al 2018

Energy efficiency measures contributed to people's **general well-being** by making homes warmer, and easier and cheaper to heat to a comfortable level.

Warmer homes also made people feel **less socially isolated**. However, we found no evidence that energy efficiency measures **improved people's mental and physical health**. Improving the energy efficiency of homes provides social and economic benefits to people living in them.

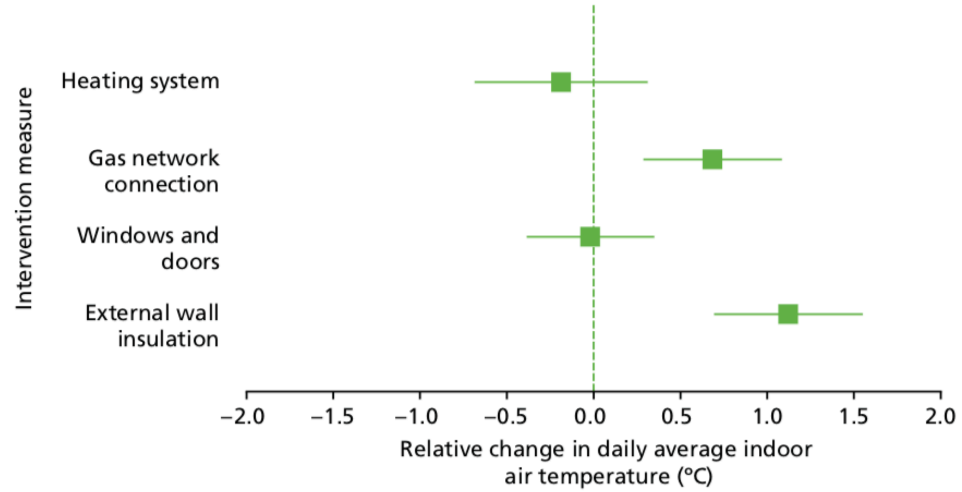
Area-based programmes **may not improve chronic health conditions**, reduce the number of hospital visits or reduce costs for the health service.



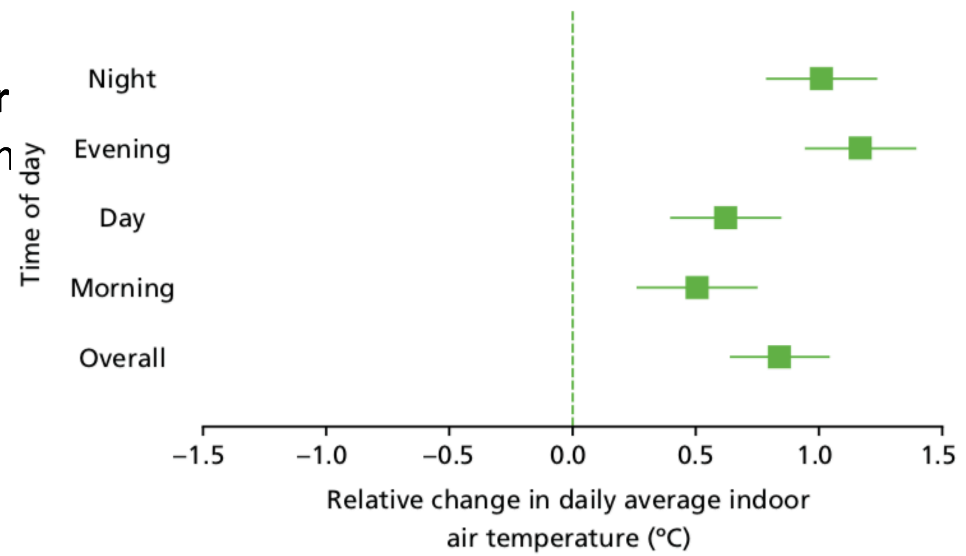


The health impacts of energy performance investments in low-income areas: a mixed-methods approach, Poortinga et al 2018

Secondary health impacts:
The impacts of the interventions on the secondary psychosocial outcomes showed that the intervention **had an impact on financial difficulties, thermal satisfaction, satisfaction** of the state of repair of the home, the number of housing problems and social interactions.



Indoor environmental impacts:
Interventions successfully **increased indoor air temperatures** (~1.0–1.5 °C) as long-term average increases, **reducing the potential exposure of substandard temperatures**: bringing the majority of temperatures within a 'healthy' zone of 18–24 °C.



Costs and outcomes of improving population health through better social housing: a cohort study and economic analysis, Bray et al 2017

An historical cohort study design of households were recruited by Gentoo, a social housing contractor in North East England and were asked to **complete a quality of life, well-being, and health service use questionnaire** before receiving housing improvements (new energy-efficient boiler and double-glazing) and again 12 months afterwards.

Results

Data were collected from 228 households. The average intervention cost was £3725. At **12-month post-intervention, a 16% reduction (−£94.79) in household 6-month health service use was found**.

Statistically significant positive improvements were observed in main tenant and household **health status** ($p < 0.001$; $p = 0.009$, respectively), main **tenant satisfaction** with **financial situation** ($p = 0.020$), number of **rooms left unheated** per household ($p < 0.001$), frequency of household **outpatient appointments** ($p = 0.001$), and accident/**emergency department attendance** ($p < 0.012$).

A pre and post evaluation of indoor air quality, ventilation, and thermal comfort in retrofitted co-operative social housing, Broderick et al, 2017

In comparison to building energy performance, assessment of the impact of energy upgrades on indoor air quality and occupant comfort has received little attention.

Concentrations of indoor air pollutants in fifteen, three bed semi-detached co-operative social dwellings were **monitored before and after an energy upgrade** during the winter periods of 2015 and 2016.

Building air tightness decreased from pre retrofit values of 9.26–10.00m3/(h.m2) @ 50 Pato an average of 5.53 m3/(h.m2) @ 50 Pa and 8.61m3/(h.m2) @ 50 Pa post retrofit (CW group and HB group, respectively).

The study highlights the importance of **characterising indoor air quality post energy retrofits** within the overall building energy performance to ensure improved health outcomes for building occupants post retrofit.

Cold homes, fuel poverty and energy efficiency improvements: A longitudinal focus group approach. Grey et al 2017

The longitudinal focus groups showed the importance of improving the energy efficiency of houses at risk of fuel poverty in low-income neighbourhoods.

Risk factors for fuel poverty contribute to **physical and emotional ill health**, and huge **financial stress** with associated problems of social isolation and the heat-or-eat dilemma, particularly in those with pre-existing ill health.

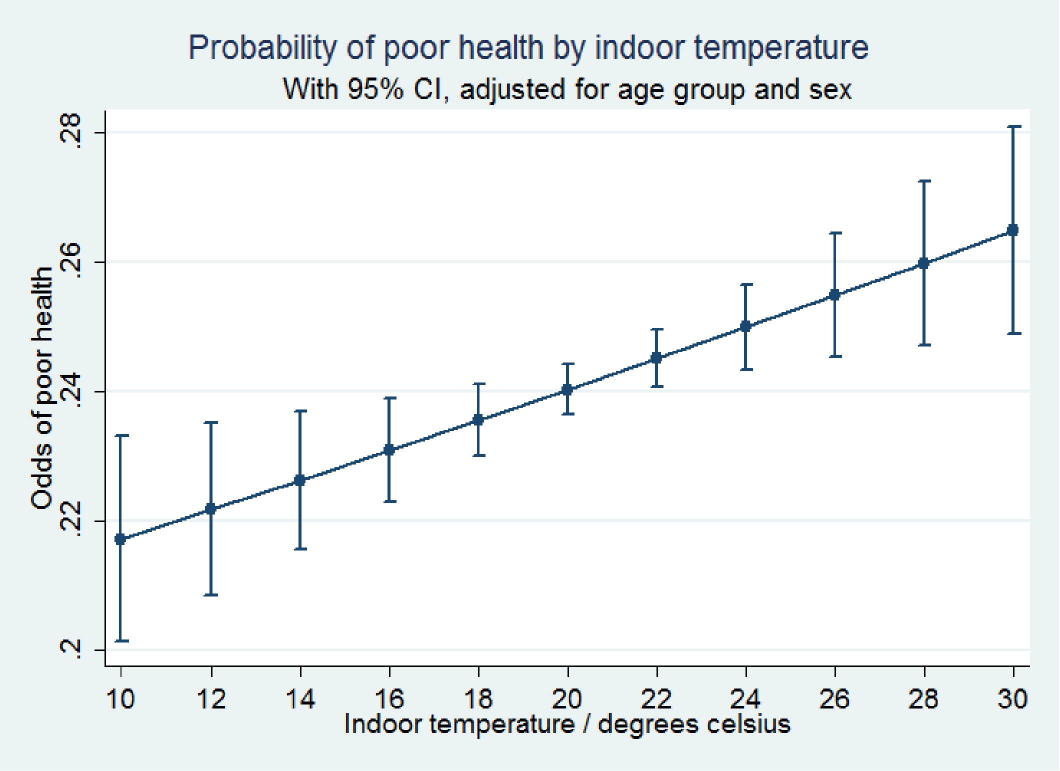
The results show clearly the detrimental effect of living in a cold home that is prohibitively expensive to heat because of fuel poverty risk factors, such as energy inefficient homes or expensive fuels. **Living in a cold home was viewed as depressing, stressful and detrimental to both mental and physical health, particularly for those with pre-existing ill health**.

According to the participants, the intervention measures to make the home more energy efficient made great improvements to the **comfort and warmth** of their homes, opened up spaces within the home and **substantially reduced heating bills**.

Associations between indoor temperature, self-rated health and socio-economic position in a cross-sectional study of adults in England, Sutton-Klein et al, 2019

Each one degree **increase in indoor temperature** was associated with a 1.7% (95% CI 0.7-2.6%) **increase in the odds of poor health**.

After controlling for the socioeconomic and housing factors, the OR of poor health for each degree increase in temperature increased by 19%, to 1.02 (95% CI 1.01-1.03 P<0.01).



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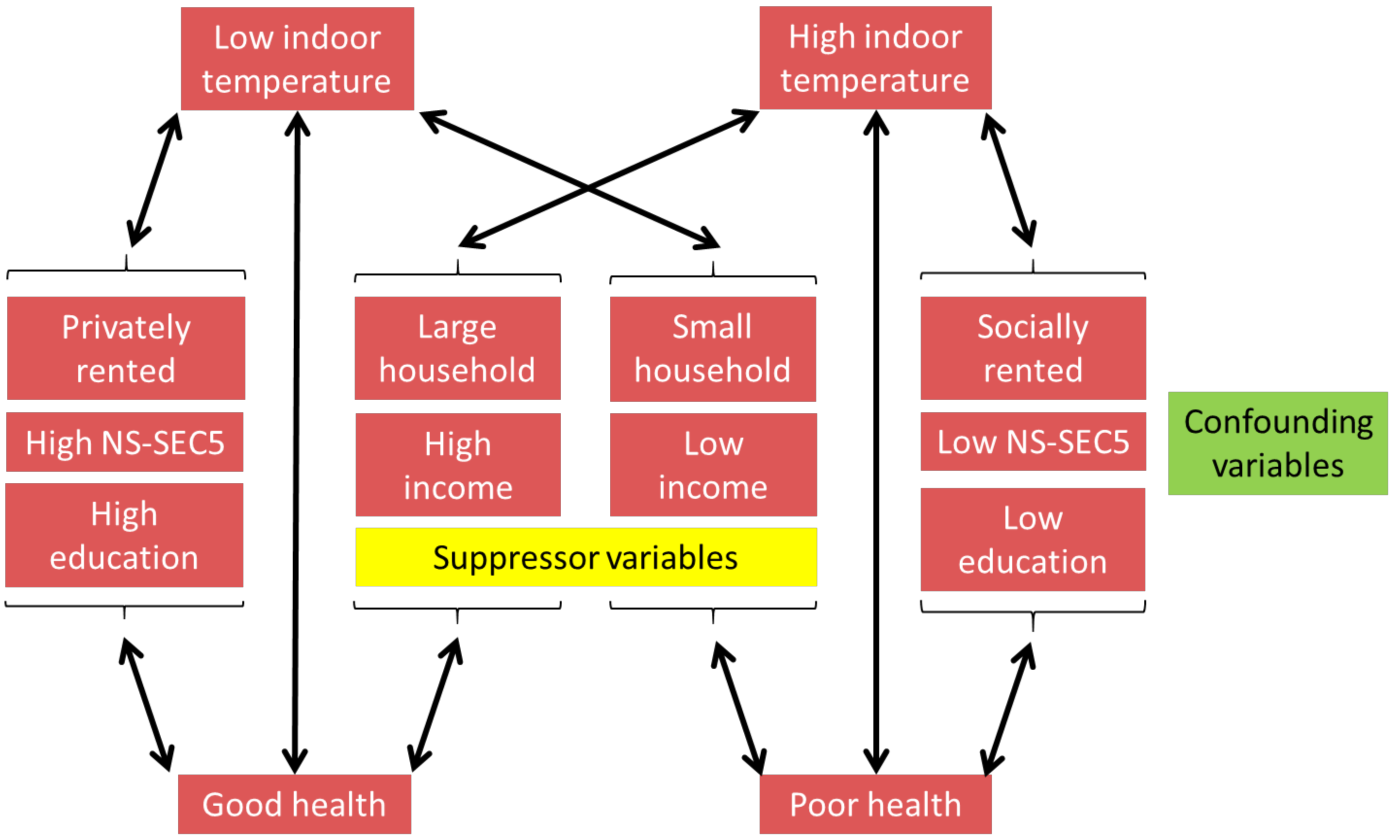


100 Unintended consequences of policies to improve the energy efficiency of the UK housing stock. Shrubsole et al. 2014

A scoping review identifying more than 100 unintended consequences impacting building fabric, population health and the environment.

Many impacts are connected in complex relationships. Some are negative, others possibly co-benefits for other objectives.

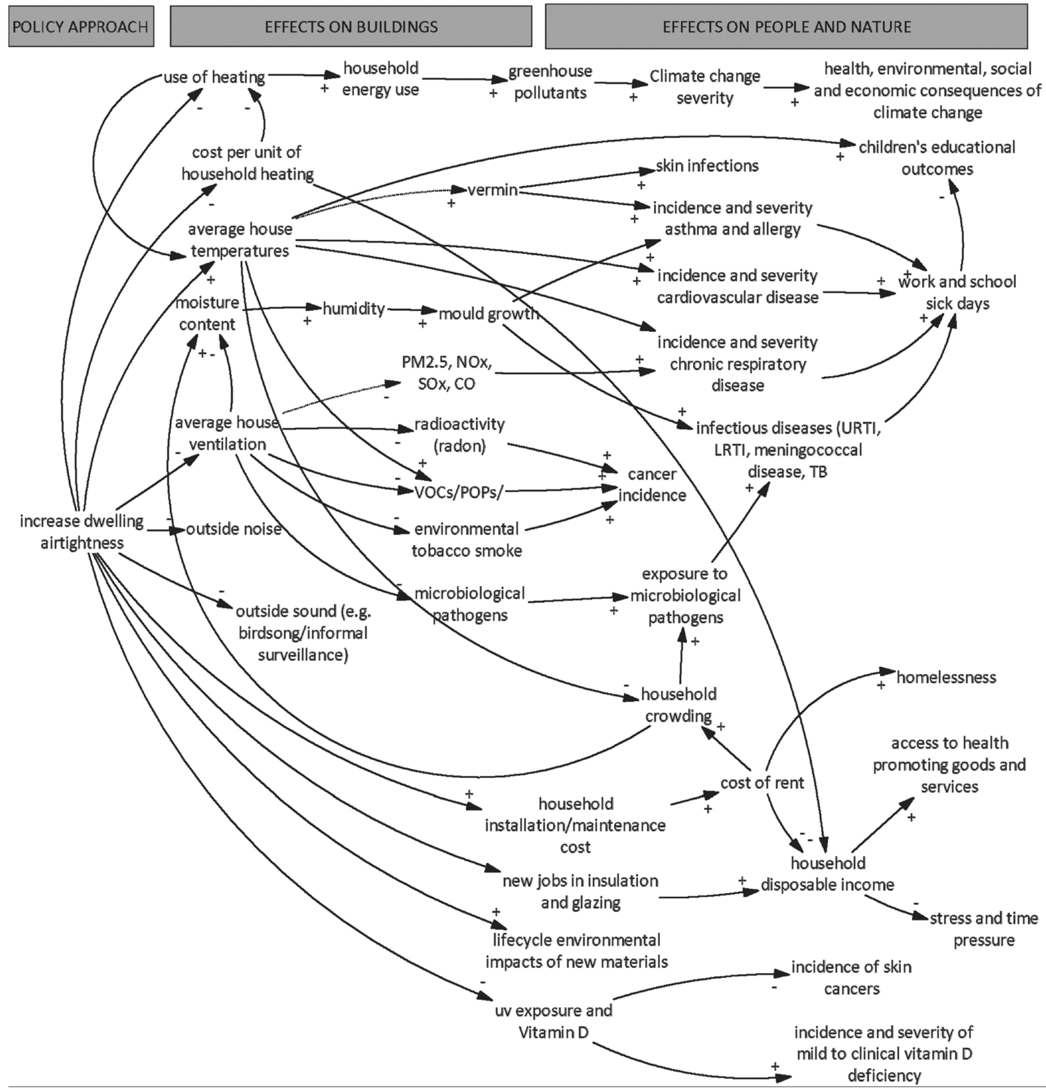
While there are likely to be unavoidable trade-offs between different domains affected and the emissions reduction policy, a **more integrated approach to decision making** could ensure co-benefits are optimised, negative impacts reduced and trade-offs are dealt with explicitly.

	Direction of influence			
Domain	+ve	−ve	+/−ve	Totals
Physical health	16	47	13	76
Mental health	4	4		8
Psychological well-being	9	5	2	16
Child development	1	1		2
Social cohesion		3		3
Social inequalities		1		1
Social mobility		2		2
Occupant behaviour		1	2	3
Household finances		2	1	3
General economic	9	1	2	20
Building fabric	1	17	2	20
Legal		3		3
Environmental	7	31	9	47
Totals	47	118	31	196

Domains of impact and their direction of influence.

100 Unintended consequences of policies to improve the energy efficiency of the UK housing stock. Shrubsole et al. 2014

The complex links arising from the policy of promoting airtightness in the domestic stock and the impact on buildings, people and the wider environment.



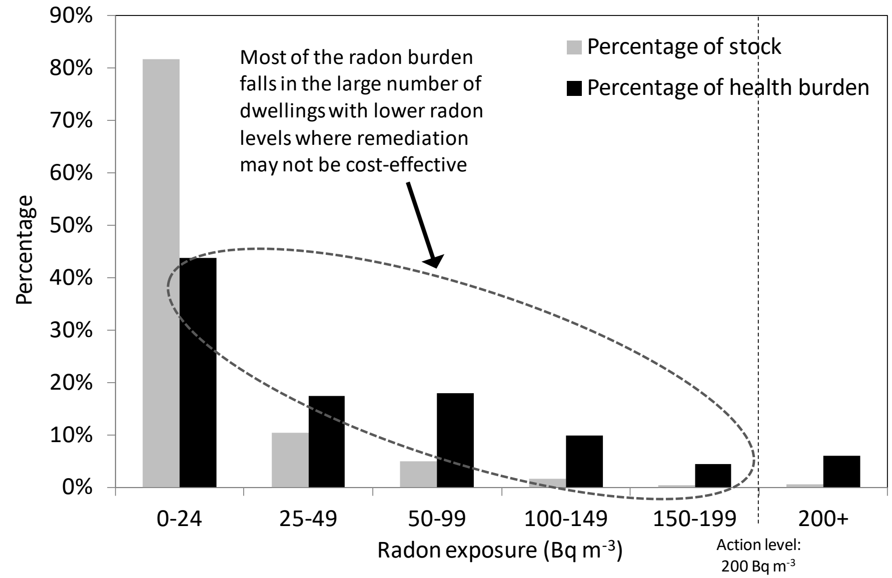
Energy efficiency and health

STRENGTHENING THE EVIDENCE

Buildings quality and health

Energy efficiency in buildings is a major target for climate change mitigation strategies and is likely to have a significant **impact on the thermal and air quality** conditions experienced by occupants.

Although there is **potential for improvements in health** related to temperature there may **trade offs for indoor air quality**



Proportions of current housing stock and attributable burden of radon-related lung cancer mortality for different radon exposures.

Buildings quality and health

UK's **ventilation guidance** for retrofits is very **unclear**.

The approved documentation used for compliance with the building regulation offer only limited guidance on **determining adequate ventilation** during works.

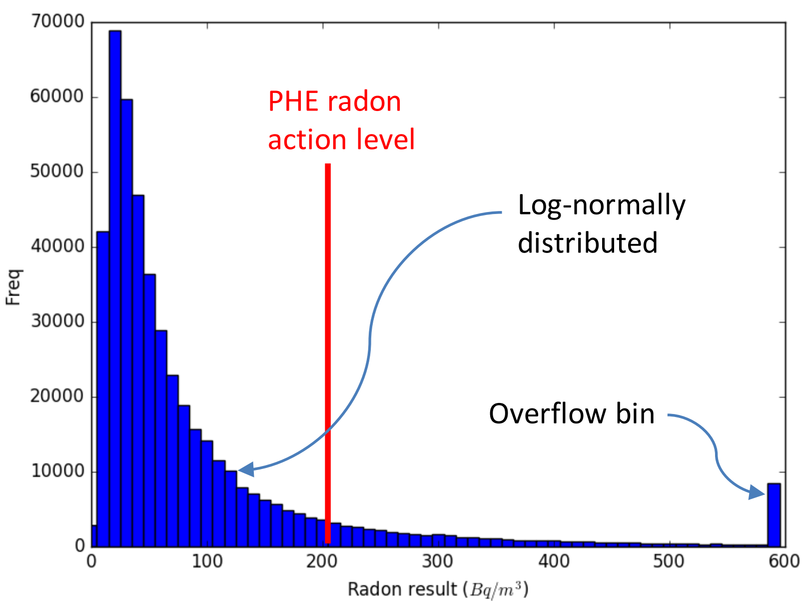
No guidance for determining the ventilation characteristics or **air quality in advance of, or following**, a retrofit.

The provision of ventilation measures is ultimately left to the **discretion of the installer or household**.

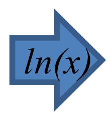
If **outdoor pollution is minimized** with mitigation measures, exposure to **indoor pollutants** will comprise the **majority of occupant exposure**.

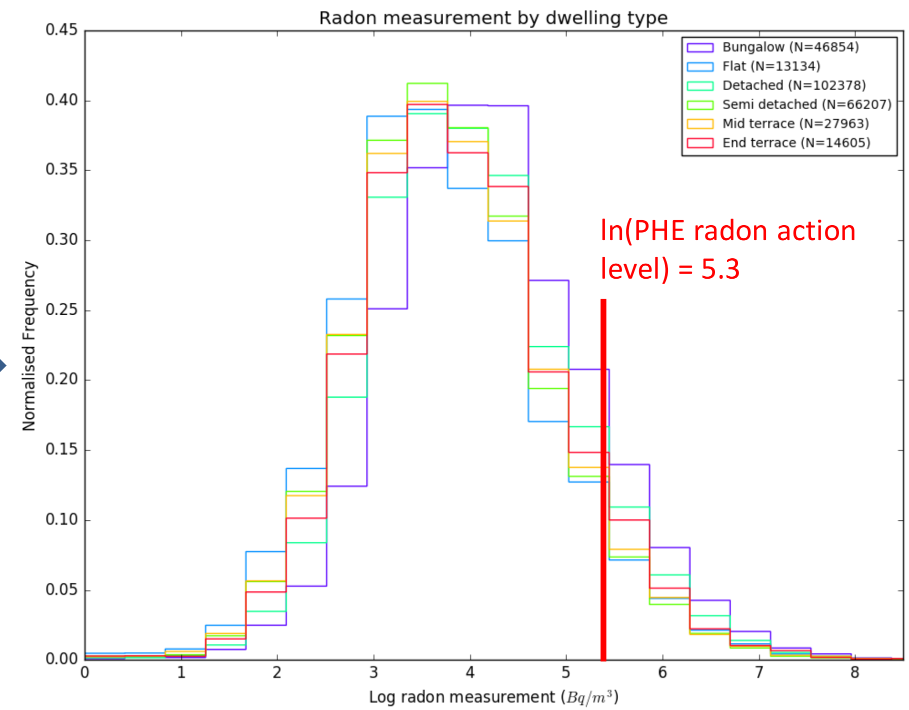
Buildings quality and health

A case of radon exposure in the UK and energy efficiency.



Histogram of all radon measurements in the HEED-radon dataset





Buildings quality and health

A case of radon exposure in the UK and energy efficiency.

Region: South West

Urban class: minor conurbations

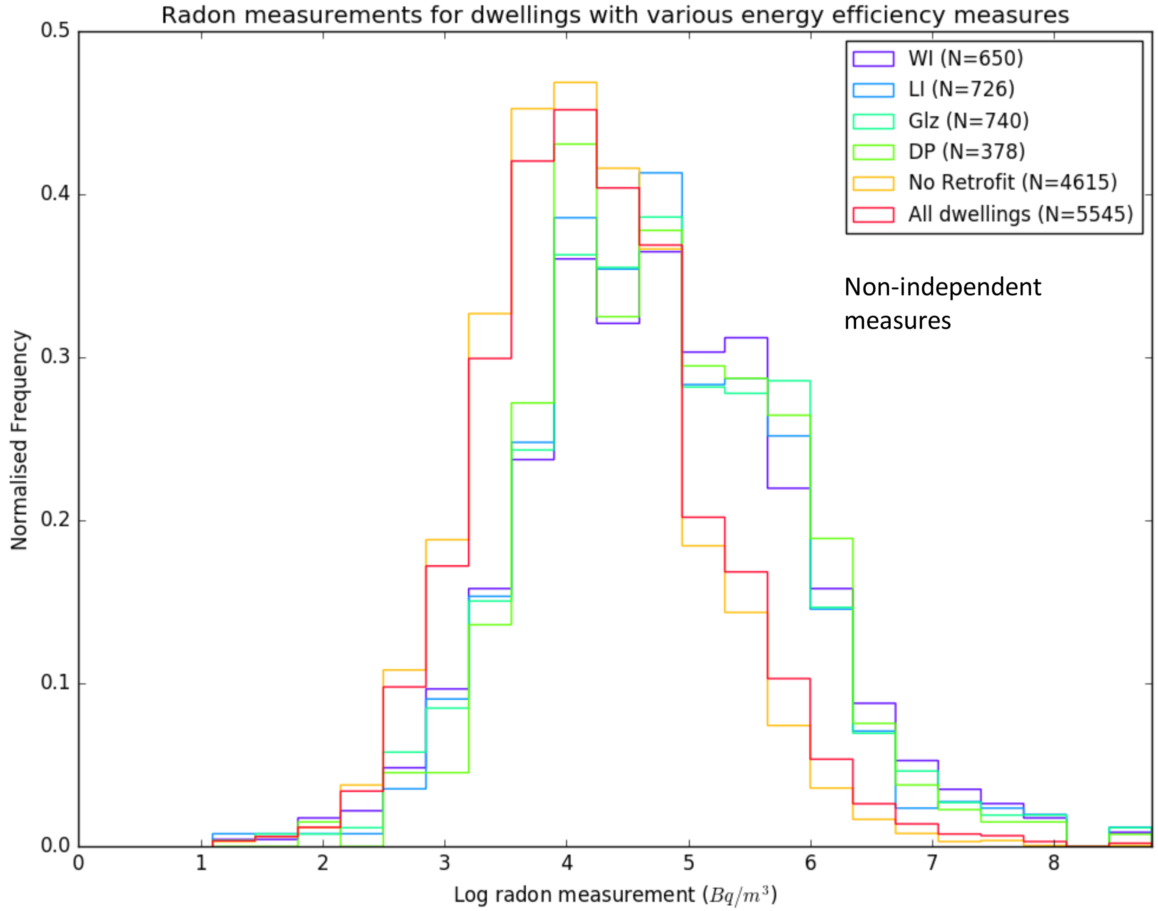
Detached homes (not bungalow)

Main fuel: Gas fired

Cavity walls

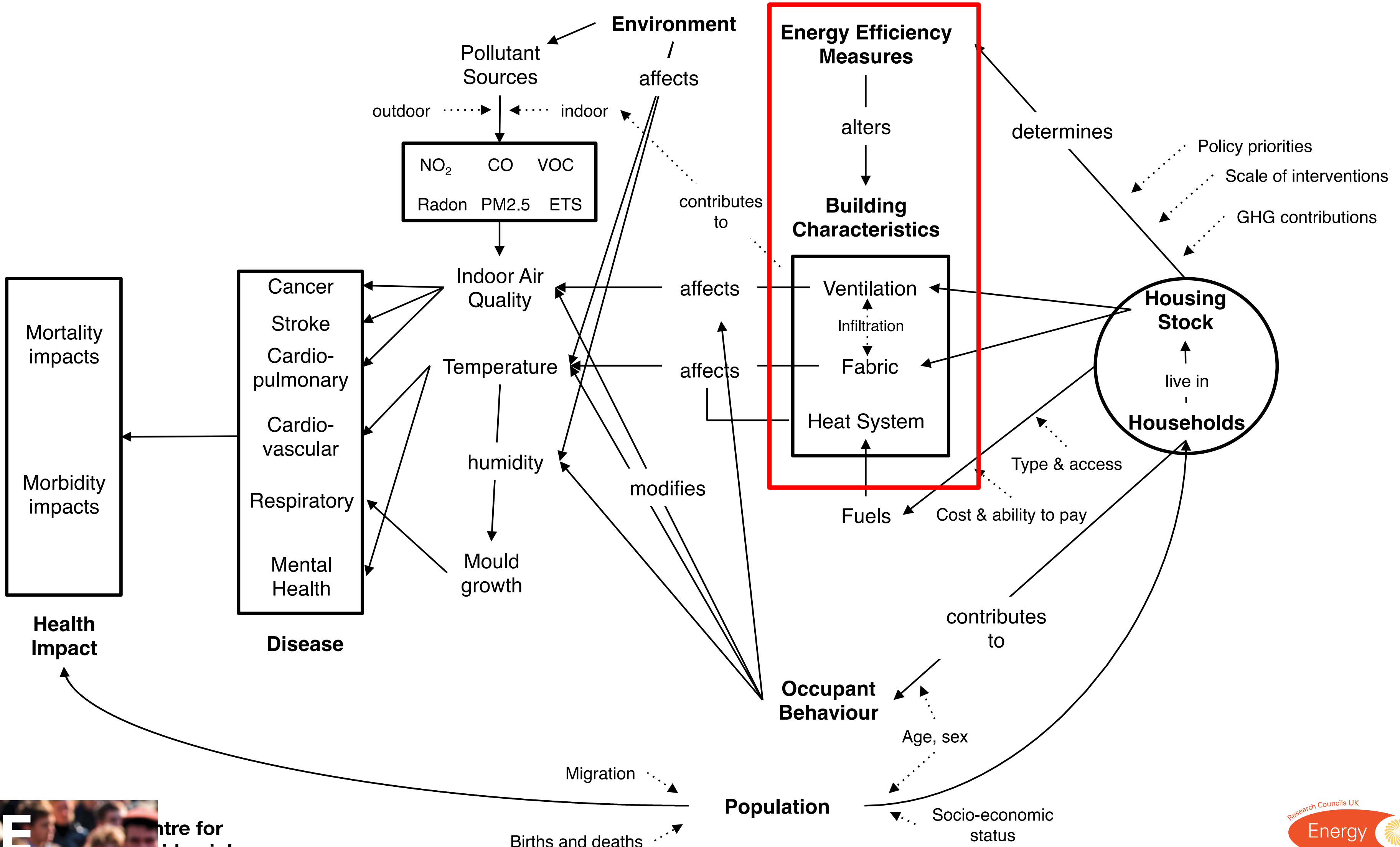
Owner occupied

Built pre 1990



Buildings quality and health

http://dx.doi.org/10.1136/bmjopen-2014-007298



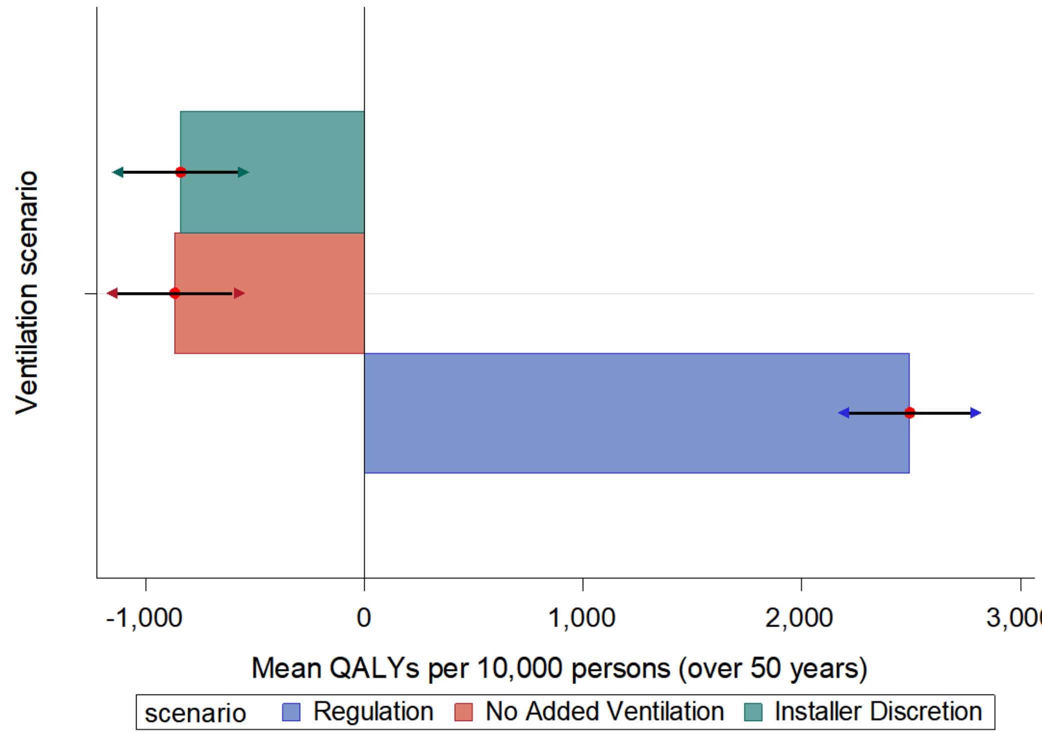
Buildings quality and health

A UK study showed

- **Scenario (1)** had positive effects on net mortality and morbidity of 2,241 QALYs per 10,000 persons over 50 years due to improved temperatures and reduced exposure to indoor pollutants, despite increase in exposure to outdoor–generated $PM_{2.5}$.

- **Scenario (2)** resulted in -539 QALYs per 10,000 persons due to an increase in indoor exposures despite targeting.

- **Scenario (3)** resulted in a negative impact of -728 QALYs per 10,000 persons due to an overall increase in indoor pollutant exposures.



Buildings quality and health

A UK case study of building retrofit

	Fabric & heating improvements	
Intervention	**No added ventilation**	**Added ventilation**
Total intervention cost (£)	102,970,000,000	123,545,000,000
Mean intervention cost (£)	5433	6525
Max intervention cost (£)	31417	32781
Energy Savings		
Mean energy savings (kWh)	2,690	2,436
Mean energy savings (£)	156	142
Total energy savings (£)	3,077,271,447	2,783,932,967
Health Impacts After 42 years		
NHS Costs (£)	24,134,214	-226,409,211
Morbidity Costs (£)	111,818,516	-11,288,773,057
Mortality Costs (£)	3,423,034,652	-123,804,894,465
Health Impact Costs (£)	3,558,987,381	-135,320,076,733
Per capita Health Impacts After 42 years		
NHS Costs (£/person)	0.52	-4.91
Morbidity Costs (£/person)	2.4	-244
Total Mortality Costs (£/person)	74.3	-2686
Health Impact Costs (£/person)	77.2	-2936

Research on the health impact of energy efficiency retrofits and financial payments in the UK

Health Survey for England
(1994-2012)
N= ~14-21,000 per year

Homes Energy Efficiency Database
(1996-2012)
N= 16.8 million total

MetOffice External Temperatures
(1994-2014)

English Longitudinal Study of Ageing
(2002-2014)
N= ~12,000 total

HIDEEM Health Impact Model
(based on English Housing Survey)

Energy Follow-Up Study 2011
N= 2,200

National Energy Efficiency Data-Framework
(2006-2013)
N= 23 million total

HSE+
- Energy efficiency retrofits
- Temperature (indoor/outdoor)
- Fuel payments
- Energy use (modelled)
- Health

ESLA+
- Energy expenditure
- Energy use (modelled)
- Energy efficiency retrofits
- Temperature (indoor/outdoor)
- Fuel payments
- Health

EFUS+
- Energy expenditure
- Energy use
- Energy efficiency retrofits (modelled change)
- Fuel payments
- Temperature (indoor/outdoor)
- Health impact (modelled)

NEED+
- Energy use
- Energy efficiency retrofits
- Temperature change (modelled)
- Health impact (modelled)

Objective 1: interventions impact on energy use and fuel expenditure

Objective 2: interventions impact on wintertime indoor temperature

Objective 3: thermal environment impact on health

Objective 4: intervention impact on health

Objective 5: Recommendations for temperature and health

Objective 6: Economic effectiveness and benefit of interventions

Energy efficiency and health

CONCLUSIONS

Buildings quality and health: Implications

The built environment has **significant impact on health** via, for example, **indoor environmental** quality (a function of both the quality of a building and its immediate urban environment)

Appropriate **interventions to improve health** can coincide with responses to **climate change** (adaptation and mitigation) and the desire for energy security

The complex nature of the impact of such interventions means that the possibility of **negative unintended consequences** exists

However, there is increasing **acknowledgement and understanding of this complexity**. The success of relevant policies is not dependant on a capricious and unpredictable reality – rather that the reality is amenable to study, of which we must do more.

Key messages:

Energy efficiency retrofits is the largest natural experiment being undertaken in UK households and the impacts on health need to be known.

There are numerous pathways that energy efficiency retrofits can affect health, cardio respiratory, cardiovascular and mental health.

Methods for determining the health impacts requires careful planning and execution.

Retrofit programmes have delivered qualitative benefits to households but the extent of the impact is not straightforward to attribute.

There is evidence to show that with careful planning, the continued future role out of retrofits can result in appreciable health benefits.

Questions:

Does the argument of the health benefits of energy efficiency really work?

What evidence do policymakers need to make the case for programmes and regulations that protect health through energy efficiency retrofits?

What actions do those working on housing retrofits need to prioritize to achieve beneficial health outcomes?

What key messages need to be taken forward to ensure that health benefits are achieved when implementing retrofit programmes?

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THANK YOU

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