Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

WP5 Social welfare

Draft methodology for quantifying social welfare impacts

D5.2

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1 Background

1.1 Project description

The COMBI project aims at quantifying the multiple non-energy benefits of energy efficiency. It is coordinated by the Wuppertal Institute for Climate, Environment and Energy and implemented together with the research partners University of Antwerp, University of Manchester, Copenhagen Economics and ABUD/Advanced Buildings and Urban Design. The multiple benefits of energy efficiency are gaining relevance in the research and the current policy discourse, but scientific evidence is yet scarce and scattered. Therefore, this projects will gather existing approaches and evidence from the EU area, develop modelling approaches and come up with consolidated data on different benefits such as emissions (effects on health, ecosystems, crops, built environment), resources (biotic/abiotic, energy/non-energy), social welfare (disposable income, comfort, health), macroeconomy (labor market, public finance, GDP), and the energy system (grid, supply-side, energy security). All project outcomes will be available at an open-source online database and be analysable via a graphic online-visualisation tool for personalising the findings as to their geographic location and selected benefits. To this end, the development of an aggregation methodology is of central importance to avoid double-counting and presenting the various benefits on their various dimensions. Finally, insights for policy relevance will be derived and policy recommendations will be elaborated to facilitate the communication of the non-energy benefits in the relevant policy areas. In addition, the project is in touch with on-going processes of how to include multiple energy efficiency benefits into policy evaluation.

1.2 Aim of this report

Based on the literature reviews conducted for individual multiple impacts (MI), the second main step of the COMBI project is to develop a methodology to quantify and monetise MIs. Monetisation of single (sub-)MI is conducted where possible. For the set of defined EEI actions (see D2.2 report), energy saving potentials in the year 2030 are being developed reflecting official EU PRIMES scenarios (energy efficiency vs. baseline scenario) (see D2.1 report). The general COMBI approach follows the additionality principle: Only additional effects (both energy and non-energy impacts) relative to an action baseline are considered.

2 Scope of investigation

2.1 Energy efficiency improvement actions in the residential housing sector: definition of impacts, end-points and metrics/indicators

2.1.1 Thermal comfort (human health)

In 2014, 10.2% of the EU population (around 50 million) were not able to keep their houses adequately warm during the winter season due to high heating costs and/or poor housing quality (Eurostat, 2016b). There are human health consequences arising as a result of inadequate thermal comfort indoors as defined by the World Health Organization (Braubach, Jacobs, Ormandy, World Health Organization, & Regional Office for Europe, 2011). Optimal indoor temperature is considered to be between 18-21 degrees Celsius and prolonged exposure to indoor cold below recommended temperatures can be associated with cardiovascular, respiratory diseases and poor mental health (Braubach et al., 2011; Gilbertson, Grimsley & Green, 2012; Howden-Chapman & Chapman, 2012). There is sufficient evidence that indoor cold is responsible for a share of these cases in mortality and morbidity (Braubach et al., 2011; Christine Liddell & Morris, 2010). Seasonal variation mortality and morbidity in temperate climate zones is related to seasonal variations in temperature. It has been noticed that coldest seasons provoke peaks in morbidity and mortality. Suboptimal temperatures indoors may lead to prolonged cold exposure and eventually rise in respiratory and cardiovascular diseases. Occasionally these may culminate in death – more than two thirds of excess winter mortality cases are attributed to respiratory and cardiovascular diseases (Eurowinter Group, 1997; Mercer, 2003). Therefore, energy efficiency actions in residential housing are expected to contribute to improved health and life expectancy.

The relationship between cold weather and excesses in mortality and morbidity was already noticed in ancient Greece and has been studied since the 19th century (Christine Liddell, Morris, Thomson & Guiney, 2015). Exposure to cold, indoors or outdoors, leads to acute (e.g., frostbites, hypothermia, death) and chronic physiological conditions related to respiratory and cardiovascular diseases under prolonged exposures (Hassi, 2005). Some of these chronic conditions eventually lead to excess winter deaths. Respiratory diseases and cardiovascular diseases are associated with the majority of excess winter death cases (ibid).

Lowest mortality rates according to monthly data occur around a narrow range of average day outdoor temperatures of 15-25 degrees Celsius (Howden-Chapman, 2004). Excess winter morbidity and mortality cases capture the influence of many factors, such as air pollution, seasonal epidemics, suitability of outdoor clothing, poor quality housing; while comparisons between countries add another level of complexity due to socio-economic differences between countries in terms of economic development, education, health spending, diets and obesity, lifestyles and behaviour (Clinch, 2000; Eurowinter Group, 1997; Healy, 2003; Mercer, 2003).

Mortality due to indoor cold is preceded by morbidity – cardiovascular and respiratory diseases. Numerous studies have confirmed a latent effect of temperature drop on the onset of illnesses, hospitalizations and general practitioner visits: they tend to be on increase with a delay in relation to a drop in outdoor temperature. For instance, in London a drop in average daily temperature by 1 degree C below 5 degrees C was found to be associated with a 10.5% increase in the onset of respiratory diseases and general practitioner consultations; and it was found to have up to 15 days lag (Hajat & Haines, 2002). But no such relationship was found for cardiovascular diseases very likely due to their chronic nature for general practitioner consultations, but the winter excess effect could be visible on acute symptoms - hospitalizations and deaths (ibid.). Indeed, lower temperatures were found to be related to an increased risk of hospitalisation due to cardiovascular diseases (Abrignani et al., 2009; Lan Chang, Shipley, Marmot, & Poulter, 2004; Martínez-Sellés et al., 2002; Stewart, McIntyre, Capewell, & McMurray, 2002). However, other research found no relation between temperature and cardiovascular diseases (Goerre et al., 2007; Maheswaran, Chan, Fryers, McManus, & McCabe, 2004; Rothwell, Slattery, Warlow, & Wroe, 1996). Excess winter morbidity related to respiratory diseases was found to be related to fuel poverty (Rudge & Gilchrist, 2007), while another study found no connection between excess winter morbidity and social deprivation (Maheswaran et al., 2004).

Definition

Human health improvements - reduced morbidity and mortality - arising from increased indoor temperatures. They corresponding to the World Heath Organization thermal comfort guidelines (18-21 C) and result from energy efficiency improvement actions in the residential housing sector related to building envelope insulation and heating system improvement or replacement.

Physical metrics

- Excess winter mortality attributable to inadequate housing - indoor cold (number of cases or number of hospitalizations)
- Excess winter morbidity attributable to inadequate housing - indoor cold (number of cases or number of hospitalizations)

2.1.2 Indoor dampness (human health)

Energy efficiency improvement actions in residential housing may have implications for indoor dampness and associated diseases. Dampness leads to growth of indoor mould that can cause allergies and asthma. Around 13% of all dwellings in EU-28 are reported to have a dampness problem (Kolokotsa & Santamouris, 2015). Different age groups demonstrate different sensitivity and relative risk to dampness related asthma with children being the most sensitive (Braubach et al., 2011). Leaks, draughts, and poorly insulated outer walls can cause indoor dampness. In general, insulation of building envelope and improvements in heating system help to eliminate the dampness problem along with increasing indoor temperatures and thermal comfort. Another potential risk of dampness might emerge in the case of super insulation of deep retrofits, but this health risk will not be quantified in COMBI (see it discussed in chapter 6).

Definition

Human health improvements - reduced asthma morbidity and mortality – arising from decreased indoor humidity and increased indoor temperatures as a result of energy efficiency improvement actions in the residential housing sector related to building envelope insulation and heating system improvement or replacement.

Physical metrics

- Environmental burden of disease (asthma) attributable to indoor dampness (DALYs)

2.1.3 Comfort

Comfort indoors includes thermal comfort, visual comfort, acoustic comfort, air quality and ability to control the variables of indoor comfort (Frontczak & Wargocki, 2011; Kolokotsa & Santamouris, 2015). Thermal comfort bears the highest weight among those (Frontczak & Wargocki, 2011) and the strongest links with energy efficiency improvement actions.

Thermal comfort may be one of the strongest drivers for energy efficiency in residential buildings among certain socio-economic groups. Capturing the impact has been challenging as it is a subject to a few factors, such as socio-cultural norms, age, gender, behavior, preferences, history of thermal experiences, space layout and possibility of control over thermal comfort (Rupp, Vásquez, & Lamberts, 2015). Nevertheless, improvements in thermal comfort as a result of energy efficiency actions have been documented both qualitatively and quantitatively, especially in the context of energy poverty and indoor cold (Hong, Gilbertson, Oreszczyn, Green, & Ridley, 2009; Howden-Chapman et al., 2009; Milne & Boardman, 2000). The associated positive effects include reduced crowding as well as improved physical and mental health. Thermal comfort is observed and operationalized via an increase in indoor temperatures and/or an increase in the total heated area (Clinch & Healy, 2003; Howden-Chapman et al., 2009; Tirado-Herrero, 2013).

Comfort can also be framed as a rebound effect. If previously, indoor thermal comfort was unaffordable for the energy poor, energy efficiency improvement actions contribute to improving the affordability of indoor thermal comfort. Therefore, a part of the technical energy efficiency savings potential is taken back with increasing temperature and /or with an increase in total space heated. The other part is taken back as energy bill savings, and therefore, energy savings. As a result comfort equals the direct rebound effect (Milne & Boardman, 2000; Ürge-Vorsatz & Tirado Herrero, 2012). A study monitoring energy efficiency interventions in Britain has determined that lower indoor temperatures prior to the intervention are related to larger rebound effects (improved comfort). Whereas households already enjoying adequate thermal comfort before an intervention are more likely to recuperate the energy efficiency potential in the form of energy savings in full (Milne & Boardman, 2000).

The split between energy savings and comfort has been observed in intervention studies that document the impacts of so called 'easy retrofits' – housing retrofits that aim at the improvement of one or more elements in a non-systematic way, e.g. replacement of single glazed windows by double glazed windows, external wall insulation, cavity wall insulation, draught proofing and etc. (ibid). The COMBI project only plans to account for "deep retrofits" – energy efficiency improvement actions in the existing housing sector that include envelope insulation, air sealing (additional insulation), upgrade of heating/cooling and venting systems in order to achieve more than 50% reductions in energy savings on par with energy consumption standards per m^2 of passive houses (own definition). There is no evidence in the scientific literature on the split between comfort and energy savings in the case of deep retrofits. In this case energy consumption reductions are so dramatic, that even if there is a take-back in comfort, it is likely to be very small and the value of it would not be adequate to approximate for the gain in comfort as suggested above (e.g. comfort gains are a full by-product of deep retrofits).

Noise reduction or acoustic comfort is another aspect of general comfort, which could be potentially assessed on the geographical scale of COMBI due to the availability of data. The links between thermal and acoustic insulation are well established (Diamant, 1986), however, there are still too few studies examining the effect of thermal insulation of building envelope on the acoustic comfort after the intervention, especially in residential buildings. Synergies occur when thermal insulation materials or elements of building retrofit also have the features of acoustic insulation. Some studies report mostly positive effects of building retrofits on acoustic comfort (Guigou-Carter, Foret, Villot, & Chene, 2010), others report mixed or no effects (Bonnefoy, Braubach, Krapavickaite, Ormand, & Zurlyte, 2003; Shrubsole, Macmillan, Davies, & May, 2014). The results are expected to vary depending on the type of retrofits – easy versus deep. In general low-energy consuming houses report better noise protection from outside sources of noise due to well insulated walls (Zalejska-Jonsson, 2012), but indoor noise sources may even be amplified (Larsen, Jensen, & Daniels, 2012). Trade-offs are reported to occur due to installation of noisy venting systems (Mlecnik et al., 2012; Morelli et al., 2012), increased reverberation (Larsen et al., 2012) and in new buildings due to a few design elements of green buildings (such as daylighting, radiative heating and cooling, material efficiency and types of materials used) (Muehleisen, 2011; Newsham et al., 2013). Acoustic performance can be improved including the acoustic standards at the design phase of retrofits and training the end-users to perform maintenance of the ventilation systems (Mlecnik et al., 2012; Muehleisen, 2011).

Definition

A general improvement in human well-being due to an increase in temperature, total heated area and noise exposure reduction as a result of energy efficiency improvement actions in the residential housing sector related to building envelope insulation and heating system improvement or replacement.

Physical metrics

- Projected rebound effect per household/projected foregone energy efficiency saving per household (EUR, kWh) (not applicable to COMBI)
- Share of total population unable to keep home adequately warm (%)
- Share of total population living in households considering that they suffer from noise (%)

2.1.4 Disposable income

Subsidies helping to cope with utility bills are the most widespread method of state support for the energy poor. This approach has been criticized as it endorses the status quo and does not address the root of the problem: social inequalities and high carbon intensity (Boardman, 2010; Bouzarovski, Petrova, & Sarlamanov, 2012; Scott, 1996; Ürge-Vorsatz & Tirado Herrero, 2012). Only a handful of countries in Europe[1] have launched energy poverty reduction programmes with an aim to improve the energy efficiency of the residential housing sector (Pye, Baffert, Brajkovic, De Miglio, & Deane, 2015). These state-sponsored programmes aim to systematically address the problem of inadequate housing and also household income via disposable income aspects. As mentioned before in 2.1.3, technical energy efficiency savings potential can be split between a take back in comfort (rebound effect) or as savings on energy utility bills. In the case of deep retrofits to be studied in COMBI, this split becomes irrelevant due to the dramatic reduction in energy requirements to heat a unit of space. Increase in disposable income is of importance due to other deprivations that may arise in competition with energy bills. Secondary disposable income impacts may extend further to a better nutrition (Beatty, Blow, & Crossley, 2014; Bhattacharya, DeLeire, Haider, & Currie, 2003) and a better mental health (Gilbertson et al., 2012; C. Liddell & Guiney, 2015; Christine Liddell & Morris, 2010).

The definition of disposable income used in this research will somewhat deviate from the traditional meaning attached to it. Disposable income is a sum of household income from various sources (salaries, rental income, transfers and benefits) minus all taxes (income, social security, property and etc.) (OECD, 2014). In this research, disposable income is a sum of all household income minus taxes and energy utility bills. It equals to all "non-energy-bill" expenditure plus savings.

[1] United Kingdom, Ireland, Cyprus and France.

In COMBI it will not be possible to account for such details as e.g. financial details of the investment (public, private or both) or pay-back times, but they are of crucial importance for the disposable income effect. State-sponsored energy efficiency improvement actions in the residential buildings of the energy poor would imply an immediate effect on their disposable income. In all other cases, an increase in disposable income effect would only result after the pay-back of the initial investment is over and, therefore, with a delay. It is impossible in COMBI to model these different situations with time delay and, therefore, disposable income will simply be equated with energy savings (net of rebound effect).

Definition

Disposable income due to energy efficiency improvement actions in residential income is defined as a decrease in energy utility bill expenditure.

Physical metrics

- Projected average energy savings and energy bill savings per household (kWh and EUR)

2.1.5 Noise (human health)

125 million people in the EU are exposed to unsafe road traffic noise levels and noise causes 10 thousand premature deaths, 900 thousand cases of hypertension and 43 thousand hospital admissions every year (European Environment Agency, 2014). The World Health Organization estimates that in total 1.0-1.6 million of DALYs (disability adjusted life years) are lost in Europe due to noise, among them - 61 thousand years due to ischaemic heart disease, 45 thousand years due to cognitive impairment of children, 903 thousand years due to sleep disturbance, 22 thousand years due to tinnitus and 654 thousand years due to annoyance every year (Theakston & World Health Organization, 2011). As it was suggested in 2.1.3, building envelope insulation can be the necessary and sufficient response in tackling outdoor noise pollution.

Laboratory tests have proven a pathway of noise leading to cardiovascular diseases via stress (Babisch, 2003). Noise can be a stressor that activates the nervous system. It is beneficial in short-term as it mobilizes the organism for a response, however, under long-term exposure the chronically activated nervous system may become misbalanced and could lead to psychological and physiological health disorders – depression, anxiety, panic, sleep disturbance and insomnia, tinnitus, annoyance and cardiovascular diseases, e.g. ischaemic heart disease and hypertension (Braubach et al., 2011). Cardiovascular diseases are on the top of the list of mortality causes in the EU and the developed world. The WHO suggests that the share of cardiovascular diseases attributed to noise could be estimated given the different noise level exposure estimates of affected population exist (Braubach et al., 2011). Road traffic noise exposure is suggested as he main risk factor among those creating noise (Braubach et al., 2011; European Environment Agency, 2014).

Definition

Improvement in human health – reduced morbidity and mortality due to cardiovascular diseases – as a result of a reduced exposure to noise due to energy efficiency improvement actions in residential buildings, namely insulation of building envelope.

Physical metrics

- Environmental burden of disease (cardiovascular diseases) attributable to noise (DALYs)
- Alternative or additional quantitative end-points for health impacts of noise may include annoyance, sleep disturbance, cognitive impairment in children, hypertension. If recommended and feasible within the research project timeline these can also be added to the assessment as described by Houthuijs, Beek, Swart, & van Kempen (2014).

2.1.6 Indoor air pollution (human health)

There are many kinds and origins of indoor air pollution. Indoor air pollution is related to outdoor air pollution via natural and mechanical ventilation and infiltration. Outdoor air pollution is a proxy for indoor air pollution for such substances as sulphur dioxide, nitrogen oxides, ozone, particulate matter, volatile organic compounds and others. The impact of these pollutants will be assessed in WP3 Indoor environments. The impact of microbial and biological indoor air pollution will be assessed in WP5 Human health (indoor dampness). Indoor furnishings and the use of various substances indoors maybe a source of another large group of indoor air pollutants, such as benzene, formaldehyde, naphthalene and others, however, energy efficiency improvement actions are not likely to lead to any changes in those.

Nevertheless, energy efficiency improvement actions may contribute to changes in some building material structures that may be a source of indoor air pollution. For instance, asbestos roof may be replaced; lead paint or lead containing structures may be removed. Lead in paint and asbestos use have been banned (Gee & Greenberg, 2002; Needleman & Gee, 2002), but their legacy still lurks in the existing building stock posing a threat to human health (Braubach et al., 2011; Kameda et al., 2014). Asbestos are a risk factor for several types of cancer and asbestosis (WHO regional office for Europe, 2013), and lead is associated primarily with mental retardation and cardiovascular diseases among other health impairments (Braubach et al., 2011).

Indoor radon is a naturally occurring air pollutant that seeps into the buildings from the ground as a result of natural processes, concentration of which varies across Europe with the largest prevalence in the Czech republic, Finland, parts of France, Italy, Austria, Portugal (European Environmental Agency, 2016). Ground floor of a building is the most affected with indoor radon pollution. Exposure to unsafe levels of radon is associated with lung cancer (Braubach et al., 2011). Insulation of the building envelope actually may increase the indoor radon exposure and dose, unless necessary protective actions are taken, e.g. ensuring proper ventilation and/or sealing the basement of the building. If protective measures against indoor radon are included in the energy efficiency improvement actions in prevalent areas, this health risk can be reduced with positive implications for human health.

Instead of having a separate programme for indoor radon safety, asbestos and lead removal, the state bodies could integrate multiple goals into their building retrofit programmes.

Also see chapter 6 for key assumptions and early warnings.

Definition

Improvement in human health – reduced morbidity and mortality - due to reduced exposure to indoor radon, lead and asbestos as a result of a reduced exposure due to intended or unintended actions that (could) go along with energy efficiency improvement actions in residential buildings.

Physical metrics

- Environmental burden of disease (lung cancer) attributable to indoor radon (DALYs)
- Non-occupational environmental burden of disease (lung cancer, mesothelioma and asbestosis) attributable to asbestos exposure
- Environmental burden of disease (cardiovascular diseases) attributable to lead exposure

2.1.7 Impact end-points under consideration

A few additional impact end-points have been suggested after an internal round of reviews. Their inclusion and the level of engagement depends on a few factors:

1. If the impact pathway is induced by one of 30 energy efficiency improvement actions (if it is within the scope of COMBI);
2. Sufficiency of evidence of a relationship proving the impact pathway in question;
3. The existence of quantification methodologies of disease burden attributable to housing risk factors on the scale of COMBI – national or EU-28 scale;
4. Availability of data necessary for the assessment.

In the absence of (3) and (4) the impact end-point may be added and discussed only qualitatively pointing out to gaps in scientific knowledge and directions for further research.

The suggested impact end-points include features of passive houses:

- Installed ventilation equipment leads to a (presumably) better indoor air exchange contributing to a better indoor air quality via reducing the prevalence of airborne biological pathogens and, therefore, also reducing the probability of onset of airborne diseases.
- Installed air filters lead to a better indoor air quality via reducing air pollutant and allergen concentrations, compared to outdoors, and therefore, reducing the probability of air pollution damage on health and allergy reactions.

2.2 Modal shift in passenger transport: definition of impacts, end-points and metrics/indicators

2.2.1 Physical activity (human health)

The lack of physical activity and its repercussions for health in developed societies have been pointed out a few decades ago. Physical activity is coming back as an important co-benefit in the studies on climate change mitigation and sustainable urban transportation (Mzavanadze, Kelemen, & Urge-Vorsatz, 2015). Physical inactivity is considered to be among the leading causes of morbidity and mortality globally (No 4), after high blood pressure, tobacco use and high blood glucose, and its importance is growing with more population adopting sedentary life styles with inadequate physical activity levels (World Health Organization, 2010). A closer look at the risks of non-communicable diseases reveals that physical activity could be linked to a solution or at least a reduction of some of the most important health risks: high blood pressure, high glucose levels in blood, and obesity (cause No 5) (Loprinzi, 2015). Non-communicable diseases related to physical activity include cardiovascular diseases, diabetes, a few types of cancer, as well as mental diseases, such as depression, dementia and Alzheimer's disease (Kahlmeier, World Health Organization, & Regional Office for Europe, 2013). Non-communicable diseases currently account for nearly a half of the global disease burden (World Health Organization, 2010). One of the ways to increase physical activity is to transform transportation systems, especially urban transportation systems to those more suitable for cycling and walking. As research shows a large share of total motorized trips especially in urban environments - between one third and two thirds - are short and medium distance and they could be in principle replaced by walking or cycling (Grabow et al., 2011; Maizlish et al., 2013; Woodcock et al., 2009; Xia et al., 2015).

Definition

Improvement in human health – reduced morbidity and mortality - due to an increased physical activity as a result of a modal split in favour of cycling and walking.

Physical metrics

- Number of lives saved due to a reduction in mortality rate due to non-communicable diseases linked to physical activity (avoided deaths)
- Change in disability adjusted life years (DALYs) due to an increase in physical activity in relation to multiple diseases linked to physical activity (DALYs).

2.2.2 Road accidents (human health)

Every travel mode bears a different probability of traffic related accident based on past data, therefore, modal shift is likely to change the distribution of these risks. Modelling of traffic accidents due to modal shift has not been unanimous. Some predict an increase in the traffic accidents (de Hartog et al. 2010; Macmillan et al. 2014; Rojas-Rueda et al. 2012) taking into account that cycling is a more risky travel mode according to the current data. While others argue for a decrease (Maizlish et al. 2013; Woodcock et al. 2009; Xia et al. 2015) due to a general decrease in vehicle road traffic as the biggest threat to cyclists and pedestrians. The reason of the split may also be context dependency (e.g. availability of favourable infrastructure) and also differences in the temporal scale. The "safety in numbers" effect happens over many years along with changing attitudes, while in the short term an increase in traffic injuries can be expected in places where "safety in numbers" effect has not yet occurred.

Although the number of road accidents in the EU is on a decrease trend in the last few years, over 25 thousand people died in road accidents in the EU in 2014 with large differences between countries per capita (European Comission, 2015). 8% of all fatalities in 2014 occurred to cyclists, while 22% occurred to pedestrians (ibid.).

Definition

A change in human health due to a change in road accidents linked to modal shift towards walking and cycling.

Physical metrics

- Number of lives saved/lost due to road accidents as a result of a modal shift towards cycling and walking (number of lives saved/lost)
- Change in disability adjusted life years (DALYs) due to a change in the incidence of road accidents (DALYs).

2.3 EEI actions relevant for social welfare impact end-points

Table 1: Relevance of EEI actions to social welfare impacts.

#	EEI actions	Considered	Reason for inclusion/exclusion
1	Residential existing buildings – improvements of building envelopes Content	Yes	Sufficient evidence in scientific literature on the implications to social welfare
2	Residential new buildings – PassivHaus standards for heating and cooling demands	No	Passive houses represent maximum social welfare attained already.
3	Residential existing buildings – improvements of heating systems	Yes	Sufficient evidence in scientific literature on the implications to social welfare
4	Residential – improvements of domestic hot water systems	No	Little evidence, difficult to operationalise
5	Residential existing buildings – improvements of (room) air-conditioning systems	No	Little evidence, difficult to operationalise
6	Residential – improvements of lighting systems	No	No evidence
7	Residential appliances – improvements of refrigerators / freezers	No	Little evidence, difficult to operationalise
8	Tertiary existing buildings – improvements of building envelopes		To be considered and addressed (compare D5.2a report)
9	Tertiary new buildings – PassivHaus standards for heating and cooling demands		
10	Tertiary existing buildings – improvements of heating systems		
11	Tertiary – improvements of domestic hot water systems		
12	Tertiary existing buildings – improvements of air-conditioning systems and fans		
13	Tertiary – improvements of lighting systems (including street lighting)		
14	Tertiary – improvements of commercial refrigeration and freezing		
15	Passenger transport – improved efficiency of road vehicles (cars)	No	No evidence
16	Freight transport – improved efficiency of light and heavy duty trucks	No	No evidence
17	Passengers and freight transport – improved efficiency of rail transport vehicle	No	No evidence
18	Passenger transport – modal shift	Yes	Sufficient evidence in scientific literature on the implications to social welfare
19	Freight transport – modal shift	No	No evidence
20	Process heating high temperature: iron – more efficient furnaces (BF and BOF)	No	No evidence
21	Process heating high temperature: steel – more efficient Electric Arc Furnaces (EAF)	No	No evidence
22	Process heating high temperature: cement –more efficient kilns	No	No evidence
23	Process heating high temperature: glass – more efficient (glass melting) furnaces	No	No evidence
24	Process heating high temperature: olefins – more efficient steam crackers	No	No evidence
25	Process heating high temperature: paper – more efficient driers	No	No evidence
26	Electrochemical processes - more efficient primary aluminium production	No	No evidence
27	Electrochemical processes - more efficient chlor-alkali production	No	No evidence
28	Process heating – more efficient steam systems, including CHP	No	No evidence
29	Machine drive – more efficient fan and pump systems	No	No evidence
30	Industrial facilities – more efficient space heating		To be considered and addressed by ABUD

2.4 Evaluation perspectives

Table 2: Evaluation perspectives for social welfare impact end-points.

Impact end-point	Evaluation perspective
Human health - thermal comfort	Societal
Comfort	End-user
Disposable income	End-user
Human health - noise	Societal
Human health .- indoor air quality	Societal
Human health - physical activity	Societal
Human health - road accidents	Societal

2.5 Distributional aspects

Distributional aspects are relevant only to these social welfare impact end-points that originate from energy efficiency improvement actions in the residential housing sector. Impact end-points originating from modal shift towards walking and cycling are not restricted to any socio-economic group and are relevant to the whole society.

Table 3: Distributional aspects of energy efficiency improvement actions in residential housing.

Impact end-point	Distributional aspects
Human health (WP5: thermal comfort)	Relevant only to the energy poor, who are not able to keep their homes adequately warm during the cold season and are exposed to dampness indoors.
Comfort	Especially relevant to the energy poor, who are not able to keep their homes adequately warm during the cold season; but relevant also to others as acoustic discomfort may not be restricted to the energy poor only and deep retrofits may signify a whole new level of comfort indoors.
Disposable income	Especially relevant to energy poor, who are not able to keep their homes adequately warm during the cold season and/or pay disproportionately high energy utility bills measured as a share of the total household income, but also relevant to the whole society.
Human health (WP5: noise)	No evidence found of any socio-economic group being disproportionately exposed to this health hazard.
Human health (WP5: indoor air quality)	Some evidence found that the energy poor may be more exposed to these health hazards (lead, asbestos) than other socio-economic groups, but overall relevant to the whole society.

Evaluating distributional aspects in COMBI is a challenge due to a very short time line and the year 2030 being as the target year for assessment for the two scenarios. In this time frame only a small part of the total building stock will be retrofitted. As it is impossible to know from the scenarios, which socio-economic group is going to benefit from the building retrofits as well as on what conditions (public, private or public and private investment), a situation is proposed to be modelled where social welfare related impacts as a result of energy efficiency improvement actions in the residential housing are proportionate to the share of the residential housing retrofitted[2].

A multiple step methodology is proposed to address distributional issues in COMBI project:

- Firstly, the current environmental disease burden attributable to poor housing will be estimated to establish a baseline.
- Secondly, based on scenarios the total environmental disease burden will be projected for 2030 in relation to ageing population and other important factors.
- Thirdly, the share of housing retrofitted for both scenarios will be calculated for each country.
- Fourthly, the same share (percentage) will be applied to calculate the avoided human health impacts calculating from the total environmental disease burden.
- Lastly, health damage avoided due to energy efficiency interventions will be estimated as a difference between the two scenarios.

2.6 Context dependency

There are no relevant context dependencies identified at this stage, especially in the light of the scenario limitations stemming from 2.5.

There is one impact end-point that is currently mapped on the theoretical framework in Figure 2 but no method for quantification is proposed yet due to high context dependency on where it occurs – reduced congestion.

3 MI interactions and side effects

3.1 Impact pathways

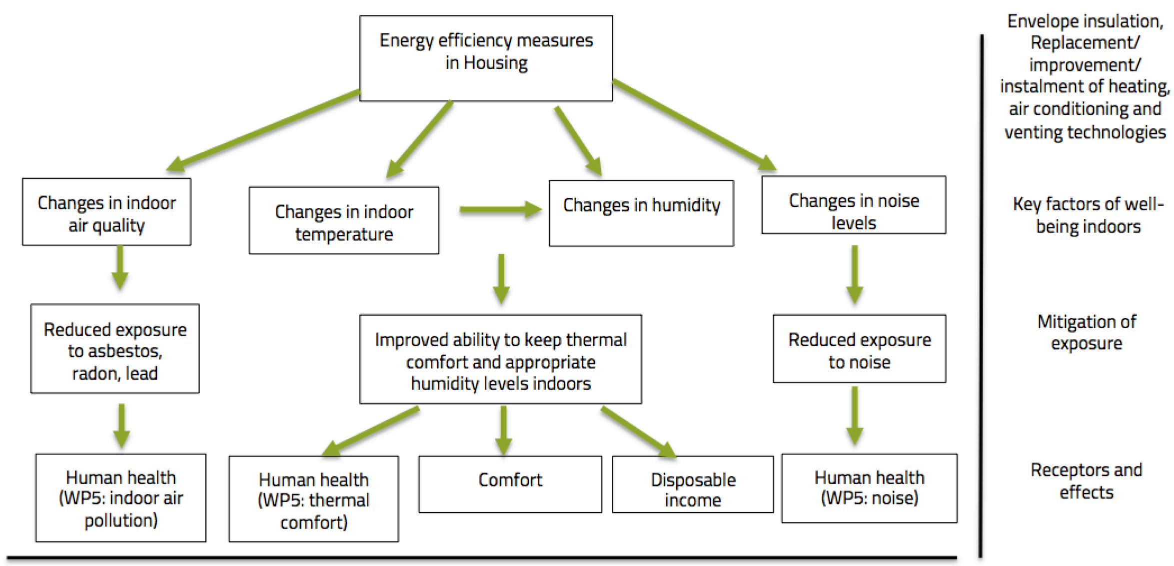

Figure 1. Impact pathways for energy efficiency improvement actions in the residential housing sector.

[2] Based on feedback fromWP2 lead researcher during the Manchester meeting on 9-10th of March, 2016.

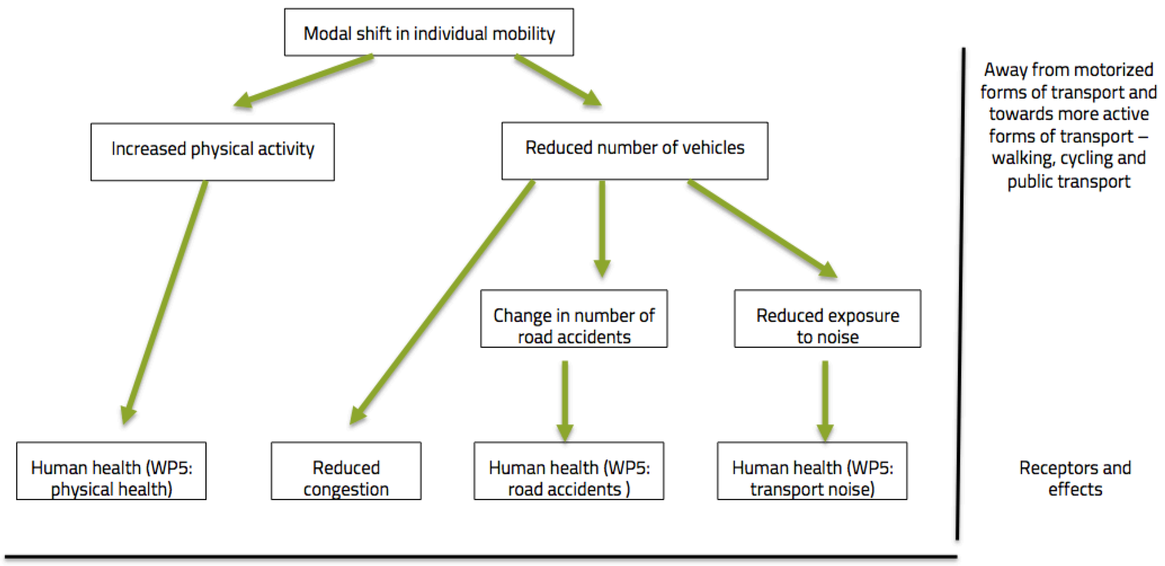

Figure 2. Impact pathways for social welfare pathways of modal shift in passenger transport.

3.2 Interaction with other impacts

Table 4: Interactions of social welfare impact pathways end-points with other work packages

MI Social welfare		Type of interaction
Air Pollution	Health	(1) Links between indoor and outdoor air pollution and related illnesses. Outdoor air quality is a proxy for indoor air quality, therefore, it will largely be addressed in WP3.
	Eco-system	
	Crops	
	Built environment	
Resources	Organic resources	
	Non-organic resources	
	Energy resources	
Social welfare/ commercial productivity	Disposable income/fuel poverty reduction	
	Improved comfort	
	Health	
	Productivity in commercial buildings	
Macro-economy	Employment	
	GDP	(1) Increase in GDP as a result of increase in disposable income (likely minor effect if at all). (2) Increase in GDP as a result of an increase in productivity due to health effects.
	Public budget	(1) Reduced burden on public health care budgets as a result of health effects
Energy system/ security	Energy system costs	
	Energy security	

3.3 Rebound effects

Due to the fact that in COMBI plans to consider deep retrofits only, the idea to apply different rebound effects to different subgroups within each EU member state is cancelled as documented by Milne & Boardman, 2000 (see also 2.1.3).

The rebound effect will affect only one impact end-point in this package – disposable income. Data inputs will be provided by WP2.

4 Approach for impact quantification and monetization

4.1.1 Thermal comfort (human health)

Excess winter mortality

The number of excess winter mortality cases is calculated adding up the number of deaths occurring during the months that are universally agreed to represent winter in Europe (December, January, February and March) and subtracting the total number of deaths occurring during the rest of months (April to November) divided by two (see $\boldsymbol{EWD = \sum_{i=12}^{3} deaths - \sum_{i=4}^{11} deaths/2}$ Equation 1). Excess winter deaths index is calculated dividing the total number of excess winter deaths by the total number of deaths occurring during the rest of months (April to November) divided by two (see $\boldsymbol{EWD_i = \frac{\sum_{i=12}^{3} deaths - \sum_{i=4}^{11} deaths/2}{\sum_{i=4}^{11} deaths/2}}$ Equation 2).

$$\boldsymbol{EWD = \sum_{i=12}^{3} deaths - \sum_{i=4}^{11} deaths/2} \qquad \textbf{Equation 1}$$

$$\boldsymbol{EWD_i = \frac{\sum_{i=12}^{3} deaths - \sum_{i=4}^{11} deaths/2}{\sum_{i=4}^{11} deaths/2}} \qquad \textbf{Equation 2}$$

where EWD – excess winter deaths, EWD_i – excess winter death index, i – number of the month (1 – January, 12- December) .

In countries of the European Union excess winter mortality rates ranged from 7.8% to 28.3% with an average of 13.9% in 2014 (Fowler et al., 2015). The estimates of southern and mild climate countries exceeded those of northern and continental countries which somewhat was attributed to better housing quality and better insulation in the latter ones (Clinch, 2000; Fowler et al., 2015; Healy, 2003). In the past the formula has been uniformly applied across the whole European continent with the same delineation between winter and non-winter months. The figure fluctuates from year to year depending on the severity of winter.

Attribution of excess winter deaths to indoor cold

Once the excess winter death rate is estimated, the key challenge is to attribute the part of excess winter mortality to among many factors to indoor cold, and therefore, poor quality housing. To this day there are no robust methodologies to estimate this ex-post or ex-ante. To complicate the matter, annual variations in severity of winter render different figures of EWDs and it is likely that the share of these attributed to poor quality housing also varies. Expert estimates have been used to date to estimate the number of excess winter deaths to indoor cold in poor quality housing (see Table 5).

Table 5: A review of expert estimates on the share of excess winter deaths attributable to indoor cold in poor quality housing.

Citation	Method	Country	% of EWDs attributed to poor quality housing
(Braubach et al., 2011)	Expert estimation: (1) J.D. Healy; (2) P. Wilkinson; (3) W.R. Keatinge	(1) Ireland, United Kingdom; (2) United Kingdom; (3) 7 European countries	(1) 33% (2) 30% (3) 50%.
(Tirado-Herrero, 2013)	Own estimation based on international expert estimates and available local sources on the circumstances of all cause deaths (e.g. number of cases of hypothermia)	Hungary	20%
(Hills, 2012)	Own estimation based on (University College, Marmot Review Team, & Friends of the Earth, 2011)	United Kingdom	10% (conservative estimate)
(University College et al., 2011)	Estimation based on (Wilkinson, 2001)	England	21,5%

As demonstrated in Table 5, only a few countries have expert estimates on the subject matter as energy poverty is still a rather new concept in the EU-28 context, mostly researched in the United Kingdom and Ireland. At this point, COMBI's evaluation of excess winter deaths attributable to indoor cold in poor quality housing for each country of the EU-28 poses major challenges due to absence of energy poverty studies and associated expert evaluations.

At this point a few solutions are possible with different implications for research time allocation:

- Select a conservative rate, e.g. 10% of excess winter deaths, and apply uniformly across all countries;
- Perform desktop research on mortality, poverty, social deprivation in each country and come up with a conservative estimate for each country based on (1) national public health data, such as a number of registered deaths due to hypothermia that was found to be related to energy poverty in Ireland (Romero-Ortuno, Tempany, Dennis, O'Riordan, & Silke, 2013) and (2) secondary data sources, such as the EU Survey on Income and Living Conditions (Eurostat, 2016b);
- Engage public health experts of all countries in a consultation/survey.
- A mix of options above.

Recent methodological critique

Liddell et al., (2015) provide a methodological critique on the uniform application of the excess winter deaths formula (see $\boldsymbol{EWD = \sum_{i=12}^{3} deaths - \sum_{i=4}^{11} deaths/2}$ Equation 1 and $\boldsymbol{EWD_i = \frac{\sum_{i=12}^{3} deaths - \sum_{i=4}^{11} deaths/2}{\sum_{i=4}^{11} deaths/2}}$ Equation 2) to European countries. Using heating degree days[3] data, the authors point out that the indicator of excess winter deaths is accurately calculated according to the formula only for two European countries, where over 85% of heating degree days fall in the period between December and March. The figures for the rest of the country may be underestimated or even severely underestimated as the cold weather period extends beyond the conventional four winter months as described before. The paper suggests that customization of the cold weather period according to the heating degree days data and recalculating the index of excess cold weather deaths may be necessary. The authors also point to large climatic differences within countries and suggest a need of regional customization of the formula as well as a small change in the terminology – excess cold weather deaths instead of excess winter deaths. This critique also poses doubts, if the attribution of excess winter deaths to indoor cold has been accurate and if the previous estimates could be used as a guidance at all.

At the same time, with this approach the issue of excess heat deaths remains to be unresolved. While climatic differences in Europe are stark, some countries in the South may have an analogue phenomenon happening in summer due to heat and difficulties with keeping the indoor environments cool enough – excess summer deaths or excess heat (hot weather) deaths. This phenomenon also deserves attention, as otherwise excess summer deaths are ignored and may contribute to underestimation of excess cold weather deaths.

The suggested approach for COMBI quantification is to account for the recent methodological critique and calculate EWD_i customizing the cold weather period to include at least 85% of heat degree days for each EU member country.

Excess winter morbidity

Research from energy efficiency intervention studies proves that energy efficiency can have a positive effect on human health via increased thermal comfort indoors (Chapman, Howden-Chapman, Viggers, O'Dea, & Kennedy, 2009; Howden-Chapman et al., 2008, 2009). However, attribution of the excess winter morbidity to indoor cold is still problematic as there is insufficient empirical evidence in testing the relationship between indoor cold and morbidity in the context of all other factors, such as epidemics, air pollution (Braubach et al., 2011). Morbidity data is not routinely available as mortality data, therefore, the approach to estimate excess winter morbidity due to indoor cold in principle would be the same as in the case of excess winter deaths attributed to indoor cold. However, there are no guidelines what share of these excess cases in respiratory and cardiovascular diseases could be attributed to indoor cold. The only study applying this method estimates excess winter hospitalizations due to cardiovascular and respiratory diseases to be 50% of the total (Brophy, University College, Energy Research Group, University College, & Environmental Institute, 1999). Other uncertainties and difficulties involved in estimating this end-point include (1) absence routinely available data on the monthly number of registered respiratory and cardiovascular diseases and/or hospitalization rates related to these diseases

[3] One heating degree day stands for the average daily temperature outside being below the thermal comfort level by 1 degree C for 1 day. The heating threshold being 15 degrees C and the thermal comfort being 18 degrees C (Eurostat, 2016a; Christine Liddell, Morris, Thomson, & Guiney, 2015).

(separate inquiries would need to be made to national public health agencies of all EU member states); (2) possible discrepancies between countries due to the share of private and state health care services and possibly non-disclosure of data from private health care providers; (3) complexities in determining the attributable share of indoor cold in each EU member state.

An alternative methodology could be based on the same principle as the estimation of the other health related impact end-points – estimation of the population attributable fraction based on exposure figures and relative risk estimates (e.g., how much more likely is getting sick with cardiovascular and respiratory diseases among those experiencing indoor cold and the rest of the society). However, such studies do not yet exist.

In relation to above mentioned difficulties and also confounding evidence elaborated in 2.1.1, evaluation of excess winter morbidity attributable to indoor cold may not be possible within the time frame available with sufficient scientific scrutiny. On the other hand, excess winter mortality attributable to indoor cold could as well serve as a proxy of excess inter morbidity attributable to indoor cold, but further elaboration of methods based on that would be necessary.

4.1.2 Comfort

Due to the scale of the assessment and also the assumption of deep retrofits in the scenario, there is no straightforward way to quantify the thermal and acoustic comfort impact. Thermal and acoustic (dis)comfort of residential housing is reported on a national scale by the EU Survey on Income and Living Conditions (SILC) as:

- Inability to keep home adequately warm (Code: ilc_mdes01)
- Proportion of population living in households considering that they suffer from noise (Code: tsdph390)

These two indicators help to define the baseline – the current extent of experienced thermal and acoustic (dis)comfort among the populations of the different EU member states. In the case of a long-term goal of a complete deep-retrofit of the whole residential housing stock, the values of these two indicators would be approaching zero. Therefore, it would be possible to project the values of these two indicators based on the share of the residential housing retrofitted assuming the comfort benefits occur proportionally. Thus, the impact equation for acoustic and thermal comfort is:

$$C = C_{baseline} * \ (1 - S)$$

where C – projected acoustic/thermal discomfort level in the society by the end of the studied period; $C_{baseline}$ – baseline level of acoustic/thermal discomfort in the society; S – the share of residential buildings retrofitted by the end of the studied period.

4.1.3 Environmental burden of disease approach for human health impact end-points

Environmental burden of disease approach can be applied to assess the health implications of multiple impact end-points related to human health. The impact end-points to be estimated using this method include:

- Indoor dampness (human health) – asthma cases attributable to inadequate housing

- Noise (human health) – cases of cardiovascular diseases attributable to exposure to noise
- Indoor air pollution (human health) – (1) cases of lung cancer due to indoor radon exposure, (2) cases of cardiovascular diseases and mild mental retardation due to exposure of lead and (3) cases of mesothelioma, lung cancer and asbestosis die to exposure to asbestos.

Burden of disease refers to the prevalence of certain health conditions in the population in question and its implications (Pruss-Ustun, Mathers, Corvalan, & Woodward, 2003). "Environmental" refers not only to the environmental factors (e.g. air pollution), but in general to all factors that are external to human host in causing certain health impairments (e.g., work environments or poverty). Global burden of disease reports provide the final results on the human health assessment in a society in a way that includes morbidity and mortality rates in one indicator called disability adjusted life years (DALYs) (ibid).

$$DALYs = YLLs + YLDs$$

where DALYs are disability adjusted life years, YLLs – years of life lost and YLDs – years lived with disability.

Years of life lost refer to the difference between the etalon of life expectancy (80 years for men and 82.5 for women) and the age at the time of death due to a certain cause. It is calculated as a sum of these differences.

$$YLLs = \sum N \times LE \qquad \text{(ibid.)}$$

where N is the number of cases and LE is the life expectancy at the time of death.

Years lived with disability refer to the time in life that an individual has spent being not in perfect health.

$$YLDs = \sum I \times DW \times L \qquad \text{(ibid.)}$$

where I is number of disability incidences, DW – disability weight, L – length of disability.

Many illnesses have more than one factor influencing its onset. For instance, the total disease burden of asthma in the society will be influenced by these factors: genetic factors, inhaled allergens (dust mites, animal fur, mould, pollen and etc.), inhaled irritants (tobacco smoke, cooking and heating fumes, vehicle exhaust, cosmetics, aerosols), medicines (aspirin); actions provoking asthma include respiratory infections, exercise, acute stress, tobacco smoke, consumption of certain foods, drinks or medicines, occupational exposures (Global Asthma Network, 2014).

It is possible to attribute the share of total disease burden in the society due to a certain health risk, e.g. exposure to mould or noise. To enable this evaluation an attributable or relative risk value is needed from the epidemiology literature. Attributable/relative risk is a percentage difference in observed morbidity between the exposed and unexposed populations. Or in other words it is the share of the disease burden that would no longer occur if the risk factor were eliminated (Pruss-Ustun et al., 2003). This method has an inbuilt flaw of somewhat inflating the values of attributive risk, because assessments of this scale will not be able to fully control for other risk factors that may be causing the disease in question (Pruss-Ustun et al., 2003).

$$PAF = \frac{P \times (RR-1)}{P \times (RR-1)+1}$$ (Braubach et al., 2011)

where PAF is population attributable fraction, or the proportional share of responsibility born by the environmental risk factor in question in the total environmental disease burden, P – proportion of population exposed, RR - attributable or relative risk of disease onset under exposure.

As a consequence the disease burden attributable to the environmental risk factor in question will be calculated as a share of the total disease burden:

$$AEDB = PAF \times EDB$$ (Braubach et al., 2011; Pruss-Ustun et al., 2003)

where AEDB is attributable environmental disease burden, EDB – total environmental disease burden and PAF – population attributable fraction.

The net health effect will depend on the difference between baseline PAF, business as usual PAF and energy efficiency scenario PAF. The key variable the value of which will change will be p – proportion of population exposed.

The change in the disease burden attributable to environmental risks of housing as a result of energy efficiency improvement actions will be assumed to be proportional to the change in the share of population exposed – in this case to indoor dampness and noise. In turn, the change in the share of population exposed will be proportional to the share of the residential housing retrofitted and scenarios will determine the extent of the housing retrofits.

For instance, if one scenario assumes 10% share of all housing retrofitted, for this work package methodology we will assume a 10% in the value of p. If 15% of the population was exposed to indoor dampness beforehand, then under the proposed scenario a proportional10% decrease in exposure will be 15% - 0.1 x 15% = 13.5%.

4.1.4 Customization and uncertainties in the environmental burden of disease approach

A few customization issues and uncertainties remain in the estimation of abovementioned human health impact end-points (see the first paragraph of 4.1.3).

In the case of indoor dampness and asthma, the relative risk values differ for different age groups with children and youth being more susceptible to asthma than adults (Braubach et al., 2011). Therefore, it may be adequate to consider human health implications for different age groups, especially when the estimates of exposure are available for different age groups from the EU Survey on Income and Living Conditions (EU SILC) (Eurostat, 2016b) - one group from 0-17 years old and the rest of the adult population. The only uncertainty related to that is the availability of a detailed environmental burden of disease data for different age groups and also relative risk estimates for different age groups.

In the case of noise, relationship between noise exposure and human health also depends on the characteristics of noise, one of them being the level of noise (Wolfgang Babisch, 2008). Although the data on noise exposure in Europe has improved greatly in the last years, there are still large gaps: some member countries still have not reported noise exposure figures and the figures are largely limited to urban populations only (European Environment Agency, 2014). This poses a challenge in the attribution of the total cardiovascular disease burden. A solution could be to select a relative risk figure on the lower end of health implications in order to attribute a conservative health impact and avoid overestimation for those countries, for which a more detailed estimate is not available.

In the case of multiple exposure groups, the formula for calculation of population attributable fraction is

$$PAF = \frac{\sum P_i \times RR_i - 1}{\sum P_i \times RR_i}$$ (Braubach et al., 2011; Pruss-Ustun et al., 2003)

where PAF is population attributable fraction, P – proportion of the population exposed, RR - attributable or relative risk of disease onset under exposure, i – relating to separate population groups.

Alternative or additional quantitative end-points for health impacts of noise may include annoyance, sleep disturbance, cognitive impairment in children, hypertension. If recommended and feasible within the research project timeline these can also be added to the assessment as described by Houthuijs, Beek, Swart, & van Kempen (2014).

In the case of indoor air pollution with lead, there is much uncertainty about the exposure levels of lead as a result of building structures covered with leaded paint. The ban on lead paint occurred at different times in the European countries, the implementation lagged (Needleman & Gee, 2002) and the only reasonable proxy of lead exposure, as suggested by the WHO report, is the age of housing (Braubach et al., 2011). Very few countries have decent estimates on the exposure levels to lead from housing. Nevertheless, the WHO suggests a proxy of exposure in Europe based on a few national, regional and local level studies (all of them limited to Western Europe and the US) that confirm similar results: around 40 % of the European housing was built before 1940s and among them lead exposure on average is 4 times higher than in newer housing stock.

In the case of asbestos, population attributable fraction does not need to be calculated as the only risk factor of asbestosis and mesothelioma is exposure to asbestos. The extent of asbestos contribution to lung cancer is considered to be of the same amount as mesothelioma (WHO regional office for Europe, 2013). However, a long incubation period of the asbestos related diseases (up to a few decades) (European Forum of the insurance against Accidents at Work and Occupational Diseases, 2006) poses a challenge for a relatively short period of COMBI evaluation – to what extent and when the projected benefits of asbestos removal could actually be claimed. The same applies to indoor radon and lung cancer (World Health Organization, 2009).

It is also unclear what share of asbestos and lead caused health impairments can be attributed to occupational and non-occupational exposure. The question arises if COMBI should include occupational health impacts on the personnel implementing the energy efficiency improvement actions (see also chapter 6).

Last but not least, the environmental disease burden methodology presents the disease prevalence and weight on the society experienced on a certain date. In principle, environmental disease burden should be projected for the business as usual scenario of COMBI. In practice, it is unclear how to do it and if it is feasible within the available timeline. The current estimated disease burden may as well be considered for use taking into account that the timeframe in COMBI is not large.

Advice on the above mentioned issues will be sought among the Advisory Board members and beyond.

4.1.5 Physical activity (human health)

There are two tools at hand for estimating a change in human health impacts due to physical activity. The first is the Health Economic Assessment Tool (HEAT) built by the World Health Organization (Kahlmeier et al., 2013). The second is the Integrated Transport and Health Impact Modelling Tool (ITHIM) developed by the Centre for Diet and Activity Research (CEDAR), the UK. Access to HEAT is unrestricted, access to ITHIM can be acquired upon request. Both tools function based on the same relative risk of death and burden of disease methodology, but HEAT is solely devoted to measuring of the health benefits of physical activity and ITHIM encompasses a comprehensive assessment methodology in relation to health impacts of modal shift to cycling and walking – health impacts of air pollution, road accidents and physical activity. The final decision on which one to use to estimate health impacts of physical activity will be taken depending on scenario input data and also in consultation with the Advisory Board.

4.1.6 Road accidents (human health)

There are two methods that can be used to estimate the human health implications of a change in road accidents due to modal shift.

The first one involves using relative risk data on road accidents related to each mode of travel. The change in traffic accidents in this case can be written down as

$$\Delta RA = R_0 \times D_0 - R_1 \times D_1$$

where RA stands for a change in road accidents, R stands for risk of being injured or killed in a road accident using a particular travel mode per distance travelled (deaths or injuries per km) and D – total distance travelled.

The second option includes using the Integrated Transport and Health Impact Modelling Tool (ITHIM) developed by the Centre for Diet and Activity Research (CEDAR), the UK. This model essentially applies the same principles, but has more input parameters, such as distance, speed, risk, age and gender.

Although modal shift is likely to be limited mostly to urban populations, modelling of traffic related risks per vehicle/km on a country level may be the most practical approach for the scale of assessment (Bickel et al. 2006).

It is unsure to what extent and how "safety in numbers" phenomenon could be included in the estimates, as large differences exist between the member states of the EU in terms of bicycle and pedestrian friendly infrastructure or if it is already reflected in the relative risk of traffic accident figures. Advice from the Advisory Board members will be sought on this issue.

4.2 Monetization approach

With regard to monetization it would be possible to separate a few types of impact end-points:

- Impact end-points that can only be quantified; monetization of which is not possible on the geographical scale of COMBI (e.g., comfort);
- Impact end-points that can be quantified and monetized with market prices. Monetization of disposable income is straightforward and related to the WP2 input data on projected energy savings. Monetization of morbidity can be done with the help of the population attributable fraction, estimating the number of hospitalization or disease cases occurring due to a certain environmental risk in housing and ascribing cost of illness or cost of hospitalization. Monetization of morbidity effects also may be carried out within the assessment of productivity impacts. The need for a separate monetization via cost of illness approach may not even be necessary. This depends on how synthesis of results will be organized: whether there will be a need of monetization at every step of sub-impact or just at the end-point. In this regard, human health end-points of the WP5 and WP3 are intermediary steps for productivity and economic assessments. Monetization of morbidity via cost of illness approach is very data intensive requiring research on separate average financial values for each member state or via some country groupings.
- Impact end-points that can be quantified and monetized with non-market prices using the estimates of past contingent valuation studies (e.g. mortality and the value of a statistical life (VSL) or value of a life year (VOLY)). Monetization of human life is also an ethical issue.

5 Data

5.1 Use of common WP2 input data

Table 6: Data needs and data sources.

Impact end-point	Sub-impact	Data needs	Data sources
Human health - thermal comfort	Excess winter mortality	Monthly data on the number of deaths registered in each EU member state Share of residential housing stock retrofitted	Eurostat and/or national public health agency data WP2 input data
	Excess winter morbidity	Monthly data on the number of cardiovascular and respiratory diseases registered in each EU member state or hospitalizations Share of residential housing stock retrofitted The share of cardiovascular and respiratory diseases that could be attributed to indoor cold	National public health agency data WP2 input data Epidemiology literature (not yet identified)
	Asthma disease burden	Share of total population living in a	EU Survey on Income and

Human health - indoor dampness	attributable to indoor dampness	dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames of floor Share of children (aged 0 to 17) living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames of floor Share of residential housing stock retrofitted Relative risk of asthma due to exposure to dampness Total burden of disease due to asthma	Living Conditions (EU SILC) WP2 input data Epidemiology literature Global burden of disease report and WHO databases
Comfort	Thermal comfort	Share of total population unable to keep home adequately warm in each EU member state (%) Share of residential housing stock retrofitted	EU SILC WP2 input data
	Acoustic comfort	Share of total population living in households considering that they suffer from noise in each EU member state (%) Share of the total population exposed to different levels of noise originating from various forms of transportation Share of residential housing stock retrofitted	EU SILC European Environmental Agency and the EU Joint Research Centre (alternative source of data) WP2 input data
Disposable income - energy cost savings		Yearly energy cost savings per household in each EU member state (EUR)	Input data from WP2
Human health - noise		Share of total population living in households considering that they suffer from noise in each EU member state (%) Share of population exposed to different levels of traffic noise during the day Share of residential housing stock retrofitted Relative risk of cardiovascular diseases under noise exposure Total burden of disease due to cardiovascular diseases	EU SILC European Environmental Agency data WP2 input data Epidemiology literature Global burden of disease report and World Health Organization databases
Human health - indoor air quality	Mortality and morbidity related to exposure to radon, lead and asbestos	<u>Radon</u> Share of population exposed to unsafe indoor radon levels (%) Relative risk of lung cancer due to exposure to radon Total burden of disease due to lung cancer	World Health Organization, European Environmental Agency and Joint Research Centre databases Epidemiology literature Global burden of disease report and World Health Organization databases

		Share of residential housing stock retrofitted	WP2 input data
		Asbestos Total mortality and morbidity due to asbestos related diseases Estimates of occupational versus non-occupational cases of asbestos related diseases	World Health Organization, Eurostat, national public health agency data Not yet identified
		Lead Total burden of disease due to cardiovascular diseases Share of population exposed to lead Share of buildings possibly still containing lead paint based on their age (lead exposure proxy) Relative risk of cardiovascular diseases due to exposure to lead	Global burden of disease report and World Health Organization databases Not identified National statistical data on the age of the building stock. Epidemiology literature
Human health - physical activity		Yearly changes in modal split in vehicle/km per country	Input data from WP2
Human health - road accidents	Number of fatalities in road traffic accidents Number of injuries in road traffic accidents	Yearly changes in modal split in vehicle/km per country	Input data from WP2
		Yearly road accident statistics per mode of transport	Eurostat and/or data from national transport agencies

6 Assumptions

There are a number of assumptions that are unavoidable in operationalizing the impacts of energy efficiency actions. Stating them clearly is a must and quoting them together with the results of the research project will draw attention to some key aspects in designing energy efficiency programmes. Early warning associated with potential risks of energy efficiency improvement actions may help to enhance social welfare and minimize negative impacts.

Table 7: Key uncertainties, assumptions and early warnings.

Impact end-point	Key uncertainties, assumptions and early warnings
Acoustic comfort	Research has shown that housing retrofits are effective in reducing outdoor noise sources, but may not be effective in elimination of indoor noise sources, such as from within the household or neighbours if this is a multi-storey apartment building (see 2.1.3). Installing ventilation equipment may add to indoor noise pollution. Additional measures are needed during retrofits in order to ensure elimination of indoor noise sources (additional noise insulation solutions for noise from ventilation, neighbours, within the household). Assessment of acoustic comfort impacts is problematic as EU SILC data records general complaints about noise without separating them into indoor or outdoor sources – neighbours or street.

	The key assumption in COMBI is that both are to be improved during housing retrofits. An early warning for residential building retrofits would be to account for ventilation equipment noise and include other solutions to mitigate indoor noise sources.
Human health (indoor air quality): radon, lead and asbestos	There are warnings that building envelope insulation leads to air tightness and, therefore, may increase exposure to radon indoors in areas where radon emissions are prevalent (Bone, Murray, Myers, Dengel, & Crump, 2010; Milner et al., 2014). In order to avoid an increase in human health damage due to radon exposure (e.g., lung cancer), special protection solutions are to be implemented that prevent radon from penetrating the indoor environments (ibid.). In COMBI, the key assumption is that such solutions are to be implemented and they help to minimise radon exposure. An early warning for building retrofit programmes would be to include screening for indoor radon and protection from indoor radon emissions. A few sources warn of an increased exposure to asbestos and lead during the retrofits to the workers and also inhabitants around (Canadian Environmental Law Association, 2011; European Commission, 2012) Unless precautions are taken, there may be an increase in negative impacts on human health due to exposure to asbestos and lead in negative human health impacts. In COMBI the key assumption is that housing retrofits are executed ensuring full protection from these health hazards. An early warning for building retrofit programmes would be to include health and safety training to the workers and health and safety information to the residents.
Human health (thermal comfort): dampness	Insulation of building envelope leads to increased air tightness. Many sources have warned of a potential risk to human health In the absence of ventilation installations (Bone et al., 2010; Shrubsole et al., 2014; Willand, Ridley, & Maller, 2015). Increased air tightness may lead to increased indoor dampness and mould growth. This may eventually be the cause of asthma and allergies. There are sources already that building retrofits proceed regardless of these warnings (Dimdina, Krumins, & Lesinskis, 2014). In COMBI the key assumption is that deep building retrofits are implemented with a holistic approach to the indoor air quality and building envelope insulation comes together with ventilation installations. An early warning for building retrofit programmes would be to adopt a holistic approach to indoor air quality and always couple envelope insulation with ventilation solutions.

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