

### Checklist for reporting modelling studies

Dimension of Quality	Reporting item	YES/NO	Notes
<b>STRUCTURE</b>			
Decision problem/objective	Is there a clear statement of the decision problem?	YES	The decision problem is stated in the third paragraph of the Introduction (paragraph beginning "While current English building regulations...")
	Is the objective of the evaluation specified and consistent with the stated decision problem?	YES	Though not a strict evaluation the objective of the study is set out in the last paragraphs of the introduction, with the line beginning "We do this to characterize..."
	Is the primary decision-maker specified?	YES	The paper is examining a point of principle relevant to many bodies and decision-makers, including individual householders. Guidance notes on retrofitting of properties are issued by various bodies including independent agencies such as the Institute for Sustainability. Some, but not all, aspects are covered by building regulation. We suggest the UK Government as the key target as it is responsible for many aspects of guidance and regulation.
Scope/perspective	Is the perspective of the model clearly stated?	YES	The perspective is stated in the first paragraph of the Methods section.
	Are the model inputs consistent with the stated perspective?	YES	The model inputs are described (and referenced) in the Methods section (pages 5 to 7). They relate to the characteristics of the housing stock, and in particular to changes in the distribution of dwelling air permeability, which are described and justified (see, in particular, page 5). The basis for assumptions about thermal and indoor sources of pollutant emission rates is referenced (see references 11,18-20 & 23). Life-table data are based on

			published sources as described (see page 6).
	Are definitions of the variables in the model justified?	YES	See above.
	Has the scope of the model been stated and justified?	YES	Described in the Methods.
	Are the outcomes of the model consistent with the perspective, scope and overall objective of the model?	YES	The main outputs of the model are distributions of indoor temperature and air pollutant exposures (i.e. radon, mould risk, PM2.5 from indoor and outdoor sources, and second-hand tobacco smoke) changes in the population and population-level health impacts (see for example tables 1 and 3).
Rationale for structure	Is the structure of the model consistent with a coherent theory of the health condition under evaluation?	YES	It is established that reducing home ventilation may increase indoor air pollutants and that these pollutants pose a risk to health through a number of established health outcomes (page 5). Therefore, to evaluate the intervention it is necessary to combine a building stock model, an exposure model and a health impact model.
	Are the sources of data used to develop the structure of the model specified?	YES	References are provided for all data sources used to inform the development of the scenarios (see pages 5 and 6).
	Are the causal relationships described by the model structure justified appropriately?	YES	See above.
Structural assumptions	Are the structural assumptions clearly stated and justified?	YES	There are many structural assumptions. These are justified (and referenced) throughout the Methods section. In particular, the broad structure of the model is described at the start of the section. We further test structural uncertainty in the work.
	Are the structural assumptions reasonable given the overall objective, perspective and scope of the model?	YES	The structure used (the combination of three sub-models: a building stock model, a model of exposure and a population-level health impact model) is required to make

			predictions of the type presented in the paper.
Strategies/comparators	Is there a clear definition of the options under evaluation?	YES	The options under evaluation are the three scenarios described in the section titled "Modelling Application".
	Have all feasible and practical options been evaluated?	N/A	The paper presents three potential future scenarios covering a range of plausible strategies. Innumerable variants are possible, but the scenarios specified illustrate the main options.
	Is there justification for the exclusion of feasible options?	N/A	No major categories of alternative options have been excluded.
Model type	Is the chosen model type appropriate given the decision problem and specified causal relationships within the model?	YES	See above.
Time horizon	Is the time horizon of the model sufficient to reflect all important differences between options?	YES	See page 5 and table 3. We show evidence of health impacts over a time course that allows for the evolution of selected disease risk with appropriate onset lag.
	Are the time horizon of the model, the duration of treatment and the duration of treatment effect described and justified?	YES	The interventions are assumed to occur instantaneously. The time horizon of the modelled health impact is 50 years, in order to cover the lifetime of the interventions and allow for sufficiently long disease development.
Disease states/pathways	Do the disease states (state transition model) or the pathways (decision tree model) reflect the underlying biological process of the disease in question and the impact of the interventions?	YES	We used a standard life table. The relationships between indoor air pollutant exposure and cardio-respiratory and lung cancer mortality are well established and described in Table 1.
Cycle length	Is the cycle length justified?	N/A	
Parsimony	Is there indication that the structure of the model is as simple as possible and that any simplifications are justified?	NO	More simple (or more complex) exposure models can be used to study radon. However, these would not be appropriate to model the distribution of exposures at the population level. Simpler health models would not have captured the time-varying nature of the

			health impacts.
<b>DATA</b>			
Data identification	Are the data identification methods transparent and appropriate given the objectives of the model?	YES	All data sources are listed and referenced in the Methods section (pages 5 to 7).
	Are results reported in a way that allows the assessment of the appropriateness of each parameter input and each assumption in the target settings?	N/A	
	Where choices have been made between data sources, are these justified appropriately?	N/A	The most recent version of the housing survey at the time of the model development was used to specify the building stock model. Other data, including the baseline mortality data from ONS (see page 5), were chosen to match the year of this survey as closely as possible.
	Where data from different sources are pooled, is this done in a way that the uncertainty relating to their precision and possible heterogeneity is adequately reflected?	N/A	
	Are the data used to populate the model relevant to the target audiences (i.e., decision-makers) and settings?	YES	All data sources are listed and referenced in the Methods section. These data are commonly used in assessments by, e.g., the Department of Energy and Climate Change.
	Has particular attention been paid to identifying data for the important parameters in the model?	YES	The basis of the building stock model was the English Housing Survey 2010 (5). The baseline health data were obtained from ONS (page 5).
	Has the quality of the data been assessed appropriately?	YES	All data are from reliable sources (see references in the Methods section) and used commonly in the field of research.
	Where expert opinion has been used, are the methods described and justified?	N/A	
Data modelling	Is the data modelling methodology based on justifiable statistical and epidemiological techniques?	YES	Although it does not fit the category of data modelling, the life table (see page 5/6) is a well-established technique and is used widely to model health

			impacts in epidemiological studies.
Baseline data	Is the choice of baseline data described and justified?	YES	All baseline data were chosen to match the year of the housing stock survey. Baseline data for the exposure model are described at the bottom of page 7. Baseline data for the health model are described on page 5/6
	Are transition probabilities calculated appropriately?	YES	We used a standard life table. The relationship between temperature and air pollutant exposure and mortality and morbidity are well established and described in table 1. The time lag functions used are shown in appendix figure 3.
Treatment effects	If relative treatment effects have been derived from trial data, have they been synthesized using appropriate techniques?	YES	The treatment in this case is the energy efficiency intervention. The relationship between temperature and air pollutants exposure and selected cardio-respiratory and cancer mortality and morbidity is well established and described in Table 1.
	Have the methods and assumptions used to extrapolate short-term results to final outcomes been documented and justified? Have alternative assumptions been explored through sensitivity analysis?	YES	See above.
	Have assumptions regarding the continuing effect of treatment once treatment is complete been documented and justified? Have alternative assumptions been explored through sensitivity analysis?	N/A	The interventions would result in a permanent change to the housing stock.
Risk factors	Has evidence supporting the modeling of risk factors as having an additive or multiplicative effect on baseline probabilities or rates of disease incidence or mortality been presented?	YES	Described on Page 5, to avoid double counting we removed deaths in those sub-categories from the larger categories. For outcomes affected by more than one exposure, we assumed the relative risks were multiplicative.
Data incorporation	Have all data incorporated into the model been described and referenced in	YES	All data incorporated into the model is described and referenced in the Methods

	sufficient detail?		section and in further detail in the Appendices.
	Has the use of mutually inconsistent data been justified (i.e., are assumptions and choices appropriate)?	N/A	
	Is the process of data incorporation transparent?	YES	See above.
	If data have been incorporated as distributions, has the choice of distribution for each parameter been described and justified?	N/A	
	If data have been incorporated as distributions, is it clear that second order uncertainty is reflected?	N/A	
Assessment of uncertainty	Have the four principal types of uncertainty been addressed?	YES	Both parametric uncertainty and structural uncertainty analyses were used to determine sensitivity of the model results on key areas of uncertainty. Parametric uncertainty was carried out for (1) the intervention effect on exposures and (2) exposure-response relationships, and (3) utility weights for outcomes. Structural uncertainty tests were carried out for 1) toxicity of indoor PM2.5 and 2) cold-related death group size. Distributions of modelled indoor pollutant concentrations were compared with empirical measurements in Appendix 1.
	If not, has the omission of particular forms of uncertainty been justified?	NO	See below.
Methodological	Have methodological uncertainties been addressed by running alternative versions of the model with different methodological assumptions?	YES	The three scenarios are based on different methodological assumptions (see pages 6 and 7).
Structural	Is there evidence that structural uncertainties have	YES	See above.

	been addressed via sensitivity analysis?		
Heterogeneity	Has heterogeneity been dealt with by running the model separately for different subgroups?	YES	The exposure model was run for different housing types, and health impacts calculated by age, sex and for smokers and non-smokers.
Parameter	Are the methods of assessment of parameter uncertainty appropriate?	YES	The selected assumptions used in the uncertainty analyses reflect the range of plausible alternatives.
	If data are incorporated as point estimates, are the ranges used for sensitivity analysis stated clearly and justified?	N/A	
	Which sensitivity analyses were carried out?	YES	See above. Uncertainty analyses that varied assumptions about intervention effect on exposures, exposure-response relationships, and utility weights for outcomes. Structural sensitivity analysis that examined differences in pollutant toxicity and cold-related disease risk.
<b>CONSISTENCY</b>			
Internal consistency	Is there evidence that the mathematical logic of the model has been tested thoroughly before use?	N/A	The building stock, exposure and health models are based on established and tested mathematical principles (see references 20, 21, 23 and 37).
External consistency	Are any counterintuitive results from the model explained and justified?	N/A	All results are in line with expected patterns and distributional effects.
	If the model has been calibrated against independent data, have any differences been explained and justified?	N/A	
	How was the model calibrated?	YES	Model outputs have been compared against known exposure distributions. The exposure model was calibrated against published observed data. This is described at the start of the Results section and a comparison is shown in appendix 1.
	Calibration - description of source data	YES	See references in Table 1.

	Calibration - description of search algorithm	N/A	
	Calibration - description of goodness-of-fit metric	YES	
	Calibration - description of acceptance criteria	N/A	
	Calibration - description of stopping rule	YES	See reference 37.
	Have the results of the model been compared with those of previous models and any differences in results explained?	YES	Magnitudes of exposure changes and health impacts compared with references 21, 27, 35.
<b>VALIDITY</b>			
Output plausibility	Has evidence of face validity - evaluation by experts in the subject matter area for a wide range of input conditions and output variables, over varying time horizons – been presented?	N/A	
Predictive validity	Was the validity of the model tested?	NO	Both the exposure model (see reference 20) and the health model (see reference 24) are well established and validated methods.
	Is there a description of how the validity of the model was checked?	NO	See above.
	How was the validity quantified? (e.g., % explained)	NO	See above.
<b>COMPUTER IMPLEMENTATION</b>	Is the software used in the study listed and its choice justified?	YES	Exposure model software (CONTAM) listed on page 5. Health model software (IOMLIFET) listed on page 5.
<b>TRANSPARENCY</b>	Is the model available to the reader?	YES	The individual components of the model are freely available.
	Is a detailed document describing the calibration methods available?	N/A	
	Do the authors provide relevant appendices?	YES	Additional supporting figures are provided in an appendix.
<b>SPONSORSHIP</b>	Is disclosure of relationship between study sponsor and performer of the study provided?	YES	See statements on page 13.