INTARESE

Project No. 018385
INTARESE
Integrated Assessment of Health Risks of Environmental Stressors in Europe

Integrated Project
Thematic Priority

D23 Housing Assessment Protocol

Due date of deliverable: April 07
Actual submission date: May 07

Start Date of Project: 1 November 2005	Duration: 60 Months
Organisation name of lead contractor for this deliverable: LSHTM	Revision: Final Version

Project co-funded by the European Commission with the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	x
CO	Confidential, only for members of the consortium (including the Commission Services	

INTARESE

WP3.2 HOUSING PROTOCOL

MAY 2007

(LSHTM, ICL, KTL, NILU, ASL, RIVM, CSTB)

1. ISSUE FRAMING

Housing is not a simple factor, and it differs from 'more conventional' toxic environmental hazards in several ways.

- the relationships between housing parameters and health cannot often be characterized by simple dose-response relationships
- the factors we have control over are often not the hazards themselves, but the determinants of a range of exposures, for example ventilation rate and energy efficiency, which may influence health through a range of pathways
- behavioural factors frequently have a crucial role in determining exposures and housing related-risks

Assessing environmental risks often involves unpacking numerous interacting and complex pathways that can be a resource-intensive process. For this reason we will apply a pragmatic approach to risk assessment as a useful aid to decision-making.

The evidence relevant to housing and health was reviewed during the scoping phase of the work package and any related documentation should be referred to as a supplement to this protocol.

1.1 Summary table

(– to be finalized once case studies decided)

Hazards	Exposure Media	Health impacts	Sub-groups	Geographic area
Extremes of indoor temperature	n/a	Mortality, thermal comfort, productivity	65+	Urban, deprived areas, areas with old housing stock
Damp and mould	Air, particulates, dust	Asthma and allergic symptoms, respiratory symptoms, general symptoms	Children, asthmatic and allergic individuals, adults, individuals with chronic illnesses or immune deficiencies	Deprived areas, areas with high humidity precipitation, or risk of flooding
Indoor air quality (Radon, NO_2)	Air, particulates, dust	Respiratory symptoms, general symptoms, Cancers	Geographic area, children, older people, individuals with existing respiratory illness	Specific areas with known concentrations, others
Noise ??	n/a	Nutrition, psycho-social impacts, thermal comfort	Geographic area, older people, poor	Urban

1.2 Single model approach

A pragmatic approach, addressing important policy questions, resulted in the development of a common framework for risk assessment focussing on impacts relating to the central concept of home energy efficiency. This brings the advantages of having a strong rationale in Europe (in terms of the energy efficiency implications of climate change, the considerable burden of cold related deaths, and energy security), and allowing each of the selected hazards (Table 1) to be incorporated into the framework (Figure 1). This framework represents a simplified version of all the possible pathways that could be included, but each of the different pathways of the framework forms the basis of the different case studies and so each case study will be responsible for developing their own framework more extensively in the first and second pass.

The far left hand side (the starting points for assessment) of the framework represents typical characteristics that play an important part in framing the policy questions. The relationship between each of the characteristics and the direct drivers (3rd column) of exposure needs to be investigated for each case study.

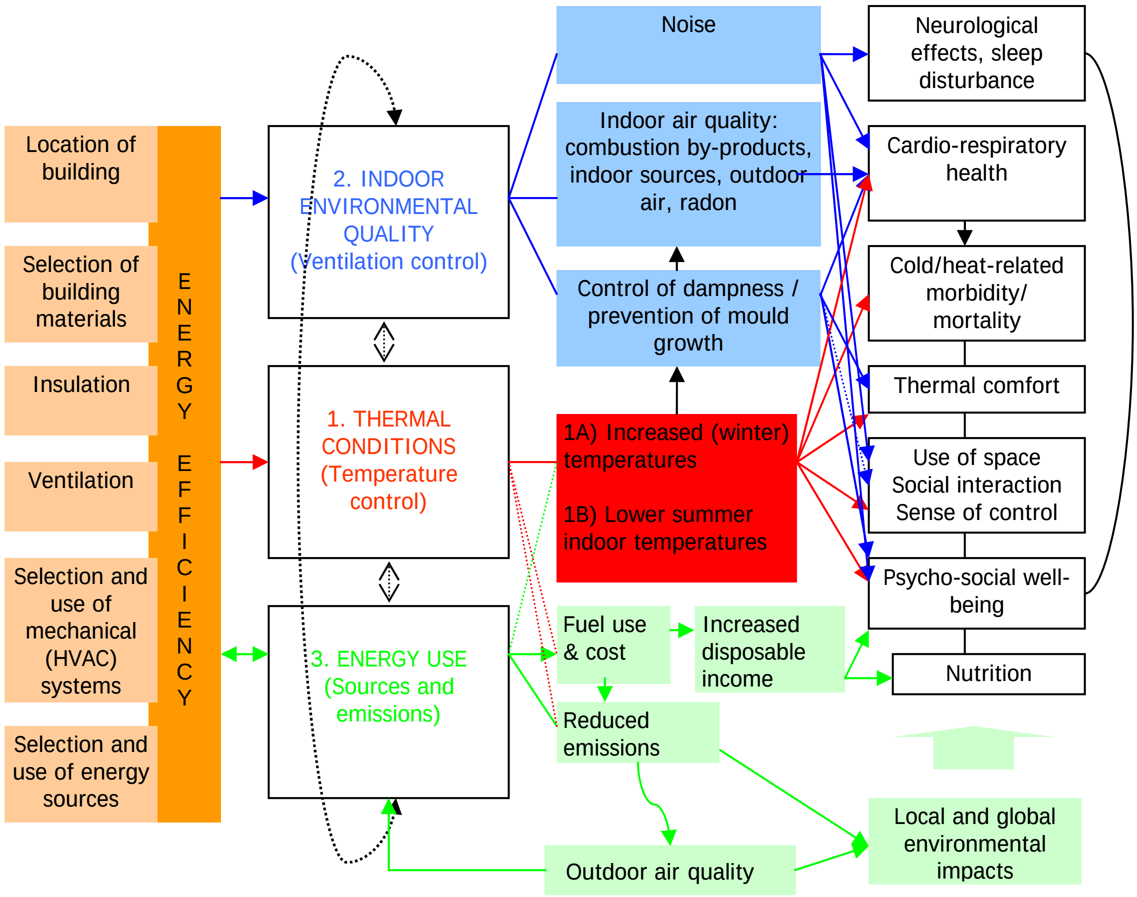


FIGURE 1: Preliminary framework linking housing and health, describing policy selection to health outcome. The model is centred on energy efficiency policy.

1.3 Identification of major pathways

Four major pathways operate in the framework, reflecting both the positive and negative health effects which may result from an energy efficiency policy. It should be noted though that whilst the risk assessment focuses on hazards in the home, some health impacts extend beyond the household. For example, a policy leading to reduced energy use should reduce emissions to the wider environment, potentially reducing negative health effects in the wider population.

Four major pathways are shown. In red, the impacts of indoor air temperature; in blue, the impacts of a change in frequency of indoor air-exchange; and in green, the impacts of reduced energy use in terms of i) costs to households and ii) emissions to the external environment. An explanation of the major pathways is given below.

1. Indoor air temperature and the health impacts of cold and heat (Figure 1 - in red).

   Improved energy efficiency (e.g. as a result of improved insulation) should lead to increased winter indoor air temperatures and hence reduce the risk of cold-related events. Direct benefits include a reduction in cardio-respiratory morbidity and mortality, greater comfort in the home, productivity, and possibly improved psychosocial well-being. Indirectly, warmer, more comfortable conditions may lead to freer use of space in the home and offer a greater sense of control, resulting in improved nutrition and psychosocial well-being. Higher indoor temperature lowers indoor relative humidity and reduces risk of condensation on cold surfaces, hence lowering the risk of microbial manifestation.

   Improved insulation may also reduce uncontrolled air leaks throughout the building envelope, which, together with mechanically provided and filtered outdoor air, may prevent outdoor air pollutants from entering in the building, and also prevent chemical and microbial particles manifesting in the building materials entering in the building.

   On the other hand, a reduction in ventilation (unless mechanically provided outdoor air), as a result of improved energy efficiency, may result in hazardous conditions further discussed below (2).

   Of additional consideration is the impact of thermal efficiency on summer temperatures. Under the projected climate change-related increases in summer temperatures, cooling may become necessary to avoid negative health impacts. This may be particularly relevant in the Mediterranean regions of Europe.

2. Altered ventilation characteristics and indoor air quality (Figure 1 – in blue).

   In order to improve energy efficiency, air exchange is often reduced (see point 1 above), increasing risk of higher bacterial concentrations. Reduced ventilation also may, in operation with warmer indoor temperatures, increase humidity, and mould growth and dust mite presence. Mould and dust mites have been associated with respiratory health impacts. Additionally, there may be further reductions in indoor air quality. Depending on other factors - such as the type of indoor furnishing, the use of chemicals for cleaning or pest-control, behaviour, and property location - there may be increased levels of hazards including environmental tobacco smoke, particle matter, radon gas, carbon monoxide, nitrogen dioxide and other chemicals, each of which can have adverse health effects.

3. Reduced household fuel costs and increased disposable income (Figure 1 – in green).

   Improved energy efficiency is likely to reduce household fuel costs, and therefore increase disposable income. This may lead to improved nutrition, and have further impacts, albeit through less clear pathways and more difficult to quantify, on health outcomes such as cardio-respiratory disease.

As a negative effect, building costs are likely to be higher in an energy efficient dwelling as compared to a less efficient one. It may be more difficult for an economically poorer part of the population to become home owners, or it may result in higher rents which may decrease disposable income of a part of the population. It is not necessarily straight forward to determine the interest group who will gain the benefit of reduced fuel cost, whether it is the home owner, occupant, or some entirely different group.

4. Reduced emissions to the external environment leading to a reduction in air pollutants and green house gases (Figure 1 – in green).

   Energy efficiency is likely to decrease fuel use. As a result, emissions may be reduced with impacts realised on two timescales. Firstly, in the present, air pollution will be reduced, potentially producing immediate population health benefits. Secondly, in the longer term, a reduction in the release CO_2 and other greenhouse gases could have a mitigating effect on future climate change.

2. Risk Assessment Framework

The risk assessment framework consists of four steps: hazard identification, hazard characterization, exposure assessment, and risk characterisation. Within this process a risk assessment model will be developed and the model will be implemented for the assessment of policy questions defined for the case studies.

2.1 Step 1: Hazard Identification

In general terms, it was decided that a hazard would be included if it was:

i) a characteristic of a dwelling;

ii) that the health impact could be clearly defined and measured; and,

iii) that the risk associated with exposure to that hazard was largely a function of the presence of the hazard, in contrast to being a function of the hazard *and*, for example, behaviour or socio-economic conditions.

The intention is not for these criteria to suggest that behaviour and other factors are either unimportant or not amenable to policy intervention; rather, it is a pragmatic decision: adopting these criteria make it possible to identify and prioritise a hazard and minimise the associated risk to a defined level by instituting a policy which addresses that hazard.

In addition to these exclusions, hazards with a limited health impact in Europe were excluded.

TABLE 1: Selection of hazards for inclusion in the risk assessment model.

Hazard	Reasons for inclusion/exclusion
Included:	
Extremes of temperature	Epidemiological evidence suggests an excess of winter morbidity and mortality associated with indoor air temperature. Climate change brings with it the potential for an increase in excess heat-related deaths exists.
Damp and mould growth	Mould and damp are common problems that have been consistently associated with a range of mild to moderate health effects. Attending to excessively low indoor temperatures and/or poorly ventilated dwellings may increase exposure to mould and damp as a result of condensation and reduced air circulation.
Indoor air quality	• Radon gas is a well characterised hazard associated with lung cancer (in many countries, second in importance to tobacco smoke). Despite this, and the risk of exposure in multiple areas across Europe, there is currently no regulation at the European level. • Exposure to environmental tobacco smoke is partially behaviourally driven, but may be, along with other indoor air pollutants, altered by ventilation characteristics of a dwelling associated with improved insulation. • Exposure to VOCs can be 2 to 5 times higher indoors than outside, and increasing due to better thermal insulation coupled with poor ventilation. Suggested adverse health effects include mild symptoms to cancer. • Products of combustion (Carbon monoxide and particle matter). In the UK, more than 50 people die from accidental carbon monoxide poisoning every year. Situation is worse if fuel is burnt in an enclosed and unventilated building.
Fuel use and fuel costs	Fuel poverty (the spending of >10% of household income on fuel costs[1]) is recognised as an important problem that impacts on vulnerable groups by WHO Europe and many countries within the EU. A reduction in fuel needs has the potential to avert health events due to low indoor temperature, increase disposable income, and reduce emissions associated with air pollution and climate change.
Noise	Noise has links with transport, but frequently arises from neighbours. There are exposure response functions for traffic noise (possibly also for neighbour noise as well).
Excluded:	
Hazards associated with unintended injuries	The risk of unintended injury is arguably one of the most important housing-related risks. There are, however, difficulties in attribution due to the behavioural element of the risk, and as a result, there are definitional difficulties in terms of what constitutes a minimised risk.
Asbestos	While asbestos is potentially a very hazardous material, the risk to the public from asbestos in the home and public buildings is low[2].
Water and sanitation	Water and sanitation provision across Europe is generally good; not housing-related.
Lead in drinking water	Exposure to lead in drinking water is minimal in Europe, and the existing short segments of lead piping are widely subject to replacement programmes.
Overcrowding and psychosocial impacts	Overcrowding is bound up with multiple-occupation dwelling and socio-economic conditions, and results in non-specific risks. Psychosocial impacts are potentially important for poor housing estates and local environments but are challenging to investigate.

2.2 STEP 2: HAZARD CHARACTERISATION

Several hazards of relevance in Europe where identified, which may be, in broad terms, grouped by the level of their attributable health burden:

- Major scale burdens: temperature extremes, radon, unintended injuries and possible environmental tobacco smoke (ETS).
- Medium scale burdens: damp and mould, products of combustion e.g. carbon monoxide and other indoor air pollutants (VOCs, particle matter), overcrowding and psychosocial impacts.
- Small scale burdens: water and sanitation, lead, noise, asbestos.

Table 1 outlines the major hazards considered and briefly outlines the justifications for their inclusion or exclusion based on scientific evidence (or lack of).

2.3 STEP 3: EXPOSURE ASSESSMENT

2.3.1 Dose-response relationships

Exposure data, including data on risk relationships, will be by collected (according to WP1.2 guidelines??) from published epidemiological studies: routine sources, meta-analyses, surveys or local epidemiological sources: whichever is available or provides the best data. Where there is limited, questionable or no data available on exposure relationships then WP4.2 will model best estimates provided by WP3.2 as well as performing sensitivity and uncertainty analyses.

Exposure data will be collected at different levels of interest and, in the first pass, by age group (if data available), and summarised according to different severity levels of health outcome.

We also need to investigate how different building characteristics modify each of the pathways from Figure 1. This needs to be context specific. For example, building type or location may have different effects on temperature control which in turn affects estimates of damp prevalence. This information will provide some of the baseline data against which the different policies can be assessed.

2.3.2 Identification of health outcomes

The severity levels will range from severe to mild although the types of classification will be determined by the context and available data. For example, in the UK, it is possible to use severity levels ranging from death (categorised as both short and long term e.g. life-threatening cancers) to hospital attendance to primary care consultations, since data is available for this. For other case studies, however, these classifications may change to reflect the available data or reflect the best way in which to represent the particular policy question and context. Mortality may be further categorised into short term (acute deaths from e.g. CO poisoning) and long term (e.g. death from life threatening cancers).

In order to give the assessment some relativity then each case study needs to include data on the underlying rates of disease in the population or sub-groups of the population and by severity class.

Health outcomes will be appreciated more fully as the case studies evolve.

2.4 STEP 4: RISK CHARACTERISATION

WP1.4 to provide methodology?

The model is based on a common framework, beginning with input specific to a policy option and ultimately producing a measure of its overall health impact; Figure 2 diagrammatically illustrates the model. The input requirements of the model are briefly outlined in this section (Figure 2, Table 3) and expanded upon further ahead in the document (section 3.7).

Risk characterisation ultimately leads to a quantification of the risk (including uncertainty analysis) on the health impact from a change in current exposure levels over time and different measures of impact can be used to reflect different requirements (economic, days gained/lost). The attached spreadsheet provides an example of how risk can be quantified when different policy options are put into place to improve insulation, thereby reducing damp.

Section 4 describes some of the uncertainties that will need to be considered for the analysis and final model.

See Appendix I for worked examples.

2.5 CASE STUDIES

Each of the case studies will be used to test and develop the framework and methods of implementation (outlined in the next section & Appendix II). Each case study will take a different approach to energy efficiency (e.g. insulation, alternative energy sources), and explore a set of relevant policy options. This means each case study will realise and emphasise different aspects of the framework. Further, collectively, the case studies will consider a range of European climates. A summary of the case studies is provided in Table 2 below.

See Appendix III for example of Scandanavian case study.

TABLE 2: A summary of case studies.

Topic	Principle pathways	Location & climate	Time scale
Home insulation	Indoor air temperature, ventilation, fuel use and costs.	UK	2001-2015
Indoor air quality (Damp, mould, radon, NO_2)	Ventilation, dampness, and indoor air pollution, fuel use and costs.	Finland France Netherlands	2001-2015
Noise	Insulation	Netherlands	2001-2015
Efficiency and heat stress	Indoor air temperature, ventilation.	Italy	2001-2015-2050

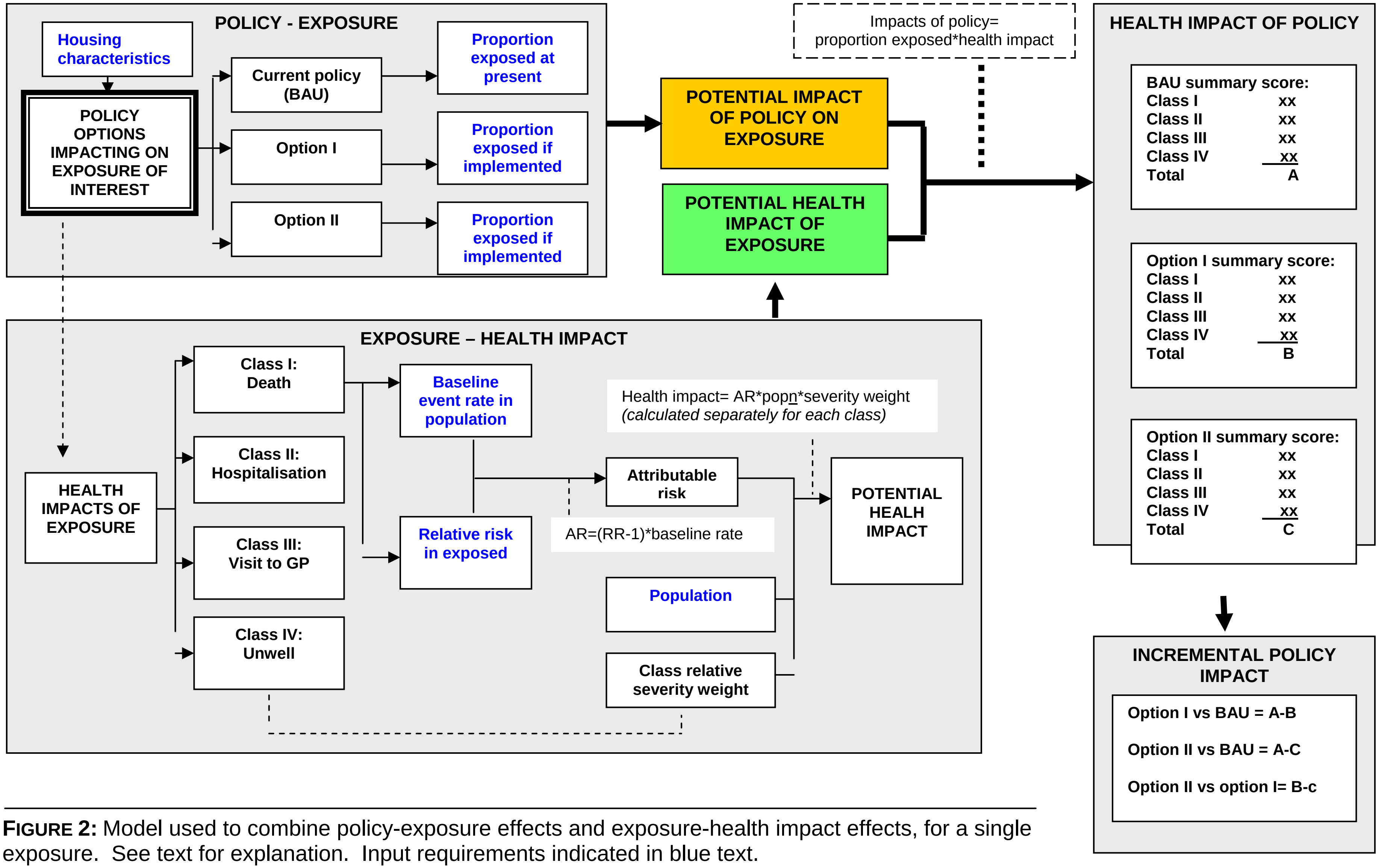


FIGURE 2: Model used to combine policy-exposure effects and exposure-health impact effects, for a single exposure. See text for explanation. Input requirements indicated in blue text.

However, for the first pass, a trial run through in collecting all the necessary data and uncertainties and putting this information into the model will focus on the UK. Each member of WP3.2 will be allocated one or two exposures to focus on for a first model run during the first 6 months of the first pass (Appendix IV) and then will develop their own case studies during the second part of the first pass.

TABLE 3: An outline of the inputs required for implementation of the model. Expanded details are provided in the 'Information and data needs' section.

Policy-exposure ***Policy details:*** Different building characteristics will influence the direct drivers of exposure and these need to be defined. For example, the type or location of building may modify pathways that eventually impact on prevalence of damp. Viable policy options to address aspects of home energy efficiency (e.g. insulation, energy source) must be identified. Specifically, there is a need to assess the exposures a policy will impact upon, and, what proportion of the population will be exposed to these with implementation of the policy. Additionally, it may be necessary to identify realistic time-scales over which implementation will occur, and target groups. ***Data:*** Survey data for housing characteristics. Proportion of the population currently exposed to exposures of interest, possibly broken down into age groups, socio-economic status etc. This is also relative to data availability: e.g. with respect to dampness, we can draw best/most reliable health risk estimates for children, however, data on population currently exposed is very limited within Europe, and further scattered due to differences in definitions.
Exposure-health effect ***Data:*** Health outcomes related to an exposure. Baseline rate of outcomes of interests in the population perhaps disaggregated into specific groups (e.g. age, socioeconomic status). Relative risk of a health outcome in the exposed, perhaps by group of interest. Population figures, perhaps disaggregated into specific groups. ***Judgements:*** Grouping of health outcomes by level of severity (e.g. those causing death, those causing discomfort etc.) and assigning a relative severity weight.

3. ASSESSMENT METHODS

3.1 IMPLEMENTATION OF RISK ASSESSMENT MODEL

The comparative health impacts of the policy options considered in each of the case studies will be assessed using a prototype model, which utilises Excel as a platform (see Figure 3 for an example of damp assessment).

The next section describes preliminary plans for how the model may be further developed during the first pass.

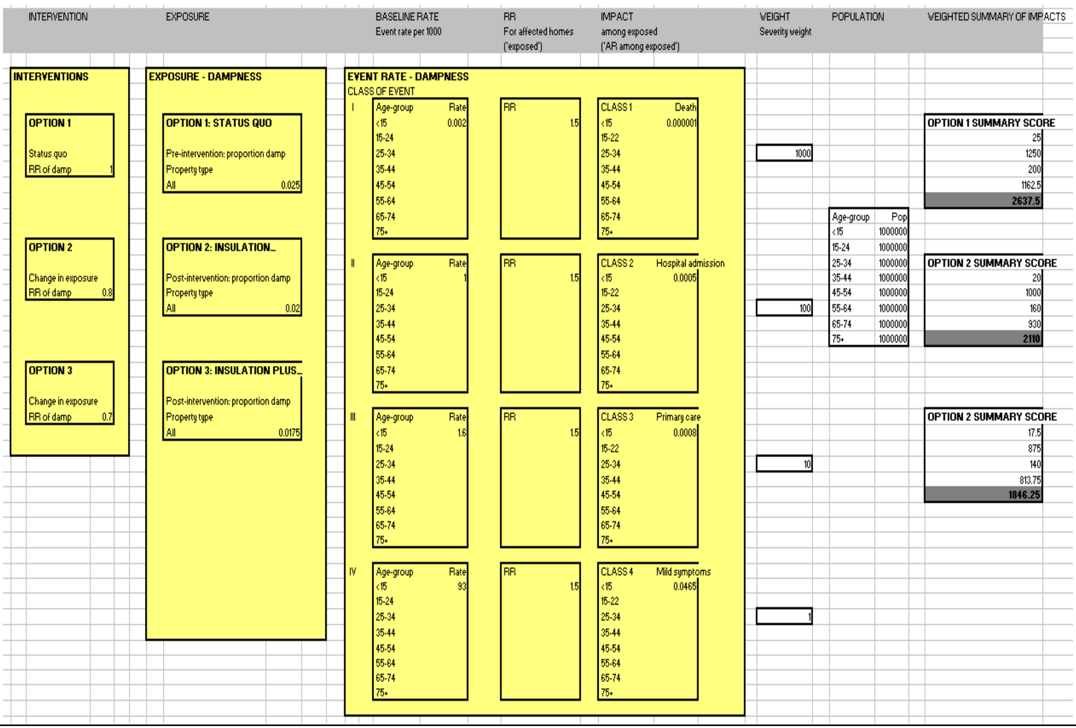


FIGURE 3: Excel spreadsheet showing damp/mould as example

3.2 POLICY – EXPOSURE

3.2.1 Step 1: Identify policy options

3.2.1.1 Identify policy options

The first stage of implementation involves the comprehensive review and identification of viable policy options - including the current policy - for addressing a particular issue; for example, the insulation of homes. However, a set of policies will potentially impact on certain exposures, both intentionally and unintentionally, resulting in a 'non-additive' effect. For example, a policy to improve insulation is likely to reduce exposure to cold, but may unintentionally lead to a reduction of indoor air quality. Or it may be that a number of different policies have a more synergistic or mutually inclusive effect where the effect of one policy is supportive of another policy (and vice versa), for example, thermal insulation and improved ventilation schemes. In which case a combination of policies (implemented together or in sequence) may be the best way to reach set targets imagined by the policy scenarios.

3.2.1.2 Baseline and target setting

A reliable quantitative baseline against which the benefits of suitable new policy scenarios may be assessed needs to be constructed, i.e. change vs. 'business as usual' (BAU) or the 'BAU future'. This will consist of quantifying existing policy trends and possible drivers of change over the time horizons (see below) envisaged. Reliability and availability of data needs to be considered for different settings.

Appropriate targeting levels need to be set for each intervention including, eventually, the interactive effects of other interventions to inform the assessment model and forecasting outcomes. The intervention itself needs also to be addressed as this will need to be defined taking into account the different types of dwelling, possible behaviour change and the extent of intervention (targeted or national); disaggregated by, for example, socio-economic status.

3.2.1.3 Time horizons

The envisaged time horizon for each of the different scenarios will involve:

> ***Policy Horizon*** – The time realised for policy implementation. The expected time frame for this is 2001-2015 (backcasting and forecasting methods).
>
> ***Climate Horizon*** – The effect of climate change will undoubtedly impact on housing policy. This to be considered with the climate working package WP3.7.

3.2.2 Step 2: Identify exposures

Bearing in mind step 1, the second stage involves the identification of the exposures, both intended and unintended, that a set of policies may impact upon.

For each run of the model, the impacts of the policy due to a *specific intervention* are examined. The impacts of each exposure are assessed in turn and can be combined to indicate the overall health impact of the policy, as described ahead.

3.2.3 Step 3: Identify proportion of population exposed if policy implemented

Having selected an exposure of interest, the third stage is the determination of what proportion of the population will be exposed to this if the policy is implemented. As existing policy is of interest, the proportion or number of people exposed at present is also required. These figures, i.e. *the proportion exposed if a policy is implemented*, provide the estimate of the potential impact of a policy on an exposure.

Depending on policy aims and the needs of decision-makers, **two further factors** may be taken into account.

- Firstly, the impact on ***different groups*** - whether grouped by age, socioeconomic status, or other grouping – may be measured by estimating specific policy impacts on the proportion exposed in each group.
- Secondly, the benefits of a policy ***over time*** may be accounted for by running the model separately for particular time periods, such as five year blocks.

For example, groupings and time factors may be utilised when assessing a policy aiming to improve home insulation at a rate of 10% of homes per year, targeting people in the lowest socioeconomic groups in the first 5 years.

At the moment the model in its current form deals with all or nothing exposures, e.g. damp or not. This may not represent a realistic scenario as there may be different policies aimed at addressing different levels of temperature for example, depending on building type. This will be developed further with SP4.

3.3 EXPOSURE – HEALTH EFFECT

3.3.1 Step 4: Identify health outcomes associated with exposure

Having selected an exposure impacted upon by a policy, the health outcomes associated with the exposure are identified. These may range in severity from, for example, cold-related discomfort to a cold induced fatal cardiac event. The possible health outcomes are grouped by relative severity, possibly, but not necessarily, into the following classes:

Class I: death	**Class III**: primary care consultation
Class II: hospitalisation	**Class IV**: symptoms/uncomfortable

These classes only serve as a guide, and final groupings may use another classification system. Also for the first pass the analysis will be carried out on disaggregated groups, i.e analysed separately, but there will eventually be a case for combining them using some weighting system. The weights (to be agreed) might be indicative of the relative severity of each outcome. For example, Class I may be weighted at 10 000, Class II at 1000, etc. While this system is ultimately subjective, it simplifies the comparison of policy impacts as, for example, all deaths are considered together regardless of cause, and these are given greater weighting than primary care consultations. An alternative is to use DALY weightings.

3.3.2 Step 5: Estimation of exposure attributable risk

Following this, the attributable risk of the exposure for each class of event is calculated. This uses two figures: the baseline event rate in the population of interest (i.e. in exposed and unexposed), and, the relative risk (and excess) of the outcome in exposed individuals. Attributable risk is calculated as follows:

$$AR=(RR-1)*\text{baseline event rate}$$

This formula assumes that the baseline event rate is the same as the event rate in the unexposed; a reasonable assumption for low frequency exposures, although this is scenario dependent and needs to be considered.

It is possible to consider the attributable risk in specific population groups by obtaining baseline event rates for each group of interest. Additionally, group specific relative risks may be available, or alternatively, it may be assumed that this varies little between groups but acts in the context of differing baseline risks. Whichever decision is made – to assess group-specific or whole population impacts – it is necessary to obtain corresponding population figures to calculate the potential health impact.

3.3.3 Step 6: Apply severity weight and population estimates

From the above figures, the ***potential health impact of an exposure*** is calculated by multiplying the attributable risk the population figures and possibly by the relative severity weight. This figure estimates the health impacts if all of the population were exposed.

3.4 HEALTH IMPACT OF POLICY

3.4.1 Step 7: Create weighted summary of impacts

At this point, two groups of figures have been derived:

1. Estimates of the potential impact of a policy on an exposure of interest (as the proportion of the population/group exposed if the policy is implemented); and,
2. the potential health impact of the exposure of interest, grouped into classes of different severities.

These are combined by multiplication to give a score for each severity class. Finally, the figures for each severity class are added together to provide a summary figure indicating the health impact of the policy due to that exposure; the smaller the figure, the fewer the negative health events in the population; that is, the smaller the number, the better the health impact of the policy in terms of the exposure considered. In effect, this final figure combines information on:

- the impact of a policy on an exposure;
- the attributable risk of that exposure to a health outcome;
- the relative severity of an outcome; and,
- the population that the policy will reach.

The model is then re-run for each exposure, and a combined effect summary score for a policy may be obtained by simple addition. Once again, the smaller the score, the fewer the negative health events in the population.

It is also possible to use DALY/QALY weightings to determine numbers of days lost/gained (see Appendix 1)

3.4.2 Step 8: Option appraisal and decision-making

Finally, the relative health impacts of the policies may be compared with BAU and with each other by subtracting the summary scores from one another. The greater the difference in scores, the greater the difference in health impact.

3.5 Statistical uncertainty

95% confidence intervals will be calculated around the health effect estimates based on the 95% confidence intervals provided with the dose-response data. WP1.5 will be contributing methodological guidance to assist in assessing statistical uncertainties associated with the models.

3.6 Sensitivity analysis

In a situation where information is limited (data gaps), informed decisions can be based on assumptions or extrapolations. Sensitivity analysis offers a practical way of dealing with such uncertainties as it provides a method of examining model function and behaviour by measuring the variation in outputs resulting from changes to its inputs.

3.7 Information and Data needs

The following indicates information and data requirements for the risk assessment. The information requirements are location specific and for a 15 year period from 2001.

For the UK most of the sources for this data have already been identified and accessed.

3.7.1 Population data

- Population data

Population size estimates by age, sex, region, etc. For UK this information is available from the Office of National Statistics (ONS). Statistic Finland provides data from Finland. Central Bureau of Statistics (CBS) in the Netherlands.

- Life tables
For both all-cause and cause-specific mortality data, for 5 or 10 year age groups (ONS), (CBS and Statistic Finland have this data also).

Need to control for cohort effects (simulations/modelling).

3.7.2 Disease rates
Baseline information needed classified by severity of disease: Class I = death (ONS); Class II = hospitalisation (Hospital Episode Statistics –HES); Class III = primary care consultation (General Practice Research database, HES outpatient, National Health Service (NHS) direct); Class IV = mild symptoms (NHS direct, other?).

All of the data for Class I to III can be collected by routine sources. For Class IV this may be more complicated??

These classes only serve as a guide, and final groupings may use another classification system. In any case, each of the classes will be assigned a weight indicative of its relative severity: Class I may be weighted at 10 000, Class II at 1000, etc.

We also need information on exposure-specific disease rates (from routine data sources and/or from case-studies):

E.g.
1) Mould & damp (e.g.asthma/asthma symptoms)
  - Class I to IV above (Data on different classes is more limited).

2) Radon
  - Cancer incidence
  - Death

3.7.3 Exposures
For the UK there have been a number of surveys carried out that can provide data on different and specific exposures. E.g. the English Housing Condition Survey (EHCS), radon surveys. Data can also be collected from case-studies and from case-studies from other INTARESE partners e.g. information on outdoor temperatures from WP3.7 (Climate); outdoor pollution from WP3.1 (Transport)

3.7.4 Relative risk

To be determined from data collected. Guidelines available from WP1.3.

3.7.5 Disability-adjusted and quality-adjusted life years (DALYs and QALYs)

As well as the above data, diseases specific disability weights are needed in the assessment of QALYs/DALYs. These are available from the European Disability Weight Project, the Dutch Public Health Status and Forecast, the Global Burden of Disease study and from on-going WHO work on the assessment of the burden of disease from inadequate housing conditions.

General questions:

a) Stratification to be considered by:

- Age? (yes for this phase – groupings to be determined)
- SES? (maybe too much for now but to be considered in Phase II: inequities)

b) How are we going to define quality? Will this be a routine definition or some other?

c) Confidence intervals? Standard errors are needed to establish uncertainties.

4 AREAS FOR METHODOLOGICAL DEVELOPMENT

4.1 QUANTIFYING UNCERTAINTIES AND SENSITIVITY ANALYSES

This section gives a guide to where uncertainties in the risk assessment might lie, and will be expanded once more information is collected during the first (and second) pass. Our method will follow and expand upon that outlined in the WP1.5 document, 'On risk assessment, uncertainty and legitimacy in risk governance'.

For uncertainty diagnostics to be carried out, it is first necessary to assess the relevant literature and available datasets. As this process will continue into the first pass period, the following provides only a preliminary outline of the diagnostic method and suggests in general terms where and what types of uncertainties may be encountered. To simplify this, a branch of the model focusing on the impact of a policy on a single health outcome due to a single exposure is considered.

Figure 4 traces the pathway for a policy aiming to improve thermal insulation and its impacts on mortality due to respiratory causes as a result of exposure to low indoor temperatures (shown in black). For illustrative purposes, some of the possible uncertainties associated with the components and relationships in the pathway are shown: uncertainties associated with the model structure are shown in blue, and those associated with inputs or parameters are shown in green. Note the figure also indicates some instances where an uncertainty is likely to be dealt with by making an assumption. Examples of uncertainties identified are:

A. ***The relationship between the policy aim and an exposure***
   Insulation may offer the potential to have a warmer home, but it is likely this will occur in a certain proportion of homes with improved insulation. Where houses remain 'cold', it may due to technical, behavioural, or other reasons. A decision must be made as to whether it is assumed adequate insulation will lead to warmer indoor temperatures in all or a certain proportion of homes.

B. ***The relationship between an exposure and an outcome***
   Epidemiological evidence exists to support a relationship between indoor air temperature and respiratory-related deaths, making this a reasonable assumption. In other cases, however, this may not be the case. For example, as mentioned previously, the quality of the evidence to support a relationship between indoor air temperature and psycho-social well-being may be poor, or, no evidence may exist.

C. ***The relative risk of an outcome in the exposed***
   Reasonable quality studies may provide an estimate of the relative risk of respiratory-related mortality in those exposed to low indoor temperatures.

The uncertainty in this figure is likely to be quantified by a 95% confidence interval.

As each of these uncertainties differ, so do means of dealing with them. Dealing with 'A' may involve a review of the success – in terms of achieving warmer indoor temperatures - of similar policies in the past, as well as discussions with experts. From this, it may be assumed the policy will be successful in a certain proportion of households, possibly with, for example, the proportion varying by socio-economic group.

Situation 'B' may suggest that a type of sensitivity analysis is required: one run of the model may include psycho-social impacts and another may exclude them. From this, the relative importance of psycho-social outcomes could be gauged. If inclusion was found to significantly alter the overall health impacts of a policy, the support for, and method of, including them in the model would need to be elaborated.

In situation 'C', the uncertainty is quantified and the model may be run for the point estimate and the extremes of the confidence interval to obtain a plausible range of health impact due to that element. It may be that in terms of the overall impact of the policy this range is relatively small.

What becomes evident in the above and in Figure 4, is that there are likely to be multiple uncertainties simultaneously active in a model. Uncertainties will accrue both vertically (that is, along each branch), and horizontally (as the overall health impact of a policy is due to the influence of multiple branches). Given this, it may ultimately be desirable to run a series of simulations in which uncertain elements are adjusted simultaneously and randomly to ascertain a plausible range of model outcomes. This of course may present significant methodological difficulties.

4.1.1 Model Uncertainty

The risk assessment model is composed of a series of linked sub-models: indoor environment, population exposure, exposure-health response and health impact estimation. The first sub-model estimates the levels of the indoor environmental variables of interest (e.g. air pollutants, temperature, VOC), the second sub-model describes how the affected population are exposed to the indoor environmental variables (e.g. via inhalation, dermal contact), the third sub-model describes each of the exposure-health response (morbidity and mortality) relationships (e.g. linear, threshold-linear) and the fourth sub-model aggregates the health impacts over the environmental exposure variables and across the population exposure pathways.

The sources of uncertainty in the risk assessment model are reflected in the uncertainty in each of its component sub-models. There are two elements to dealing with the uncertainty in the risk assessment model: (i) characterising the uncertainty in each of its sub-models, and (ii) propagating the uncertainties between its sub-models. With regards to the characterisation of uncertainty, there are two types of uncertainty to consider: parametric and structural. The first type is associated with the uncertainty in the values of the model parameters and the second type is associated with the structure of the model.

For parametric uncertainty we propose to use probability density functions (*pdfs*) to quantify the uncertainty in each of the independent model parameters and multi-dimensional *pdfs* to quantify the uncertainty in the correlated parameters. For characterising structural uncertainty, we propose to use two methods (as

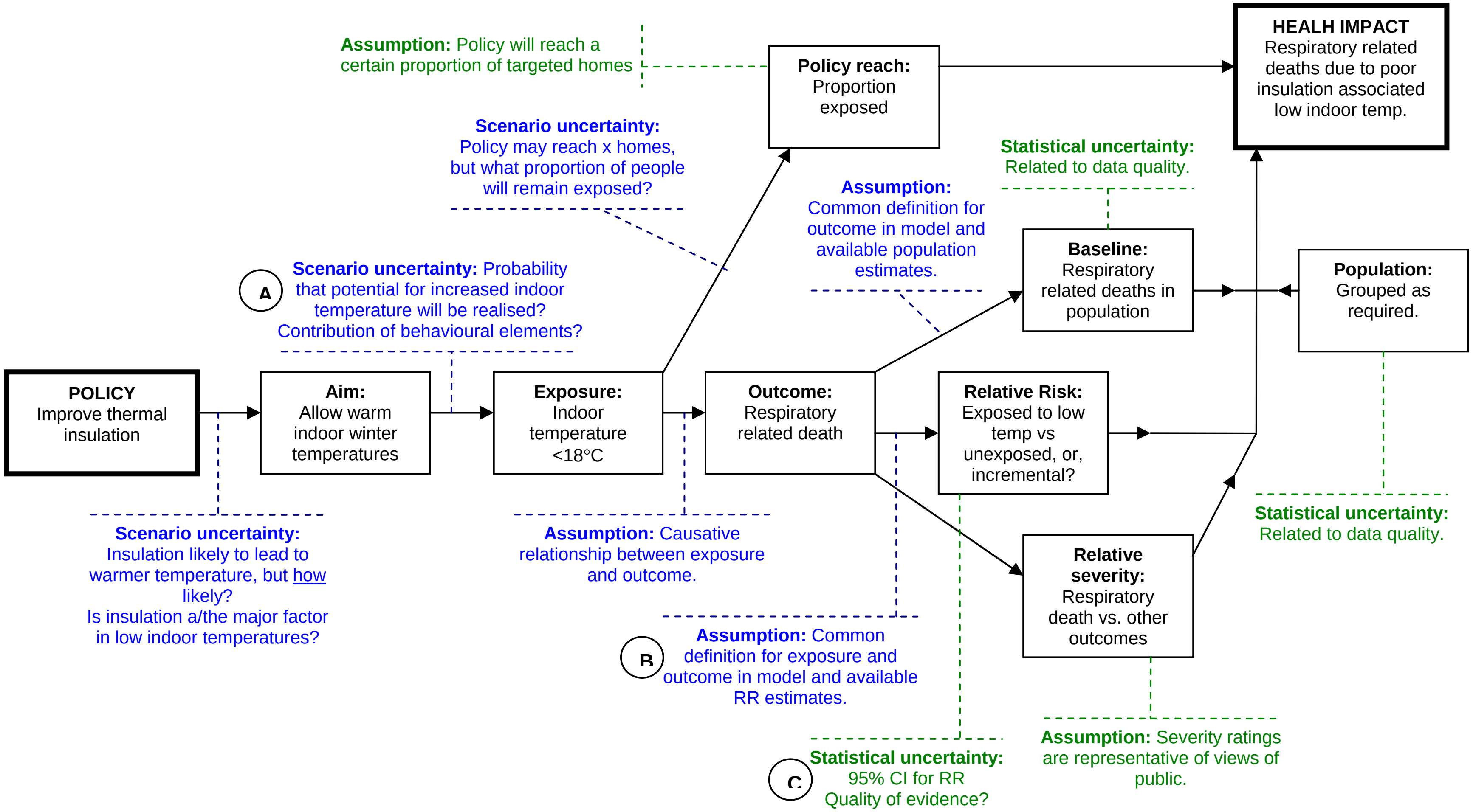


FIGURE 4: Diagnosing uncertainty and identifying assumptions in the model. The chain from policy to health impact, considering a single outcome due a single exposure, is shown in black. Uncertainties and assumptions arising in the model *structure* are shown in blue, and those associated with *inputs and parameters* are shown in green. Note this diagram is intended to illustrate the diagnostic method rather than define the uncertainties in the model: these will become clear following a full review of the literature, assessment of available data and further discussion.

appropriate): the first method converts structural uncertainty to parametric uncertainty and the second method approximates the model structure by perturbing the model about its nominal configuration. The propagation of uncertainty is done using Monte Carlo (MC) simulations or Latin Hypercube Sampling (LHS). A simple example is given in Appendix V to illustrate the approach of dealing with parametric uncertainty.

4.2 ALTERNATIVE ASSESSMENTS OF POLICY IMPACT

The standard model considers the final health, or health care, event as salient; for example, death or hospitalisation. Other aspects, such as who is affected (e.g. age, socio-economic status), duration or degree of the burden experienced due to the illness, time lag from exposure to outcome, or, costs of implementing a policy, are not accounted for. Following an initial trial and reworking of the standard model, it may be possible to modify the model to account for these factors.

The next section provides an explanation of these potential modifications. Figure 5 indicates the additional data requirements of the modifications, and Appendix I gives worked examples.

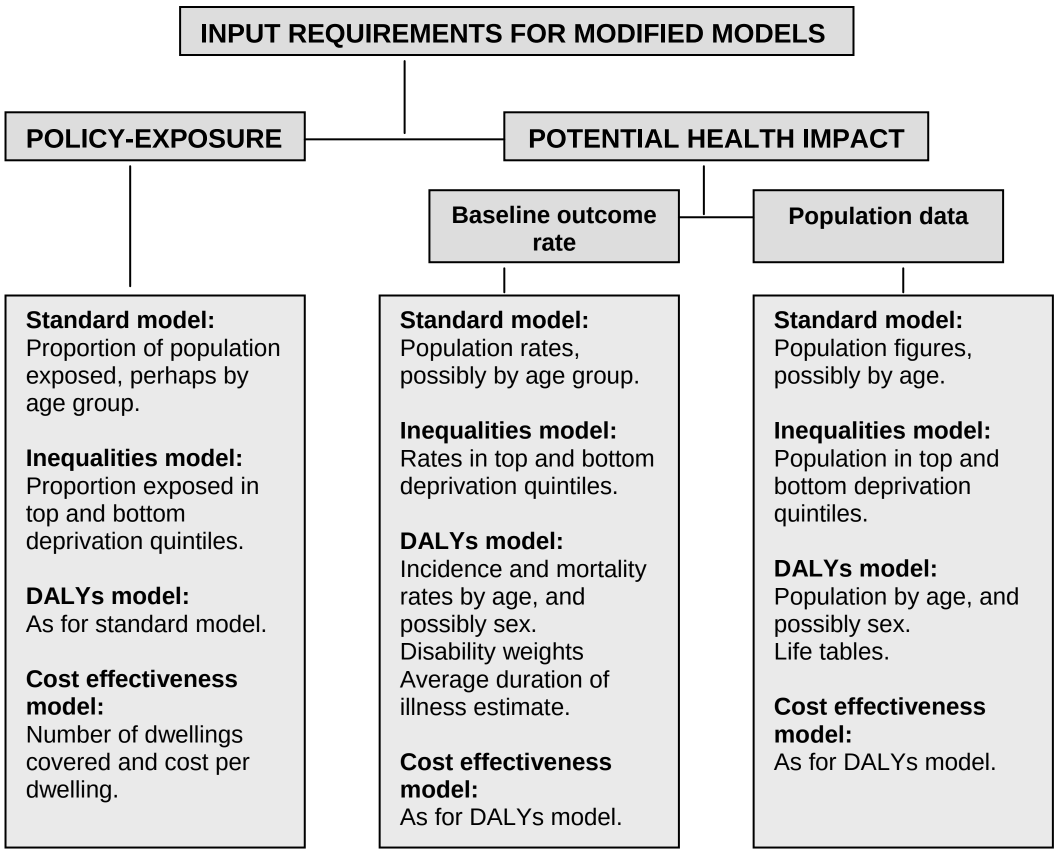


FIGURE 5: Input requirements of modified models. **Note:** Only model input requiring modification is shown. Other input remains are in the standard model.

4.2.1 Assessment of impacts by socio-economic group

A policy may, with or without intent, impact on the distribution of health within a population, either widening or narrowing the health gap between different groups. It seems reasonable to suggest, that even if a policy seeks to offer benefits universally, it should be implicit that health inequalities should not be increased. Alternatively, a policy may specifically aim to reduce inequalities by targeting certain groups.

A simple means of assessing the impact of a policy on inequalities is to compare the health impacts on the best- and worst-off socio-economic groups in a population. Such groups may be defined using the top and bottom quintiles as identified by an index of deprivation, such as the Index of Multiple Deprivation. In order to estimate the differential impacts of a policy on these groups the inputs to the model are modified as follows:

- The expected proportion of people exposed to an exposure of interest if a policy is implemented is split into estimates for the top and bottom quintiles;
- The baseline rate for each outcome of interest is obtained separately for the top and bottom quintiles; and,
- Population figures for the top and bottom quintiles are used.

The policy impacts on each of the groups are calculated using similar methods to those employed in the standard model.

To gauge the impact of a policy on health inequalities, the health impacts of the policy must be compared to those in the BAU situation. The model is run for both the proposed policy and for BAU, and the health gap under each is assessed. Having done this, the effect of the proposed policy on inequalities may be assessed. The means of doing this is illustrated in example 2, Appendix I.

When applying this method, it should be remembered that health inequalities are being assessed only in terms of the outcome due to exposures affected by a policy: it does not, of course, provide a measure of overall health inequalities. However, if gaps due to policy-relevant exposures are narrowed, and it is assumed that all other exposures remain constant, a narrowing of the health gap related to specific exposure should indicate a narrowing of the overall health gap, albeit one of differing magnitude.

4.2.2 ***Sum of severity***

See section 3.4 - Health Impact of Policy

Measurements of impact may require a longer time horizon than, for example, measuring process indicators. However, impact measurements are considered more robust when assessing causality. Also wider time horizons are necessary for understanding early antecedents to later risk factors as well as the long-term etiological processes involved in multiple disease outcomes.

The standard model ultimately views all health events in terms of their final outcome. All deaths, no matter what the cause or age of occurrence, are considered equal; as are all exacerbations of illness and other health events. Perhaps a more informative means of accounting for the relative severity of health events is to compare the DALYs (The Disability Adjusted Life Year) lost due to a health event– i.e. a measure combining information on years of life lost if a death occurs, and, the disability incurred due to an episode of illness.

The standard model may be modified so as to allow an assessment of the overall DALYs lost to the exposures associated with a policy to be estimated. In this case, health events are considered principally in terms of an illness rather than the final event associated with the illness. For example, in the standard model, deaths, hospitalisations, and primary care consultations associated with asthma are each considered separately. In the DALY model, all asthma is considered together.

Alternatively (and possibly more preferable) QALYs (The Quality Adjusted Life Year) can be calculated having been proposed as a comprehensive measure of health outcomes. QALYs are widely used in cost-effectiveness evaluations and can be likened to life expectancy except that psychological health and quality of life is also taken into consideration. Currently there is no significant agreed consensus on how to calculate the value of a QALY.

To allow the model to estimate the impact of a policy on DALYs/QALYs, the following inputs are required:

- The baseline incidence and mortality rate for each outcome of interest by age, and possibly sex;
- An estimate of the disability weight and average duration of an episode for the outcomes of interests (DALYs);
- An estimate of preference weights and the probabilities of alternative states of health (QALYs);
- Population data split by age and possibly gender; and,
- Life tables for the population.

The DALYs associated with a policy are calculated using similar methods to those employed in the standard model. It is then possible to calculate how many DALYs will be averted or QALYs gained by implementing a new policy compared to BAU. The method for calculating these figures for DALYs is outlined in example 3, Appendix I.

4.2.3 Cost-effectiveness

In estimating the health impacts of policy, the standard model does not account for the relative costs of implementing a policy. A policy apparently achieving significant health gains may only do so at a considerable cost per unit health gain. Combing the output of the above DALY/QALY model with information on the costs of implementing a policy, it is possible to estimate a ‘cost per DALY averted’ or ‘cost per QALY gained’ ratio for a proposed policy relative to the BAU situation.

In addition to the input information required for the DALY/QALY model, the cost-effectiveness model requires:

- An estimate of the number of dwellings a policy will reach; and,
- An estimate of the costs of implementing the policy on each dwelling.

Ideally, this figure would account for all costs incurred, including the costs of administering the policy.

As the relative cost-effectiveness of a policy must be compared to the baseline situation, it is necessary to estimate the costs and DALYs lost/QALYs gained due to BAU. It is unlikely that a cost-effective ratio can be calculated for the BAU situation as it is unknown what the health of the population would be if there was no policy at the present time: consequently, the DALYs averted by the BAU policy cannot be calculated. This in turn means that the cost per DALY averted by a proposed policy compared to BAU cannot be calculated. Rather, the gains achieved by at least two proposed policy options must be compared. Example 4, Appendix I provides a full worked example of this calculation.

4.2.4 Life-tables

Quantification of health impacts will also be assessed using a system of spreadsheets, developed by Miller and Hurley (http://www.iom-world.org/pubs/IOM_TM0601.pdf?PHPSESSID=551b9ccae82ad1127a41db2c144d6d9a),based on life-tables. This method will be utilised for housing outcomes and although is only presently used for mortality we will try to develop the model to take into consideration morbidity.

5 User consultation

To be done in the second pass

6 Cross-linkages

WP3.7 – climate change –especially regarding extreme indoor temperatures (heat).
WP4.2 – model development and implementation

GLOSSARY

dwelling - comparison of housing regulations on a European scale needs to take into consideration the different understanding of what a dwelling actually means in the different countries. However, there are definitions that do apply for the European region as a whole. Centrally a dwelling is understood to be "a room or suite of rooms and its accessories in a permanent building or structurally separated part thereof which […] has been built, rebuilt, converted etc. [and] is intended for private habitation. It should have a separate access to a street […] or to a common space within the building (staircase, passage, gallery etc.)"[1] New dwellings are defined as "the erection of an entirely new structure, whether or not the site on which it is built was previously occupied"[1].

[1]Bulletin of housing statistics for Europe and North America 2004, United Nations economic Commission for Europe, p66

risk - a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

hazard - Inherent property of an agent or situation having the potential to cause adverse effects when an organism, system, or (sub)population is exposed to that agent.

The following definitions are taken from "IPCS 2004 Risk Assessment Terminology, World Health Organisation".

risk assessment – A process intended to calculate or estimate the risk to a given target organism, system, or (sub)population, including the identification of attendant uncertainties, following exposure to a particular agent, taking into account the inherent characteristics of the agent of concern as well as the characteristics of the specific target system. A process involving four steps: hazard identification, hazard characterisation, exposure assessment, and risk characterisation.

hazard assessment **-** A process designed to determine the possible adverse effects of an agent or situation to which an organism, system, or (sub)population could be exposed. The process includes hazard identification and hazard characterization. The process focuses on the hazard, in contrast to risk assessment, where exposure assessment is a distinct additional step.

hazard identification – The identification of the type and nature of adverse effects that an agent has an inherent capacity to cause in an organism, system, or (sub)population.

hazard characterization -The qualitative and, wherever possible, quantitative description of the inherent property of an agent or situation having the potential to cause adverse effects. This should, where possible, include a dose–response assessment and its attendant uncertainties.

exposure **-** Concentration or amount of a particular agent that reaches a target organism, system, or (sub)population in a specific frequency for a defined duration.

exposure assessment – Evaluation of the exposure of an organism, system, or (sub)population to an agent (and its derivatives).

risk characterisation - The qualitative and, wherever possible, quantitative determination, including attendant uncertainties, of the probability of occurrence of known and potential adverse effects of an agent in a given organism, system, or (sub)population, under defined exposure conditions

APPENDIX I

APPLYING THE MODEL: WORKED EXAMPLES

Example 1: Application of the standard model

The standard model considers the final health outcome as salient; for example, death, hospitalisation etc. Other aspects, such as who is affected (e.g. age, socio-economic status), duration or degree of the burden experienced due to the illness, time lag from exposure to outcome, or costs of implementing a policy, are not accounted for.

For ease of reporting this example focuses on the impacts of a policy on a single exposure (as the proportion exposed if implemented) on a single outcome. However, in the final model there will be much more integration between the various pathways and outcomes may well be multiple, for example, exposure to mould may result in asthma exacerbations and/or other respiratory symptoms as well as increased consultation by primary care providers.

It examines a policy seeking to increase indoor winter temperatures by improving insulation, specifically examining its effect on mould in the home and resulting asthma exacerbations (note that only exacerbations are considered, not death or hospitalisation). In practice, the model is run separately for each exposure and the related outcomes, and a combined measure is calculated by simple addition.

In the example, the population of interest is considered as a whole, however, disaggregation into specific population groups is also possible.

All the figures used in the example are hypothetical.

The steps and calculations are:

1. *The impact of the policy on an exposure of interest is estimated as the proportion of the population exposed.*

   If a policy to improve insulation is implemented, a relative reduction of 20% from baseline of the population will be exposed to mould due to reduced ventilation.

2. *The health outcomes related to the exposure are identified.*

   Exposure to mould leads to asthma exacerbations.

3. *Assess the baseline rate of the outcome in the population of interest.*

   The baseline rate of asthma exacerbations is 10/1000 people annually. This is equivalent to an individual risk of 10/(1000*1000) = $1*10^{-5}$.

4. *Find an estimate of the relative risk (RR) of the outcome in those exposed.*

   In individuals exposed to mould, the RR of an asthma exacerbation is 1.5.

5. Calculate the attributable risk (AR) to asthma exacerbations (in an individual) associated with mould in the population.

AR=(Baseline risk)(1-RR) = $(1*10^{-5})(1-1.5) = 5*10^{-6}$.

6. *Find the number of cases that would occur in the population if ALL the population were exposed to mould. This is calculated by multiplying the AR by the number of people in the population.*

   The population of interest comprises 5 000 000 people.
   Potential cases = Population * AR = 5 000 000 * $5*10^{-6}$ = 25 cases.

7. *Scale the outcome using the relative severity score for the outcome (For example, in asthma, deaths may be scaled at 10 000, hospitalisations at 1000, and exacerbations at 100).*

NB: weighting is relevant only if different severity outcomes are included in the assessment.

   Relative severity for an asthma exacerbation has been scored at 100.
   Scaled potential impact = 25 * 100 = 2500

8. *Using the estimated proportion of people exposed if the policy is implemented, adjust the potential health impact to indicate the health impact of the policy.*

   If the policy is implemented, 20% of people will be exposed to mould.
   Health impact of the policy = 20% * 2500 = 500.

This score indicates the impact of the policy on asthma exacerbations. The smaller the score, the fewer asthma exacerbations there will be if the policy is implemented. The score is compared to that calculated for other policy options. For example, if under current policy, 25% of people are exposed to mould, the score for asthma exacerbations would be:

Health impact of current policy = 25% * 2500 = 625

That is, the new policy will reduce the impact of asthma exacerbations on the population (625-500 = 125).

The output from the example calculations appear obvious: a policy that leads to less mould exposure results in less asthma exacerbations. However, a policy is likely to impact on multiple exposures, which in turn are associated with multiple outcomes of differing severity. Multiple runs of the model allow these to be combined into a single summary score, facilitating the comparison of the health impacts of the various policy options.

Example 2: Impact on health inequalities

In this example, the standard model is adjusted to allow an assessment of the impact of policy options on health inequalities. Inequalities are assessed by comparing the health impacts on the most and least deprived segments of the population, as defined using an index of deprivation (e.g. the Scottish Index of Multiple Deprivation), with the bottom and top quintiles identifying the most and least deprived respectively. The impact of a policy on inequalities is assessed by comparing the differences between the most and least well-off under current policy to the differences under the various policy options.

As in example 1, the impact of a policy on a single exposure and single outcome is assessed, however, in this example, two policies are compared: current policy (business as usual, BAU) and a proposed policy. Once again, all the figures used in the calculation are hypothetical.

The steps and calculations are:

1. *The impact of BAU and the proposed policy on an exposure of interest is estimated as the proportion exposed in the bottom and top quintiles of the population.*

   If the proposed policy to improve insulation is implemented, 10% of people in the top quintile and 15% in the bottom quintile will be exposed to mould due to reduced ventilation.

   At present, exposures are 12% and 25% in the top and bottom quintiles respectively.

2. *The health outcomes related to the exposure are identified.*

   Exposure to mould leads to asthma exacerbations.

3. *Assess the baseline rate of the outcome in the top and bottom quintiles.*

   The baseline rates of asthma exacerbations are 5/1000 and 20/1000 annually in the top and bottom quintiles respectively. This is equivalent to individual risks of 5/(1000*1000) = $5*10^{-6}$ and 20/(1000*1000) = $20*10^{-6}$.

4. *Find an estimate of the relative risk (RR) of the outcome in those exposed.*

   In individuals exposed to mould, the RR of an asthma exacerbation is 1.5. Note that the RR may be very similar in the top and bottom quintiles, with the baseline risk in the groups accounting for the health differences.

5. Calculate the attributable risk (AR) to asthma exacerbations (in an individual) associated with mould in the top and bottom quintiles.

   Top quintile: AR=(Baseline risk)(1-RR) = $(5*10^{-6})(1-1.5) = 2.5*10^{-6}$.
   Bottom quintile: AR=(Baseline risk)(1-RR) = $(20*10^{-6})(1-1.5) = 10*10^{-6}$.

6. *Find the number of cases that would occur in the quintiles if ALL the population in that group were exposed to mould. This is calculated by multiplying the AR by the number of people in the quintile..*

   Each quintile comprises 1 000 000 people.
   Top quintile: Potential cases = Population * AR = 1 000 000 * $2.5*10^{-6}$ = 2.5 cases.
   Bottom quintile: Potential cases = Population * AR = 1 000 000 * $10*10^{-6}$ = 10 cases.

7. *Scale the outcome using the relative severity score for the outcome (For example, in asthma, deaths may be scaled at 10 000, hospitalisations at 1000, and exacerbations at 100).*

NB: weighting is relevant only if different severity outcomes are included in the assessment.

Relative severity for an asthma exacerbation has been scored at 100.
Scaled potential impact in top quintile is = 2.5 * 100 = 250.
Scaled potential impact in top quintile is = 10 * 100 = 1000.

8. *Using the estimated proportion of people exposed under BAU and if the policy is implemented, adjust the potential health impact to indicate health impact of the policy.*

Under BAU, 12% in the top quintile, and 25% in the bottom quintile, are exposed to mould.
Health impact of BAU in top quintile = 12% * 250 = 30
Health impact of BAU in bottom quintile = 25% * 1000 = 250.

Under the proposed policy, 10% in the top quintile, and 15% in the bottom quintile, would be exposed to mould.
Health impact of BAU in top quintile = 10% * 250 = 25
Health impact of BAU in bottom quintile = 15% * 1000 = 150.

9. *Assess the impact of the proposed policy on health inequalities.*

Relative inequalities:
BAU: (bottom quintile)/(top quintile) = 250/30 = 8.3
Proposed policy: (bottom quintile)/(top quintile) = 150/25 = 6
That is, relative health inequalities would be reduced under the proposed policy.

Absolute inequalites:
BAU: (bottom quintile)-(top quintile) = 250-30 = 220
Proposed policy: (bottom quintile)-(top quintile) = 150-25 = 125
That is, the gap between the top and bottom quintiles would be reduced under the proposed policy.

As in example 1, the overall impact of policy on multiple exposures and the associated outcomes is assessed by using multiple runs of the model and adding the summary scores together.

Example 3: Assessing outcomes as DALYs

In the standard model, health outcomes are assessed in terms of the event they precipitate, such as death or hospitalisation. This modification, by utilising disability-adjusted life years (DALYs), allows outcomes to be assessed in terms of their associated burdens. The formula for calculating the burden associated with a DALY is:

DALYs = Years of life lost (YLL) + Years lost to disability (YLD)
YLL = number of deaths * life expectancy at death
YLD = incidence * disability score * duration of illness

As in the previous examples, the impact of a policy on a single outcome associated with a single exposure is assessed in the following calculation. In this example, however, all cases of the illness are included, rather than a portion of a certain severity. That is, in the previous examples, exacerbations of asthma were considered, but deaths and hospitalisation were not; in this example, *all* asthma is considered, whatever the final outcome. Additionally, as knowing the age at event is required to calculate DALYs, the population is considered in terms of age-groups in this example. For simplicity, only three groups are used in the calculation.

As in the previous examples, all figures used in the calculation are hypothetical.

The steps and calculations are:

1. *The impact of the proposed policy on an exposure of interest is estimated as the proportion exposed in the population (This may be age specific if the policy targets certain age groups, however in this example a single figure is used).*

   If the proposed policy to improve insulation is implemented, 20% of the population would be exposed to mould due to reduced ventilation.

2. *The health outcomes related to the exposure are identified.*

   Exposure to mould leads to asthma exacerbations.

3. *Assess the baseline rate of the outcome in the age groups of interest, in terms of incidence of illness and deaths.*

   The baseline rates of asthma exacerbations are:
   <15yrs : 50/1000; risk in an individual: $5*10^{-5}$
   15-60yrs: 25/1000; risk in an individual: $2.5*10^{-5}$
   61+yrs: 10/1000; risk in an individual: $1*10^{-5}$

   The baseline rates of asthma deaths are:
   <15yrs : 2/10 000
   15-60yrs: 1/10 000
   61+yrs: 0.3/10 000

4. *Calculate the proportion of asthmatics who die due to asthma.*
   <15yrs : $2/500 = 4*10^{-3}$
   15-60yrs: $1/250 = 4*10^{-3}$
   61+yrs: $0.3/100 = 3*10^{-3}$
   [Note that the calculations ahead assume that the same proportion of asthmatics die due to asthma whether or not they are exposed to mould]

5. *Find an estimate of the relative risk (RR) of the having asthma in those exposed.*

   In individuals exposed to mould, the RR of an asthma exacerbation is 1.5. Note that the RR may be very similar in each age group, with the baseline risk in the groups accounting for the health differences.

6. *Calculate the attributable risk (AR) to asthma cases (in an individual) associated with mould in each age group.*

<15yrs: AR=(Baseline risk)(1-RR) = $(5*10^{-5})(1-1.5) = 7.5*10^{-5}$
15-60yrs: AR=(Baseline risk)(1-RR) = $(2.5*10^{-5})(1-1.5) = 3.75*10^{-5}$
61+yrs: AR=(Baseline risk)(1-RR) = $(1*10^{-5})(1-1.5) = 1.5*10^{-5}$

7. *Find the number of cases that would occur in each age-group if ALL the population in that group were exposed to mould. This is calculated by multiplying the AR by the number of people in an age group.*

   Each age group comprises 2 000 000 people.
   <15yrs: Potential cases = Population * AR = 2 000 000 * $7.5*10^{-5}$ = 150 cases.
   15-60yrs: Potential cases = Population * AR = 2 000 000 * $3.75*10^{-5}$ = 75 cases.
   61+yrs: Potential cases = Population * AR = 2 000 000 * $1.5*10^{-5}$ = 30 cases.
   These figures are the potential incidence, i.e. if all people in an age group were exposed.

8. *Calculate potential YLDs (i.e. if all people were exposed) using potential number of cases, disability score and average duration of illness [from European Disability Weights Project?]*

   Disability weight for asthma = 0.4
   Average duration of illness = 7 years

   YLD for each age group:
   <15yrs = 150 * 0.4 * 7 = 420
   15-60yrs = 75 * 0.4 * 7 = 210
   61+yrs = 30 * 0.4* 7 = 84
   Total = 420 + 210 + 84 = <u>714</u> YLDs

9. *Calculate the potential number of people who may die as a result of asthma due to exposure to mould, if all people were exposed to mould, by multiplying the potential number of cases by the proportion who die, for each age group.*

   Potential deaths = potential number of cases * proportion who die
   <15yrs: 150 * $4*10^{-3}$ = 0.6
   15-60yrs: 75 * $4*10^{-3}$ = 0.3
   61yrs+: 30 * $3*10^{-3}$ = 0.09

10. *Calculate the potential years of life lost for each group, using average age at death for each age group (Note: necessary to use average of males and females unless calculations split by sex).*

    Find expected life span using life tables (using sensible average to represent age group) (Note that in this example, the age groupings considerably wider than those that would be used in practice):
    <15yrs: 70yrs
    15-60yrs: 40yrs
    61+: 10yrs

YLL= number of deaths * life expectancy at death

<15yrs: 0.6 * 70 = 42
15-60yrs: 0.3 * 40 = 12
61+yrs: 0.09*10 = 0.9
Total = 42 + 12 + 0.9 = <u>54.9</u> years of life potentially lost due to mould exposure (if all people were exposed).

11. *Calculate DALYs by combining YLLs and YLDs*

Potential DALYs lost = potential YLLs + potential YLDs
= 54.9 + 714 = <u>768.9</u>

12. *Using the estimated proportion of people exposed if the policy is implemented, adjust the potential DALYs lost to indicate the health impact of the policy.*

If the policy is implemented, 20% of people will be exposed to mould.
Health impact of the policy = 20% * 768.9 = 153.8 DALYs lost due to mould exposure.

This figure is then combined with calculated DALYs lost if the policy was implemented due to other exposures and outcomes using simple addition. The total DALY figure for each policy, included BAU, is then compared to indicate the health impact of a policy.

Example 4: Relative cost-effectiveness of options

This modification provides a cost-effectiveness-like ratio, providing an indication of the relative health benefits of a policy compared to BAU or another policy option in terms of the costs of implementation. The estimated costs are an approximation based on planned coverage and cost per dwelling reached. For example, in reference to a policy to improve insulation (once again, using hypothetically figures):

Over five years, it is planned to reach 1000 homes with poor insulation. It is estimated that the cost of upgrading a home is £2000 per dwelling. Hence, the cost of implementing the policy is £2000 000.

The health impacts of a policy are calculated as in the examples above, and either the output from the standard (example 1) or DALY (example 3) model may used.

If a policy is already in place (i.e. as BAU), this is taken as baseline. It is unlikely that it is possible to calculate the cost-effectiveness of the existing policy as the health gains made by this policy will be unclear. For example, it is possible to estimate the health burden existing under the current policy, but it may not be possible to estimate what the health burden was before the policy was implemented. Hence, the health gains, and therefore cost-effectiveness cannot be estimated.

Using the output from the DALY model:

1. *The health impacts of the policies, including BAU, are calculated using the DALY model. The final figure that combines the outcomes resulting from all exposure is used.*

Under BAU, 500 DALYs are lost. If policy option A was implemented, 300 would be lost, and under option B, 200.

2. *The costs of implementing a policy, including the costs of BAU, are estimated.*

   The existing policy is to spend £1 000 000 every 5 years on home insulation. Policy A aims to spend £1 500 000, and Policy B, £2 000 000.

3. *The incremental cost-effectiveness ratios are calculated.*

   The formula used is:

$$\left| \frac{\text{cost of policy Y} - \text{cost of policy X}}{\text{DALYs under policy Y} - \text{DALYs under policy X}} \right|$$

[Note that the absolute value is used as, contrary to a usual cost-effectiveness ratio calculation, the figure indicating the health benefit (i.e. DALYs under a policy) decreases with increasing benefit]

Policy A c.f. BAU: $\left| \frac{1\,500\,000 - 1\,000\,000}{300 - 500} \right| = 2500$

i.e. The incremental cost-effectiveness of implementing policy A rather than BAU is £2500 per DALY averted.

Policy B c.f. BAU: $\left| \frac{2\,000\,000 - 1\,000\,000}{200 - 500} \right| = 3333$

i.e. The incremental cost-effectiveness of implementing policy B rather than BAU is £3333 per DALY averted.

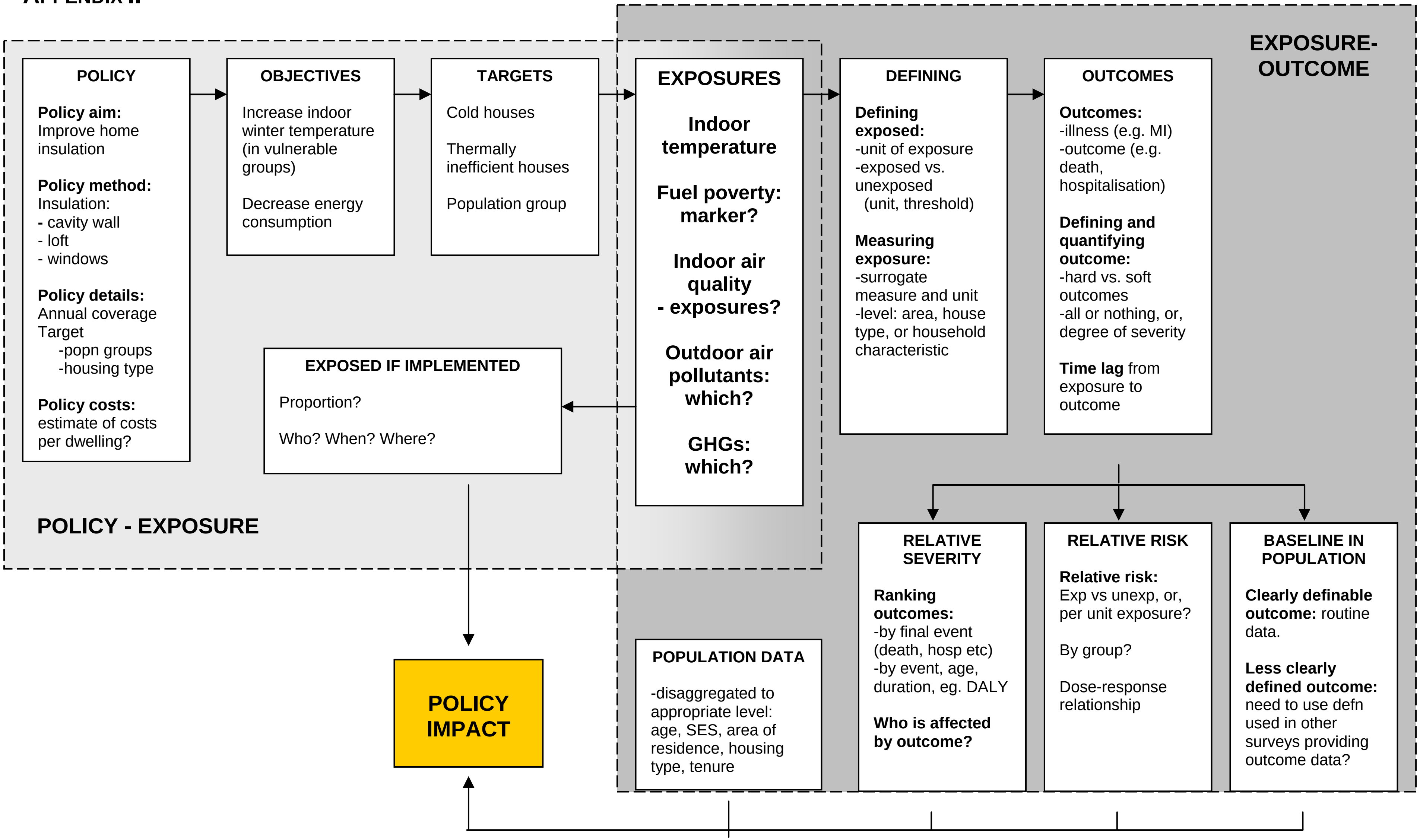
Policy B c.f. A: $\left| \frac{2\,000\,000 - 1\,500\,000}{200 - 300} \right| = 5000$

i.e. The incremental cost-effectiveness of implementing policy B rather than policy A is £5000 per DALY averted.

In other words, if policy A were to replace BAU, it would cost £2500 for each DALY averted. Further spending by implementing policy B would offer additional health benefits at a cost of £5000 per DALY averted.

Similar calculations may be made using summary scores obtained in the standard model to indicate health impacts.

APPENDIX II



EXPOSURE-OUTCOME
POLICY
Policy aim: Improve home insulation
Policy method: Insulation: - cavity wall - loft - windows
Policy details: Annual coverage Target -popn groups -housing type
Policy costs: estimate of costs per dwelling?
OBJECTIVES
Increase indoor winter temperature (in vulnerable groups)
Decrease energy consumption
TARGETS
Cold houses
Thermally inefficient houses
Population group
EXPOSURES
Indoor temperature
Fuel poverty: marker?
Indoor air quality - exposures?
Outdoor air pollutants: which?
GHGs: which?
DEFINING
Defining exposed: -unit of exposure -exposed vs. unexposed (unit, threshold)
Measuring exposure: -surrogate measure and unit -level: area, house type, or household characteristic
OUTCOMES
Outcomes: -illness (e.g. MI) -outcome (e.g. death, hospitalisation)
Defining and quantifying outcome: -hard vs. soft outcomes -all or nothing, or, degree of severity
Time lag from exposure to outcome
EXPOSED IF IMPLEMENTED
Proportion?
Who? When? Where?
POLICY - EXPOSURE
RELATIVE SEVERITY
Ranking outcomes: -by final event (death, hosp etc) -by event, age, duration, eg. DALY
Who is affected by outcome?
RELATIVE RISK
Relative risk: Exp vs unexp, or, per unit exposure?
By group?
Dose-response relationship
BASELINE IN POPULATION
Clearly definable outcome: routine data.
Less clearly defined outcome: need to use defn used in other surveys providing outcome data?
POPULATION DATA
-disaggregated to appropriate level: age, SES, area of residence, housing type, tenure
POLICY IMPACT

APPENDIX III

CASE STUDIES

CASE STUDY ON THE EFFECTS OF ENERGY EFFICIENCY OF BUILDINGS ON DAMPNESS/MOULD, INDOOR AIR QUALITY AND RELATED OUTCOMES IN COLD CLIMATE

Rationale

Estimating effects of different policies aiming to improve energy efficiency of buildings in European level has to take into account both occupant density and climate/need for heating and/or cooling. As a response to cold climate, Sweden, Finland and other Nordic countries have been on the top of the list of energy efficient buildings, and therefore have set standards for other European countries. Although the Nordic standards are already high, there is still some potential for saving energy in the Northern-European countries. However, it has been estimated that currently Southern-European countries and highly populated areas have the greatest opportunity to save energy by improved building practices, e.g. by increasing insulation. For example, if Swedish standard for insulation was applied across Europe, energy transmission through building envelopes could be reduced up to 50%.

While increasing insulation, it is necessary to ensure sufficient ventilation and pay attention to moisture control to avoid poor indoor air quality, dampness/mould growth and related adverse effects. These aspects are taken as a part of an integrated assessment proposed herein, which will be performed according to the Housing Assessment Protocol developed by INTARESE Work Package 3.2 Housing.

Energy efficiency and related aspects in the building code of Finland

The National Building Code of Finland has seven sections:
A General section
B The strength of structures
C Insulation
D Hepac and energy management
E Stuctural fire safety
F General building planning
G Housing planning and building

Sections C and D (especially sub-sections C2, C3, D2, and D3) are of special interest with respect to energy efficiency, and have gone through major changes during the past decade.

Code C2 “Moisture” took action in 1998, replacing the old code from 1975, and was mainly endorsed by notification of lack of regulations and guidelines to prevent and control moisture and mould related problems in buildings, and high prevalence of such problems found in the housing stock.

Code C3 “Thermal insulation in buildings” became effective in 2003, replacing the old regulations from 1982, as a response to EU Standards and higher energy efficiency requirements for buildings. For example, acceptable thermal transmittance of building components measured as U-values was reduced by 10% in base floor, 17% in external wall and 37% in upper-most floor structures and by 50% in windows. Taking even a longer time perspective, U-values of the building envelope based on year of construction have been reduced by over 50% in all structure types since the 1970’s.

Of the current Finnish housing stock 61% is built after 1970. By dwelling type, 62% of the apartment buildings, 90% of the row houses, and little over 50% of the single-family houses are built after 1970. Code C3 is currently being renewed again (new code expected to take an effect in 2008). According to the new C3, a further 5-10% reduction in thermal transmittance of building components is required as compared to the C3 from 2003.

Code D2 “Indoor climate and ventilation in buildings” from 2003 regulates building design and construction for achieving healthy, safe and comfortable indoor climate, and gives guidelines for acceptable room temperatures, maximum concentrations of pollutants including gases and particles, humidity, and ventilation / air flow rates. Code D3 Energy management in buildings is currently from year 1978, and aims for such design and construction of buildings that limits unnecessary energy use for achieving good energy efficiency. Codes D2 and D3 are also under renewal process; new codes are expected to take effect in 2008. Most extensive changes are expected in D3, regarding estimation of power and energy needs of buildings.

Aim of the study

This case study aims to study the effects of energy efficiency of buildings on dampness/mould, indoor air quality and related outcomes in cold climate (Finland and possibly Norway). It is built around three scenarios: ‘business as usual’ (BAU) is corresponding to the current housing stock as in 2007. BAU 2003 and BAU 2008 (in Finland) are corresponding to the scenarios of dwellings fulfilling the building codes launched in 2003 and 2008. It should be noted that the insulation requirements, for example, for external wall structures in Norway are approximately at the same level as in Finland, whereas in Great Britain, France, and the Netherlands they are about 50% less (corresponding to Finland prior to 1970’s), and in Italy about 75% less.

APPENDIX IV

Exposure	Partner
Cold	LSHTM/ASL
Heat	ASL/LSHTM
Damp/mould	KTL/NILU
Radon gas	CSTB/RIVM
PM	ICL/NILU/KTL
ETS	ICL/RIVM/NILU
NO	2nd Pass
CO	2nd Pass
Noise	2nd Pass
VOC	2nd Pass

APPENDIX V

In this example we are interested in estimating the impact of two hypothetical indoor environmental variables on 70-74 year old females. Assume that the relative risks (RRs) associated with the particular levels of environmental exposures on CVD incidence rates are 1.8 and 1.4 respectively. If the CVD baseline event rate of this population group is 0.0276 per 100,000, the total health impact is (assuming no uncertainty):

$h = (1.8\text{-}1) \times 0.0276 + (1.4\text{-}1) \times 0.0276 = 0.0331$ CVD deaths per 100,000

Assume now that we are uncertain about the CVD baseline event rate and the RRs associated with the exposure levels of the environmental variables. We characterise the uncertainty in the baseline event rate and the RRs in terms of *pdfs* and we assume that all the uncertainties can be described by log-normal *pdfs*. The parameters of the log-normal *pdfs* were chosen such that the mean values of the uncertain parameters were the same as in the deterministic scenario (i.e. assuming no uncertainty). In practice the parameters of the *pdfs* are obtained from epidemiological evidence.

Figures 1-3 show respectively the assumed *pdfs* of the baseline event rate and the RRs. Using MC simulations, we estimated the associated uncertainty in the total health impact by propagating the uncertainties in the health impact calculations (Figure 4). In this example, the mean total health is 0.0331 CVD deaths per 100,000 and its 95% CI as [0.0328, 0.0334].

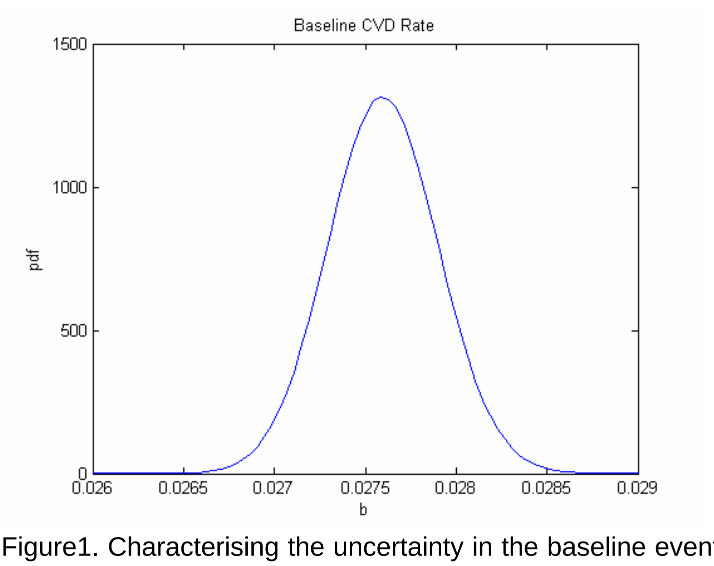


Figure1. Characterising the uncertainty in the baseline event rate. The parameters of the log-normal distribution were chosen such that the mean of the distribution is 0.0276 (as in the deterministic scenario) and the variance is 2.92×10^{-8}.

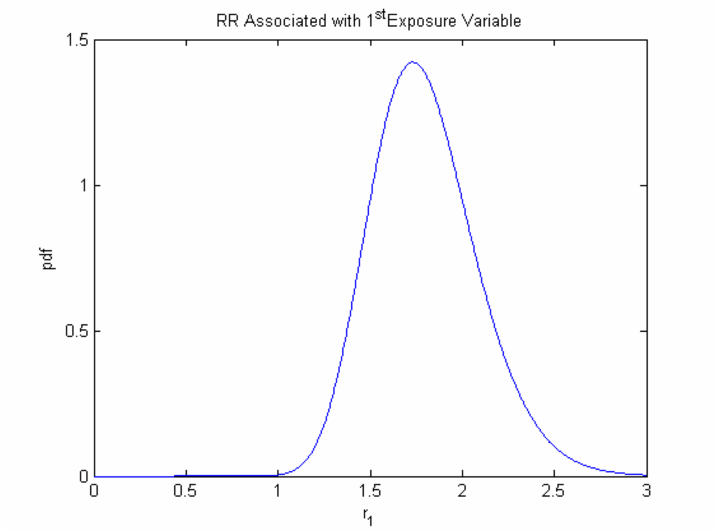


Figure 2. Characterising the uncertainty in the relative risk due to the first exposure variable. The parameters of the log-normal distribution were chosen such that the mean of the distribution is 1.8 (as in the deterministic scenario) and variance is 0.0839.

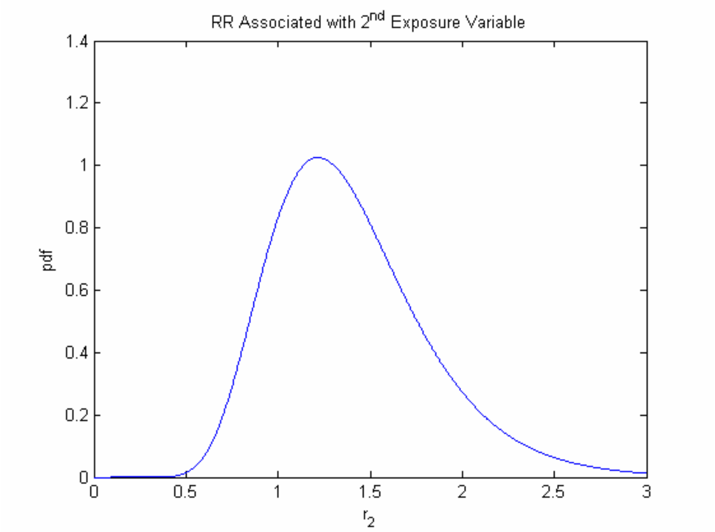


Figure 3. Characterising the uncertainty in the relative risk due to the second exposure variable. The parameters of the log-normal distribution were chosen such that the mean of the distribution is 1.4 (as in the deterministic scenario) and the variance is 0.1909.

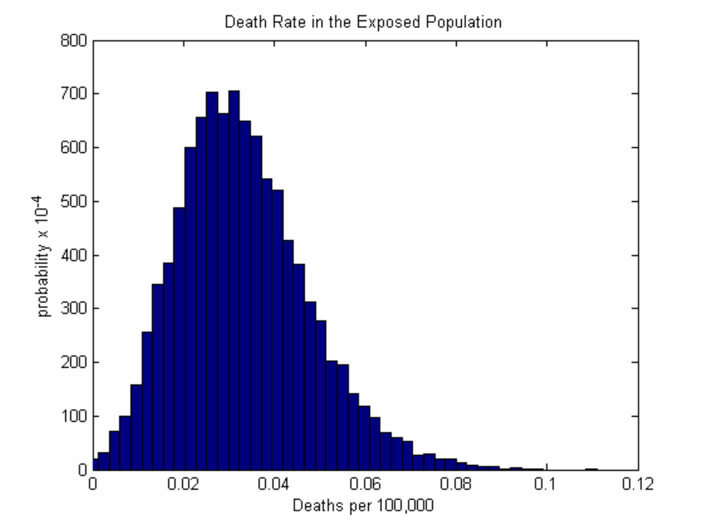


Figure 4. Estimated uncertainty in the health impact estimated using MC simulations. The calculated mean of the distribution is 0.0331 and its 95% CI is [0.0328,0.0334].