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Aphekom

Improving Knowledge and Communication for Decision Making on Air Pollution and Health in Europe

Guidelines on monetary cost calculations related to air-pollution health impacts

Deliverable D6

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Table of contents[1]

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Executive summary

This deliverable presents the rationale underlying the monetary valuation of a Health Impact Assessment (HIA).

First, general guidelines covering the main issues involved in monetary cost calculations are given, with particular reference to the air-pollution-related health effects assessed in Aphekom.

For mortality effects, we follow the standard valuation procedure, which consists in using a Value of a Statistical Life (VSL) or a Value of a Life Year (VOLY) derived from stated preferences surveys, hence relying on preference-derived values rather than market-derived values.

For morbidity effects, we use the Cost of Illness (COI) approach to assess direct costs and we use loss of production to assess indirect costs. Intangible costs are accounted for only in relation to the prevalence of chronic diseases.

For the sensitivity analysis, we perform a separate assessment of uncertainties when computing a) the number of health outcomes attributable to air pollution, and b) unit economic values. To compute the latter, we apply a +/- 33% range around the central estimate; however, a specific uncertainty assessment is performed when computing values for mortality.

Then, unit economic values recommended as best values are provided, including country-specific values to be used in computations for each city examined in Aphekom. They will be used in the deliverables D4bis, D7bis and D11bis which assess the economic burden of the health effects attributable to air pollution exposure computed in WorkPackages WP4, WP5 and WP6.

WP5 uses traditional HIA methods to assess the impact of air pollution on health in 25 European cities. We conduct a formal review of articles estimating a VSL (or a VOLY) from stated preferences surveys that specifically aim to estimate the benefits of air-pollution-reduction policies. VSL is used for long-term mortality effects and VOLY is used for both short- and long-term mortality effects, depending on the metric chosen in the epidemiological computations. The direct medical costs related to cardiac and respiratory hospitalizations are computed (COI approach), as well as the indirect medical costs.

WP4 applies innovative HIA methods to 10 European cities to assess the additional long-term impact on the development of chronic diseases (both onset and exacerbation) from living near busy roads.
The monetary valuation differs from the standard (incidence) approaches used for acute health outcomes or chronic health effects, which apply unit economic values to each case. In fact, the annual costs involved in a chronic disease in a given year are a mixture of direct medical costs, direct non-medical costs and indirect costs, all of which depend on age, the degree of severity of the disease and the probability of occurrence of each disease-related health expenditure. To estimate an average annual cost, we consulted 150 studies providing costs for the three chronic diseases with reference to both COI and stated preferences studies. Joint

assessments of chronic disease onsets and exacerbations need to be made with care, to avoid double-counting.

WP6 investigates the mortality effects of EU legislation aimed at reducing the sulphur content of fuels in 20 cities. The legislation has two potential effects on mortality: short-term and long-term. It has been decided that, in order to take a conservative standpoint, mortality effects will be considered as short-term effects. Consequently, we use a VOLY similar to that proposed in WP5 to value short-term mortality.

1. Introduction

Although initially planned for WP5 only, this deliverable presents the rationale underlying the monetary valuation of a Health Impact Assessment (HIA), with particular reference to the air-pollution related health effects assessed in Aphekom. It provides unit economic values for Aphekom Deliverables D4bis (2011), D7bis (2011) and D11bis (2011) which assess the economic burden of the health effects attributable to air pollution exposure computed in WorkPackages WP4, WP5 and WP6 (Aphekom Deliverables D4, 2011; D7, 2011; and D11, 2011). Appendix 1 sums up the different values recommended as best values in Aphekom, including country-specific values that allow computations for each city.

2. General guidelines

2.1. Choices for cost computations

Choice of a reference year

In order to be consistent, the economic data should be in accordance with the exposure / concentration data and the medical data. Hence, because the air pollution measures as well as epidemiologic data cover the 2004-2006 period for most of the cities, all costs are expressed in **euros 2005**. Similarly, because the average lengths of stay in hospital by country and by disease are date- dependent (generally decreasing with time due to improvements in medical techniques), those required for the cost computations are for 2005.

Choice of a reference currency

All monetary values should be made comparable over time and among countries and expressed in a common currency. We suggest a two-step procedure. First, every monetary value is expressed in national 2005 price levels based on the national consumer price index, as given by the World Bank database for instance (see Appendix 2). Then, it is converted to euros using the purchasing-power-adjusted exchange rates (PPPs) for private consumption in 2005, as given by the World Bank database (see Appendix 2).

Choice of an annual discount rate

When time is a factor in the valuation process, a discount rate is needed to express future flows of economic values in present value. A discount rate equivalent to the growth rate of the Gross National Product facilitates computations. It can be derived from long-term government bond yields or any other discount rate supported by a large consensus. Weitzman (2001) for instance, surveyed the opinions of 2,160 economists and suggests using the following approximation of annual discount rates for long-term public projects (see also Figure 1): 4% for the immediate future (1 to 5 years hence), 3% for the near future (6 to 25 years hence) and 2% for the medium future (26 to 75 years hence). The European Commission Directorate-General Environment suggests using an annual 4% discount rate, with sensitivities of 2% to 6%, and these values are also chosen in Cafe (2005a) for instance.

When needed, a 4% annual discount rate will be used in Aphekom, with sensitivities of 2% to 6%.

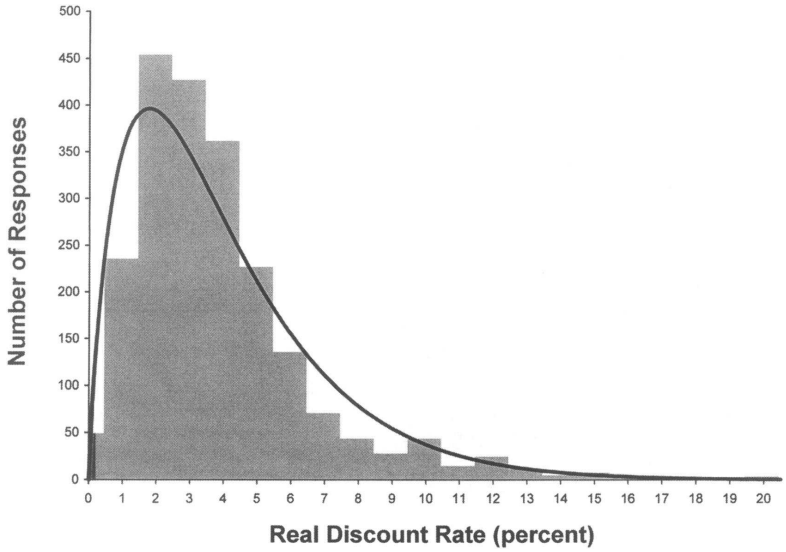

Figure 1: Actual (histogram) and fitted (curve) frequency distribution. Source: Weitzman (2001), p.263.

Sensitivity analyses

An economic assessment of the health effects of air pollution exposure has to deal with cumulated uncertainties coming mainly from exposure incidence rate, response functions, and economic values. A full and proper treatment of uncertainty accounts for all these sources through an integrated approach and Monte Carlo simulations (see for instance, Burmaster and Anderson, 1994). It consists in propagating uncertainties in the incidence rate, response functions and economic values of health outcomes (as in Cafe, 2005a; or Ostro et al., 2006).

In Aphekom, we perform a separate assessment of uncertainties when computing a) the number of health outcomes attributable to air pollution, and b) unit costs. Indeed, we apply Low, Central (also referred to as Best) and High estimates to the range of health outcomes (generally lower 95% Confidence Interval, central, and upper 95% Confidence Interval values) provided by the epidemiological computations. The complete economic results will thus represent a range of monetary valuations (Low, Central and High) for each health outcome.

Empirically, there is little information on which to base the uncertainty pertaining to the economic valuation. Ostro et al. (2006) choose different monetary values for each health outcome and give a probability weight to each estimate. Cafe (2005a) adopts a standard error of 33% for most of the economic value of the health outcomes (except mortality). See also Rabl (1999, 2000), who proposes a detailed analysis of the uncertainty in benefits estimation in the ExternE Project.

In Aphekom, we apply the same rule as Cafe (2005a): a +/- 33% range around the best / central estimate of the unit economic values, except for the valuation of mortality, for which a specific uncertainty assessment is done. Although this decision is somewhat arbitrary, it

provides a range of magnitude for the monetary benefits associated with a reduction in air pollution.

2.2. Categorization of costs

According to accepted practice, in particular as found by Barnes et al. (1996) or Akobundu et al. (2006) who did a general review on 365 articles that estimate cost of illness, three components related to the cost of a health outcome can be distinguished.

Direct costs
Direct medical costs cover medical resources consumed, like consultations (specialists, general and hospital practitioners), drugs, in-patient and out-patient hospitalizations, emergency room stays and cost of rehabilitation. **Direct non-medical costs** cover non-medical resources consumed in direct connection with the health outcome: i.e., cost of social support (like home help), transportation, major home modifications.

Indirect costs
They cover different types of resources lost:
- Loss of productive work by patient (either due to time off work or a poorer access to employment due to poorer health),
- Loss of productive work by patient's family and friends (*e.g.* mother taking time off work),
- Loss of productive work due to patient's early retirement or premature death.

Intangible costs
They apply not only to the patient but also to his/her friends and family: grief, fear, pain, unhappiness, loss of well-being and loss of quality of life.

Obviously, almost no study takes into account all these costs in such detail. Moreover, different studies may include different components under the same label, which makes accurate comparisons among studies difficult.

2.3. Perspective chosen

The three cost components are borne by different economic entities. Adapting Ungar et al. (1998) and ASCC (2008), we can broadly distinguish three perspectives:

- the Patient / Family perspective, which includes the direct medical costs not reimbursed by the health system, the disease-related real income loss not reimbursed by the society, and the intangible costs,
- the Health System perspective (state and complementary health insurances), which includes most of the direct medical costs,
- the Society perspective that includes all direct and indirect costs.

Depending on the objectives of an HIA, any of these perspectives can be chosen to compute costs. Note that an HIA may estimate costs from all three perspectives within the same study, to estimate the share borne by each of them (see for instance Ungar et al, 2001).

Since Aphekom is concerned with the overall burden of air pollution exposure, **the Society perspective** is chosen. Whether or not intangible costs should be accounted for is debatable and no clear consensus exists among economists. In order to assess the overall economic

burden of the share of the health outcomes attributable to air pollution exposure, we propose to explicitly take them into account when valuing air-pollution-related onsets of chronic diseases (i.e. prevalence, in Aphekom Deliverable D4, 2011). However, we suggest that they be ignored when valuing acute health outcomes (hospitalizations), mainly to avoid the risk of double-counting (see section 2.5. for more details).

2.4. Overview of the economic valuation approaches

There are three main methods of valuing health outcomes.

2.4.1. Method based on market prices

Mortality

This method, when applied to mortality, assumes that the value of the life of an individual is equal to future losses in productivity as measured by the discounted present value of that individual's earnings over remaining life expectancy. Its only advantage is its ease of implementation but its drawbacks are numerous: this method ignores the individual preferences on which every economic value should be established, the value of an individual being represented only by his/er production, and this production is measured only by earnings from work. Issues involved include market imperfections (unions, regulations, discrimination), the value of inactive individuals (children or retired people), the role played by the discount rate (which lowers children's and young adults' value). This method is now rarely used to assess the value of a premature death, and will not be used in Aphekom economic assessment.

Morbidity

This approach (referred to as Cost Of Illness, COI) is especially suitable for the assessment of medical treatment costs, including hospitalizations and productivity losses due to health outcomes. It consists in directly interviewing patients or in scrutinizing the health expenditure data of patients to compute a cost related to the disease. This approach is easy to implement but cannot account for intangible costs like the assessment of pain, grief and suffering as there are no market prices for these cost factors. Note that it relies on prices and tariffs generally fixed by Governments.

2.4.2. Methods based on revealed preferences

This approach involves situations in which individuals actually reveal their preferences by trading income for physical risk (risk of death or risk of disease). This method is indirect, and works *ex post*, using information available on the labor market, housing market (via air pollution exposure), averting goods (smoke detectors, seatbelts, airbags). Hedonic methods are generally used as a theoretical and empirical underlying framework.

The advantage of this method is that it deals with actual observed choices resulting from individual decisions reflecting preferences. The drawbacks are the difficulty of isolating a particular risk reduction when different risks are simultaneously being reduced (injury, loss of goods, disadvantages related to a specific job), as well as the fact that it postulates a rationality requiring perfect information on the goods, the associated risks, the influence of risk attributes on the death or disease probability and so on. Moreover, the sample may be

non-representative of the general population, over- or under-representing certain groups (workers, home owners).

This method, although still in use to assess the value of a premature death, is seldom used for morbidity Because of the major drawbacks outlined above, evidence from revealed preferences studies will not be used to value health impacts in Aphekom.

2.4.3. Methods based on stated preferences

This approach generally uses contingent valuation methods (or conjoint valuation) and works *ex-ante,* by asking individuals (more or less) directly about their Willingness To Pay (WTP) for improved safety (hence allowing the economic assessment of mortality) or for a decrease in the probability of having a health outcome (or symptoms) in hypothetical situations.

Its advantages are that it is easy to implement, that it allows very precise description of the trade-off and the health risk at stake and that it does not require a complex theoretical framework compared to revealed preferences, only requiring the individuals to be able to assess the risk and answer truthfully. WTP relates to intangible costs of the disease, but we cannot exclude that possibility that a small part of the direct and indirect costs borne by the patient (health expenditures or productivity loss) are included in the stated WTP.

The main drawbacks are the various sources of error / bias of the method that may not always be controlled for (hypothetical bias, strategic bias, elicitation bias, framing effect - the way questions are worded - context effect, incorrect sensitivity to risk reduction variations, see Mitchell and Carson, 1989 for an exhaustive presentation) and the understanding / experience of a given illness for those who have never experienced it before.

This method is increasingly used in the valuation of non-market components.

2.5. Which method should be chosen?

Mortality

Regarding mortality, we follow the standard valuation procedure adopted in ExternE (1999), New-Ext (2004), Cafe (2005a), which consists in **using a Value of a Statistical Life (VSL) and a Value of a Life Year (VOLY) derived from stated preferences surveys**, hence relying on preference-derived values rather than market-derived values.

Empirical assessments based on revealed and stated preferences methods have so far provided a range of values generally between € 0.7 and € 6.5 million (see Figure 2). Three recent meta analyses of studies examine the WTP for reductions in mortality risk, either through wage-risk studies or contingent valuation surveys: Kochi et al. (2006) with 30 studies; ASCC (2008) covering 224 studies, or Lindhjelm et al. (2010) with 75 studies.

One important finding has been that the VSL depends on the characteristics of the risk of death. Age at death (and the remaining life expectancy of the person at risk), quality of life (and health status) and nature of the underlying risk (see Figure 3) have generally been found to be relevant factors (see for instance Slovic 1987; Cropper et al. 1994; Krupnick et al. 2002; Alberini et al. 2004; Krupnick, 2007; Chestnut and De Civita, 2009).

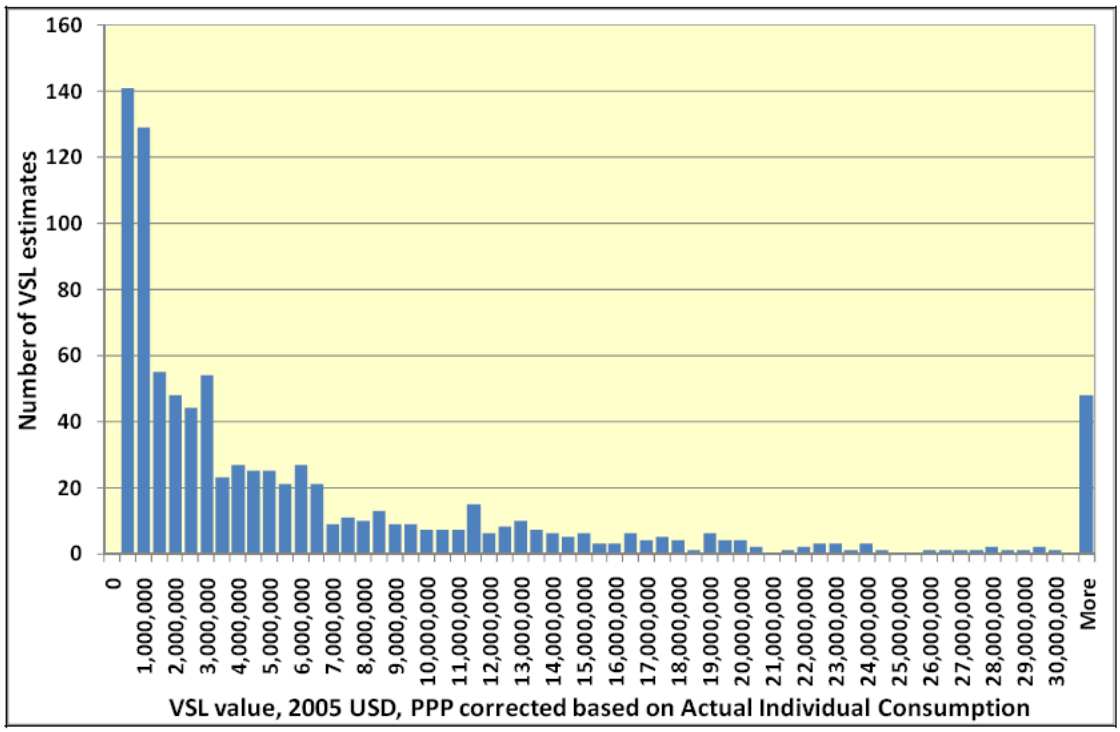

Figure 2: Frequency distribution of mean VSL estimates (854 observations from 75 surveys, truncated) in Lindhjelm et al. (2010), p.17, multiply by 0.91 to get € 2005.

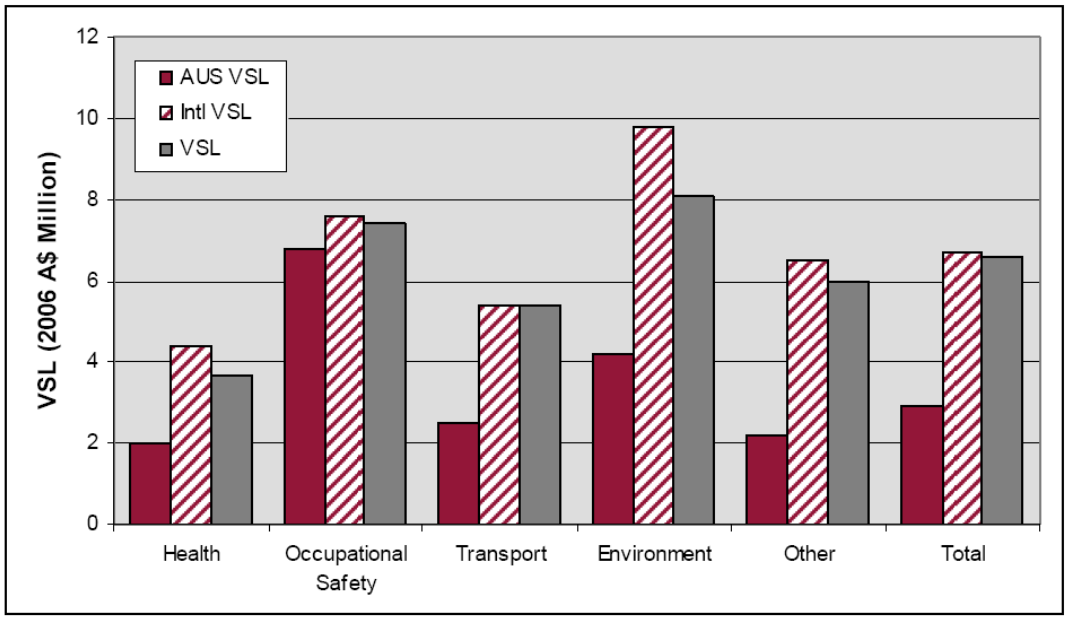

Figure 3: VSL estimates (medians) by sector and Australia/international (244 studies / observations) in ASCC (2008), p. 64, multiply by 0.6 to get € 2005.

Although numerous studies assess monetary values that can be used in accidental contexts (in transportation, at work, harmful substances in food or medication), only a few deal with environmental hazards, and even fewer with air pollution as detailed in Section 3.2.

Morbidity

It should be noted that both the market prices (COI) and the stated preferences methods underestimate the actual total health costs, respectively by the amount of the intangible costs for the former and the costs borne by the society for the latter. However, because of possible overlap between market prices and a WTP-based method (in Figure 4, the greyed part of administration and medical care costs and the economic production losses / lost consumption), combining the two methods is difficult. What is sometimes done is to use both types of method to offer a range of values, the market price approach being an "at least" approach accounting for the loss (or consumption) of resources borne by the society, and the non-market approaches accounting for the intangible costs borne by the victims.

In Aphekom, we choose to proceed as follows: **we use the Cost of Illness approach to assess direct costs and we use the loss of production measured by the average gross earnings to assess indirect costs. Regarding intangible costs, we propose to account for them only in relation to the prevalence of chronic diseases (WP4). There are two reasons for this choice.** First, a new case of chronic disease attributed to air pollution exposure is likely to generate higher intangible costs for patients and their families than an acute hospitalization. Indeed, the chronic diseases assessed in Aphekom (asthma, Chronic Obstructive Pulmonary Disease and Coronary Heart Disease) are generally lifelong and imply major loss of well-being and loss of quality of life not accounted for through direct and indirect costs.

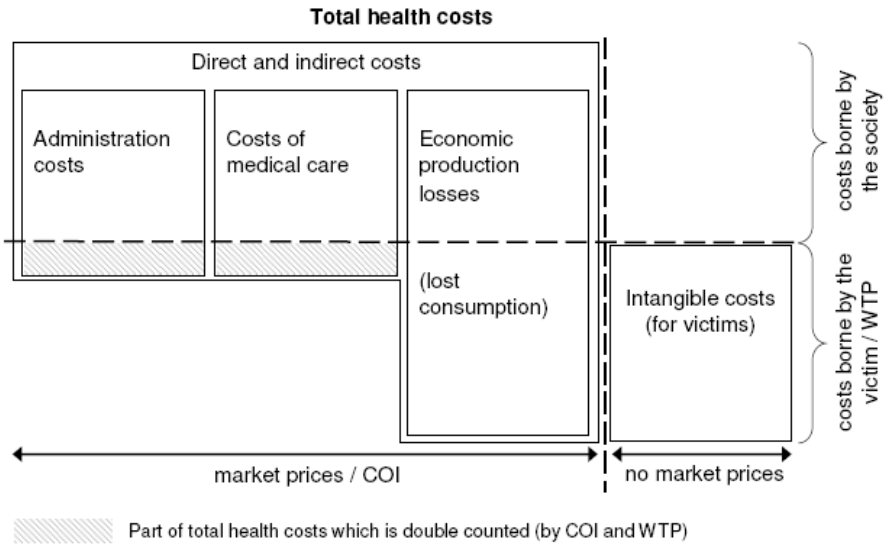

Figure 4: Economic valuation of total health costs by COI and WTP
Source: Who (2008), p. 26

Second, the Health System generally affords good financial coverage to hospitalized patients (especially those with complementary health insurance), at least in Europe. As a consequence, the intangible part of the costs related to an acute hospitalization may be less easy to isolate when individuals answer WTP-based surveys than the corresponding intangible cost of avoiding a chronic disease. The portion of administration costs and medical care that may potentially be double-counted for acute hospitalizations is thus bound to be higher than for chronic diseases.

However, it should be pointed out that we are not implying that acute hospitalizations do not generate intangible costs, merely that these intangible costs are likely to be lower and that the overlap between market prices and WTP-based methods might be higher than for chronic diseases. Generally speaking, economists have not yet reached consensus on the best way to account for intangible costs.

2.6. Valuation from a timing standpoint

Depending on the acute or chronic nature of the health benefits, there are two possible approaches to deal with the time that elapses between a reduction in air pollution exposure and the achievement of full health benefits.

In the **"steady-state" approach,** the health outcomes corresponding to two different levels of air pollution are assessed and the number of cases attributed to a change in air pollution exposure is computed as the difference between the numbers of cases resulting from the respective steady states. It is accurate for acute (or short-term, ST) health effects, and provides an idea of the magnitude of the public health problem for chronic (or long-term, LT) health effects. This approach is clear, simple and informative.

In the "**marginal (benefit)" approach,** the impact of a reduction in today's air pollution exposure on the future flow of health outcomes is estimated. Indeed, a reduction in air pollution exposure today does not produce all chronic (or long-term) effects the same year, due to their cumulative properties (see Leksell and Rabl, 2001; Miller and Hurley, 2003; Röösli et al., 2005; or Chanel et al., 2006). Miller and Hurley (2006), for instance, provide a tool (IOMLIFET) that carries out the detailed calculations required by separating the dimensions of year and calendar year. This approach is appropriate for cost benefit analysis in which chronic health effects are involved: the flow of discounted future benefits can be properly compared with the costs of the policy that generates these benefits.

Although the two approaches are similar for acute (ST) health effects, they differ for chronic (LT) health effects due to the latency period before the achievement of full health benefits and the additional impact of discounting future monetary benefits.

In Aphekom, the steady-state analysis is chosen because it is clear, simple and informative enough to assess the LT benefits that would result from a decrease in air pollution. It mimics a counterfactual approach, i.e. what if pollutant concentrations were lower, all other things being equal (see also Aphekom Deliverable D7, 2011; on this issue). It should be clear that this decrease would not fully and immediately increase the associated health benefits, which can only be obtained in the long term. Hence, these benefits should not be compared to the estimated costs of a policy that would result in a decrease in air pollution.

Finally, we should bear in mind that some health outcomes may partially overlap. In Aphekom for instance, the economic valuations for asthma, COPD and CHD hospitalizations (Aphekom Deliverable D4, 2011), and those for cardiac and respiratory short-term hospitalizations (Aphekom Deliverable D7, 2011), cannot be added together without specific assumptions.[2]

[2] Note that the metric of the exposure to air pollution also differs: proximity to busy roads in WP4, air pollution concentration in WP5.

3. Economic valuation in WP5

3.1. General overview

This WP performs a "standard" HIA of urban air pollution on (ST and LT) mortality, and ST respiratory and cardiac hospitalizations for PM and ozone (see Aphekom Deliverable D7, 2011). Note that the valuation of mortality is based on specific stated preferences studies and will use a common VSL and a common VOLY for all cities. The underlying rationale is twofold. First, from an ethical perspective, it would be difficult to accept a differing value of a human being across EU cities / countries. Second, from an empirical perspective, because reliable VSL and VOLY estimates do not exist in every country involved in Aphekom, adjustments based on other countries' VSL and VOLY would have been necessary. Moreover, accounting for differences among countries, through Gross Domestic Product (GDP) per capita for instance, would also be ethically unacceptable: this would have implied a sevenfold lower VSL in Romania than in Ireland (World Bank, 2010).

For morbidity, however, because the cost of illness approach has been chosen, differing unit costs across countries / cities are more acceptable. Indeed, they are based on country-specific health care organizations or medical protocols (average lengths of stay in hospital for instance) as well as country-specific market prices for medical resources and wages.

Mortality

We propose the use of economic values derived from stated preferences surveys (VOLY and VSL) to assess mortality effects. They will depend on the metric chosen in the epidemiological computations.

- **For acute (ST) mortality (PM_{10} and O_3)**, the annual number of premature deaths avoided per year is used. In view of the way these data are computed (through time-series analyses and proportional hazard models), the gains in life expectancy corresponding to each of these premature deaths can be considered to be in the range of a few months, certainly lower than one year (Cafe 2005b, p. 46). Consequently, a VOLY is preferred to value the short-term mortality effects (see details in section 3.2.3).

- **For chronic (LT) mortality ($PM_{2.5}$)**, the number of premature deaths avoided is also provided by epidemiology. However, unlike the acute mortality computations, they are obtained through cohort studies that monitor populations exposed to different levels of pollution. One of the crucial issues is the magnitude of the gain in life expectancy related to these premature deaths. Although no definitive answer exists, a 10-year gain seems to be supported by three pieces of evidence: medical, epidemiological and past empirical practices (see Ezzati et al., 2002; Cafe, 2005b; Watkiss et al. 2005; or Janke et al., 2009). The monetary assessment is based on a VSL.

- **For chronic (LT) mortality ($PM_{2.5}$)**, an average individual gain in life expectancy has also been computed using life tables and following a cohort until complete extinction (see details on the methodology used in Aphekom Deliverable D7, 2011). This metric obviously allows an annual total number of years of life gained in a city to be computed, by multiplying the average gain in life expectancy by the size of the relevant population. Because epidemiological computations do not take into account any impact of air pollutant

concentration on mortality before the age of 30, the annual benefits are computed by multiplying the average gain in life expectancy by the number of 30-year-old individuals in the city, and by the VOLY. This corresponds to the benefits (in terms of life expectancy) 30-year-old people would gain over their lifetime if exposed to a lower average annual level of $PM_{2.5}$ (10 µg/m^3 in the WHO Air Quality Guideline or a decrease of 5 µg/m^3) than the current existing air pollution level in the city. These benefits hence depend on the demographic structure of the population in 2005, and will evolve with the number of 30-year-old people. Aphekom Deliverable D7 (2011) provides an extensive discussion on the assumptions that underlie the computations of the average gain in life expectancy as well as on the rationale for choosing this way to account for the effects of a reduction in the levels of $PM_{2.5}$ on mortality.

Morbidity

The standard cost of illness approach is used for acute hospitalizations, and consists in applying a unit economic value approach to each case, including direct and indirect costs.

3.2. Specific values chosen for mortality

Empirical assessments based on revealed and stated preferences methods have so far provided a range of values generally between € 0.7 and € 6.5 million. However, the context of the underlying mortality risk is a relevant factor explaining the magnitude of the VSL, and "accurate valuation requires the use of scenario-specific values" (Hammitt, 2007). Ideally, the VSL in particular should depend on the specific context, but only a few studies deal with environmental hazards, and even fewer with air pollution.

For risk of death from air pollution, which has been a growing source of concern in recent years, two types of practice emerge. Some authors apply a somewhat arbitrary correction factor to existing VSLs obtained in contexts unrelated to environmental hazards (0.61 in Sommer et al. 1999; 0.7 in UK DH 1999 or Pearce and Crowards 1996; 0.8 in Ostro and Chestnut 1998). They then sometimes derive estimates of VOLY from a VSL as a flow of discounted age-independent VOLY (Viscusi et al., 1997; Leksell and Rabl, 2001):

$$VSL_j = VOLY \sum_{t=j}^{T} \frac{S_{t,j}}{(1+\delta)^{t-j}}$$

where: - VSL_j is the VSL for an individual of age *j*,
- δ is a discount rate (more precisely, the marginal rate of time preference),
- $S_{t,j}$ is the survival probability at age *t* conditional on having survived until age *j*,
- T is the maximum age an individual can reach.

Hence, the European Union suggests a value of € 120,320 in the ExternE (1999) program, and this value is also used in Droste-Franke and Friedrich (2004). Nellthorp et al. (2001) suggest VOLYs of € 109,117 (δ=0) and € 172,290 (δ=3%) for environmental contexts in the UNITE program. These values result from a doubling of VOLY obtained with a VSL of € 1.72 million for accidental contexts, to account for assumed higher WTP to reduce environmental mortality risks than accidental risks. Bickel et al. (2006) in the HEATCO program, instead used a 33% lower VSL for environmental contexts than for accidental contexts, and propose € 64,454 for acute mortality and € 42,934 for chronic mortality (also used in Infras / CE Delft et al., 2008).

The second type of practice consists in estimating a VSL (or a VOLY) from stated preferences surveys that specifically aim to estimate the benefits of air-pollution-reduction policies. Such surveys generally favor one of the two options detailed below: mimicking the consequences of air-pollution-related health effects, or using a truly contextual air pollution scenario.

3.2.1. Using VSL / VOLY obtained in scenario mimicking air pollution context

Studies that mimic the air pollution context usually present respondents with hypothetical scenarios that involve some of the features of the air-pollution-related health effects: similar diseases (mainly respiratory, cardiovascular and lung cancer), similar magnitude of annual change in risk mortality (typically 1-in-10,000 to 5-in-10,000), similar victim age-class (generally aged 40 to 75). However, these studies never mention air pollution as the source of the increase in mortality risk.

Most of these studies rely on a survey instrument, initially developed by Krupnick et al. (1998) in a pilot survey in Japan, that proposes risk-of-death reductions of the magnitude of those proposed in environmental programs to 40- to 75-year-old respondents. The hypothetical scenario involves a new product that allows a 1-in-1,000 (5-in-1,000) reduction in risk of dying from a disease or illness over the next 10 years, without any mention of air pollution. This scenario was subsequently used in several countries and yielded the following median VSL (converted to € 2005): Japan (0.47, Krupnick et al., 1999), Canada (1.35) and USA (1.13, Alberini et al., 2004), France (1.11), Italy (1.7) and UK (0.74, Alberini et al., 2006) and Brazil (0.74-1.26, Ortiz et al., 2009). Alberini et al. (2006) also estimate a VOLY by pooling the CV data of the three European countries (France, Italy and UK) and obtain € 57,500 for the median and € 173,700 for the mean. Ortiz et al. (2009) estimate a VOLY between € 59,100 and € 153,500 for Brasil.

Alberini and Chiabai (2007) estimate the WTP to reduce the risk of dying from cardiovascular and respiratory causes in a 30- to 75-year-old Italian population. The estimated VSL for a 40-year-old Italian ranges from € 0.74 million (median) to 1.59 million (mean), and “can be used for estimating the mortality benefits of (...) environmental policies that limit exposure to pollutants” (p. 256).

3.2.2. Using VSL / VOLY obtained in air pollution contextual scenarios

Another option, in use since 2004, assesses specific VSL or VOLY by explicitly mentioning in the scenario that air pollution is the cause of an increase in mortality risk. This allows the true air-pollution-contextual VSL to be determined. We conducted a formal review of articles dealing with air-pollution-related scenarios by doing a structured literature search with keywords in Scopus and a systematic review of abstracts (or full-text) of every article cited in one of the four recent reviews on the value of life (224 studies in ASCC 2008; 75 in Lindhjelm et al. 2010; 30 in Chestnut and De Civita 2009; and 45 Kochi et al. 2006). We found only six studies based on a specific air pollution scenario, three in Europe and three in Asia.[3]

[3] Note that Soguel and van Griethuysen (2000) used a sample of 199 Swiss respondents to estimate an implicit VOLY based on a scenario that isolates the WTP for a one-hour-of-life gain per year. Although their VOLY estimate is of reasonable magnitude (€ 39,000), we choose not to consider this study in the review because computing a VOLY as 24x365 times the value of a life hour seems disputable.

In a scenario eliciting health risks associated with air pollution, **Chilton et al. (2004)** obtained an average VOLY in normal health of € 45,000 (£ 27,600), with a decreasing trend with age, in a sample of UK residents. Mortality reduction is expressed as an increase in life expectancy: "you and everyone else in your household could expect to live about 1 month longer in your / their normal state of health" (pp. 6 and 65). This reduction is obtained through various measures that reduce emissions from factories and traffic and through the use of cleaner fuels, all of which increase the cost of living for the household. Note that the survey is conducted at the household level and the individual WTPs are simply obtained by dividing the household WTP by the number of household members. Hence, the VOLY is derived under the assumption of equal weights for each household member (i.e., pure altruism, see Jones-Lee, 1992).

Desaigues et al. (2007, 2010) used an approach similar to that of Chilton et al. (2004) for 9 European countries, based directly on the change in life expectancy (LE).[4] It involves new rules and laws applied to polluting firms and activities (industries, transport, etc.), thereby increasing the cost of living; the scenario also involves a public good dimension and raises the issue of potential spill-over benefits to other members of society which are not accounted for in the analysis. Using mean values based on a 3-month LE improvement, they recommend that a VOLY of € 40,000 be used in Europe-25.

More recently, **Chanel and Luchini (2010)** used a scenario derived from Viscusi et al. (1988) and Guria et al. (1999) in a French city (Marseilles). It offers the respondent a hypothetical choice between moving with his/her household to one of two cities, which are exactly the same (city size, housing, weather, public services etc.) with the exception of the cost of living and the level of air pollution. The mortality reduction is expressed as a gain in years of life for a random group of 100 people exposed to the risk and followed up to age 80, corresponding to a 4-in-10,000 annual reduction. The authors find an average estimated VSL of € 1.61 million, and explicitly estimate the weights assigned to the various members of the respondent's household.[5]

Among the studies realized in Asia, **Wang and Mullahy (2006)** estimated the VSL in a Chinese city (Chongqing), to reduce air-pollution-related mortality. The new program to reduce air pollution is financed by collecting a special fee to cover its cost and, as in Desaigues et al. (2007), the scenario also involves a public good dimension that is not taken into account. Moreover, it uses very small changes in risk (5-in-100,000 per year), which may perplex respondents (see for instance Pidgeon and Beattie 1997, or Hammitt and Graham 1999, on the perception of small risks). The VSL obtained is € 36,950, and according to the authors, broadly corresponds to a € 3.26 million estimate for a U.S. citizen when U.S./China rate of purchasing power parity and daily wage are accounted for.

In Taiwan, **Hammitt and Liu (2004)** proposed a scenario that protects everyone in the household thanks to air-pollution-control equipment imposed on factories by the government. This reduces the probability of someone in the household dying by 2-in-100,000 (8-in-100,000) per year but increases the cost of many other goods. They estimate median VSLs for a fatal industrial air-pollution-related bronchitis (resp. lung cancer) in the range € 1.2 -1.8

[4] It has recently been updated to ten countries in Desaigues et al. (2010).

[5] Note that a previous treatment of this dataset in Chanel et al. (2004) yields an average VSL of € 0.89 million, but implicitly (wrongly) assumes (as per Chilton et al., 2004) a weight of one for every member of the household.

million (rep. 1.7 -2.4 million). While the authors acknowledge that the elicited "WTP may include some component of altruism" (p.82), they did not control for it.

Finally, **Vassanadumrongdee and Matsuoka (2005)** found a VSL that ranges from € 0.71 to 1.27 million when measuring Bangkok residents' WTP to reduce mortality risk arising from air pollution. By eliciting WTP to benefit from an individual screening that would detect an impairment in the respiratory system (and hence would decrease mortality), they avoided the altruism issue in their valuation. However, unlike the 5 previous studies, their reduced mortality is obtained not through a difference in air pollution exposure but through a medical procedure in the spirit of the product used in Krupnick et al. (1998). Moreover, the very small annual changes in mortality risk proposed (3-in-100,000 and 6-in-100,000) may make risk perception by respondents difficult.

This review of the literature indicates how difficult it is to effectively tackle both spill-over benefits and the problem of perception of very small changes in death probability in the context of air pollution scenarios. When potential benefits to other members of society have been ruled out, altruism towards other family members is arbitrarily assumed to be of equal weight for every member of the household.

3.2.3. Values chosen for mortality

Overall, the values obtained in the contextual studies and those that mimic air pollution health-related features are in the range of those obtained for all other causes. We therefore choose to rely on European studies when selecting the monetary values to be used (see Table 1). First, we favor the mortality valuation study undertaken for the EC DG Research-funded New-Ext (2004) project and used in Cafe CBA (2005a) for two reasons: it estimates both VSL and VOLY values and it is representative of the European population. We choose the median VSL value (annual change 5:10,000 scenario) as low value and the mean VSL and VOLY (annual change 5:10,000 scenario) as high values. For the VOLY's low value, we decided to take the recent results from the NEEDS program (Desaigues et al., 2010, based on 3 months' LE gain with protesters and outliers deleted) realized on ten European countries. Finally, the respective arithmetic means of high and low values provide the central VSL and VOLY values. Note that the resulting central VSL value (€ 1,655 million) falls in the range of the values obtained in studies computing VSL in the air pollution context, and that the low – high range roughly represents a +/- 33% divergence from the central value.

The metrics used to assess mortality effects require the use of VSL (for premature deaths) and VOLY (for years of life saved). Indeed, we agree with Cafe (2005b) that the use of a Value of a Statistical Life (VSL) to value acute mortality is certainly not relevant, considering "that a better estimate of the average loss of life expectancy amongst those affected by acute effects of air pollution is around 1 year" (Cafe, 2005b, p. 46). Consequently, a Value Of a Life Year (VOLY) is preferred to value the short-term effects of PM reduction on mortality (with the assumption that the gain in life expectancy associated with each related premature death is 1 year), and a VSL for long-term effects of air pollutants on mortality. Note that when long-term mortality effects are expressed in terms of number of years of life saved, a VOLY will be used for their assessment.

Table 1 Monetary values chosen to assess mortality health effects (in € 2005)

	Chronic mortality	Chronic and acute mortality	Source
	VSL	VOLY	
Low estimate	1,090,000[(a)]	40,000[(b)]	[(a)] Median value of New-Ext (2004) [(b)] Mean value of Desaigues et al. (2010)
Central estimate	**1,655,000**	**86,600**	**Average of High and Low estimates**
High estimate	2,220,000	133,200	Mean value of New-Ext (2004)

3.3. Specific values chosen for morbidity (hospitalizations)

We suggest the COI method for direct and indirect costs of hospitalizations.

The direct medical costs related to cardiac and respiratory hospitalizations are computed as the cost per inpatient day times the average length of stay in hospital. These cost data are taken from CEC (2008)[6] for all twelve countries where cities analyzed in Aphekom are located (see Table 2). The average lengths of stay in days are obtained from the OECD Health Database (2010) for all countries except Romania (which is imputed from the population-weighted average lengths of the 11 other countries).

The indirect medical costs are computed as the average gross loss of production per day times twice the average length of stay in hospital. Indeed, because the number of working days lost has not been assessed by specific functions (Cafe, 2005b, for instance, used a function derived from Ostro, 1987), or through actual statistics regarding sick leaves or cessation of work, we assume that the number of working days lost is twice the length of hospitalizations (Ready and al., 2004; or Sommer et al., 1999; used a similar assessment). Consequently, we cannot verify whether these days were actual working days. We thus compute the daily loss of production as the average gross earnings in industry and services (full employment) obtained from Eurostat (2003) for each country, expressed in 2005 and divided by 365 days.

The total medical costs for cardiac and respiratory hospitalizations are obtained by adding together the direct and indirect components. As mentioned in Section 2.1., we suggest a +/- 33% range around these estimates, to account for uncertainties specific to the economic valuation. The Low and High estimates for the sensitivity analysis are then obtained by multiplying the costs respectively by 0.66 and 1.33.

[6] Note that the cost per inpatient day differs depending on the Diagnosis-Related Groups. In Sweden, it is for instance € 466 for respiratory hospitalization and € 675 for cardiovascular (personal communication Bertil Forsberg, Nov. 2010) and in Cafe (2005b, p. 116) "the inpatient unit cost is 1.92 higher than the generic unit cost". We chose a single average cost per day for both circulatory and respiratory hospitalizations because more detailed data cannot easily be obtained for most of the countries.

Table 2 Average lengths of stay, daily hospitalization costs and work loss, and total hospitalization cost per patient.

Country	Average length of stay in days in 2005 [(a)]		Average cost per day (€ 2005)		Total costs related to hospitalization (€ 2005)	
	Circulatory system	Respiratory system	Hosp. all causes[(b)]	Work loss[(c)]	Circulatory system	Respiratory system
Austria	8.2	6.6	319	83	3,977	3,201
Belgium	9.2	8.8	351	98	5,032	4,814
France	7.1	7.1	366	83	3,777	3,777
Greece	7.0	5.0	389	48	3,395	2,425
Hungary	7.4	6.5	59	18	703	618
Ireland	10.5	6.9	349	81	5,366	3,526
Italy	7.7	8.0	379	62	3,873	4,024
Romania	8.5[(d)]	7.4[(d)]	57	6	587	511
Slovenia	8.6	7.3	240	34	2,649	2,248
Spain	8.5	7.4	321	55	3,664	3,189
Sweden	6	5.2	427	92	3,666	3,177
United Kingdom	11.4	8.0	581	116	9,268	6,504
Mean[(d)]	**8.5**	**7.4**	**373**	**73**	**4,411**	**3,840**

Sources: [(a)] OECD Health Data (2010); [(b)] CEC (2008), annex 7, cost/bed/day corr; [(c)] Eurostat (2003); [(d)] population-weighted average, 2005 population data from OECD Health Data (2010).

Hence, based on Table 2, the population-weighted average direct cost of a cardiac hospital admission is 8.5 days x € 373= € 3,171 and the corresponding indirect cost related to work loss is 2 x 8.5 days x € 73= € 1,241. **Overall, the cost related to a cardiac hospital admission is € 4,411.**

Similarly, the population-weighted average direct cost of a respiratory hospital admission is 7.4 days x € 373= € 2,760, and the corresponding indirect cost related to work loss is 2 x 7.4 days x € 73= € 1,080. **Overall, the cost related to a cardiac hospital admission is € 3,840**.

For city- or country-specific valuation, the last two columns of Table 2 provide average hospitalization costs computed following the same rationale but using average lengths of stay, cost per day of hospitalization and daily work loss that are country-specific.

4. Economic valuation in WP4

4.1. General overview

This WP performs an "innovative" HIA of urban air pollution on chronic morbidity/exacerbation hospitalizations for PM and NO_2. (see Aphekom Deliverable D4, 2011).

4.1.1. Features of the innovative HIA

We estimate the economic burden associated with the **prevalence** of three chronic diseases attributable to proximity of traffic (i.e. Asthma among 0-17, Coronary Heart Disease and

COPD for 65 and over, see bloc A in Figure 5) and three exacerbations (hospitalizations) of these chronic diseases attributable to air pollution (see blocs C, D and E in Figure 5).

From an epidemiologic point of view, this innovative HIA approach is non-standard as it allows the computation of the share of a chronic disease attributable to traffic proximity (bloc A in Figure 5) as well as the exacerbation due to air pollution, whereas the traditional HIA approach computes only the exacerbations from air pollution in a chronic disease attributable to traffic proximity and to other causes. In other words, in Figure 5, the traditional HIA approach is restricted to the C + E share of the exacerbations, whereas the innovative approach adds both the D part of the exacerbations and the share of the chronic disease due to traffic, A.

From an economic point of view, this differs from all standard incidence approaches used for acute health outcomes (for instance hospitalization, asthma attack or consultation) or chronic health effects (for instance mortality or chronic bronchitis), which apply unit economic values to each case. Indeed, the annual costs involved in a chronic disease in a given year are a mixture of direct medical costs, direct non-medical costs and indirect costs, all of which depend on age, the degree of severity of the disease and the probability of occurrence of each disease-related health expenditure. Moreover, when making joint assessments of chronic disease onsets and exacerbations, care must be taken to avoid double counting, as detailed in section 4.1.2.

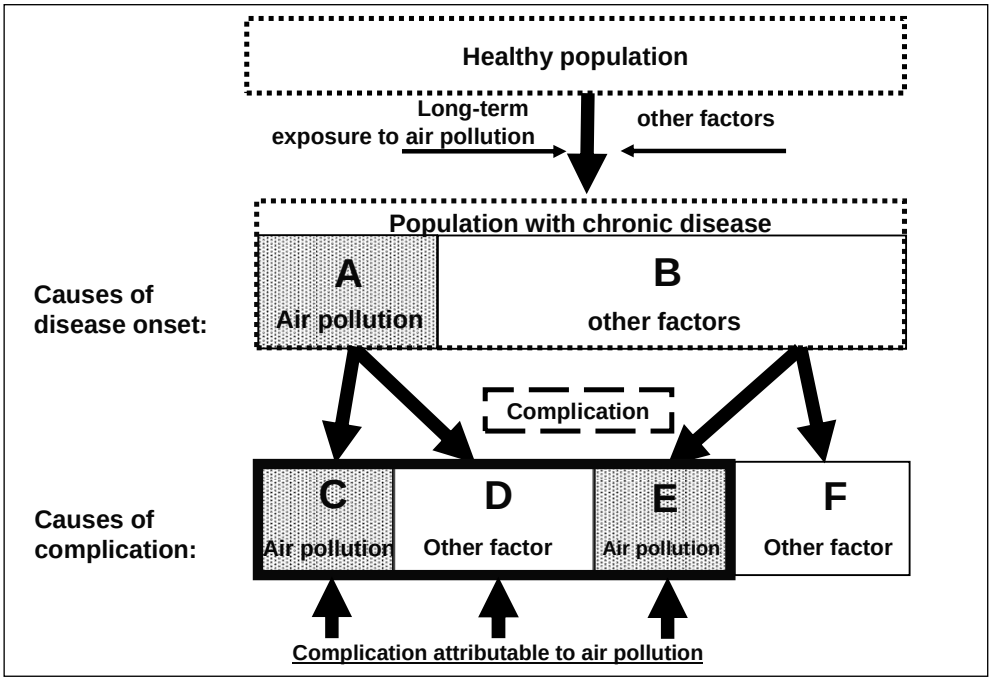

Figure 5: The burden to air pollution assuming a causal role of air pollution in both disease onset and complication. Source: Künzli et al. (2008).

4.1.2. Special features of the innovative HIA in terms of economic assessment

From an economic point of view, things are more complex than with the standard HIA approach. Indeed, Figure 6 divides the total cost of air-pollution-related health expenditure into two parts:
- the costs related to exacerbations due to air pollution among the chronic disease onsets not attributable to traffic (E).

- the costs related to the chronic disease onsets attributable to traffic (row A), including exacerbations in chronic disease both attributable to air pollution (C) and not attributable to air pollution (D), as well as other health outcomes both due to air pollution (G) and not (H). This bloc deserves attention to avoid over estimation (i.e., partial double counting) as the costs related to A and those related to C and D partially overlap when joint overall valuation of the economic burden is computed.

	Exacerbations (hospitalizations) per year		Other health outcomes per year	
	due to air pollution	not due to air pollution	due to air pollution	not due to air pollution
ONSET due to traffic (A)	C	D	G	H
ONSET not due to traffic (B)	E	F	I	J

Figure 6: Break down of CD-related costs

Hence, we proceed in three steps as follows.

First, the annual economic cost of a chronic disease onset due to traffic proximity (row A) is assessed. This is done by considering the average annual cost per patient of a given age-class with the chronic disease as an approximation of the cost of this attributable case. The underlying plausible assumption is that the average cost per patient does not significantly differ depending on the cause of the onset (i.e., asthma / COPD due to traffic exposure does not significantly differ from asthma / COPD due to other causes).

Second, the cost of exacerbations among chronic disease onsets is assessed as the direct and indirect costs of this exacerbation (hospitalization).

Finally, we determine whether the results of the economic valuation of CD onsets and CD exacerbations are to be assessed separately or jointly.

In the case of **separate assessment** of chronic disease onsets attributable to traffic proximity and exacerbations in chronic disease patients, the economic valuation consists in applying the annual cost to the number of cases in row A, while applying the full exacerbation costs to blocs C, D and E (see Table 3).

In the case of **joint assessment (overall burden)** of chronic diseases attributable to traffic proximity, we have to take account of the fact that the annual cost per patient already includes a fraction of the exacerbation cost. We should hence split the valuation of the exacerbations into two categories (see Table 3):

- patients that have chronic diseases whose onset cause is not traffic proximity (bloc E): we use the full average hospitalization cost (as in the separate assessment),
- patients that have chronic diseases whose onset cause is traffic proximity (blocs C and D): we use the full average hospitalization cost minus the fraction of the annual CD cost corresponding to exacerbations (i.e. hospitalizations).

This seems to provide a reasonable approximation of the overall economic burden of air pollution with respect to each of the three chronic diseases. However, it should be pointed out that the intangible component of costs is not accounted for in the valuation of exacerbations,

mainly to avoid the risk of double-counting (see section 2.5. for more details). Therefore, the economic assessments of CD constitute under-estimates of welfare effects.

Table 3 Comparison of the separate assessment approach and the joint assessment approach

Components of costs	**Direct and indirect costs**		**Intangible costs**
Type of valuation	**Separate**	**Joint**	-
CD onset due to traffic (A)	Annual average cost of a CD patient		Accounted for
CD exacerbation in CD onset not due to traffic (E)	Full average exacerbation cost		Not accounted for
CD exacerbation in CD onset due to traffic (C and D)	Full average exacerbation cost	Full average exacerbation cost minus fraction of annual average cost related to exacerbation	Not accounted for

4.1.3. Special features of the innovative HIA in terms of COI approach

The standard COI approach is obtained by direct interview of patients or by scrutinizing the health expenditure data of patients to compute an annual cost related to the chronic disease. The values obtained are actually observed. Three COI-based methods can also be used to assess the annual economic cost of a case of chronic disease.

- Cost of Illness using difference in average cost: This method differs from standard COI in that it accounts for co-morbidity health expenditures, i.e. the fact that people with a chronic disease may have higher health expenditures not related to this chronic disease, due to their relative frailty, for instance, or due to higher risks of developing certain co-morbidities.[7] The difference in hospital and primary care costs per person for a population having the disease and a population not having the disease is computed. The values obtained are actually observed.

- Cost of Illness using matching methods: More rarely used, it consists in comparing health-care expenditures for patients with the disease and patients without the disease by matching the patients as closely as possible in order to control for possible heterogeneity (on age, gender, revenue, place of residence, health status or family status). The values obtained are corrected for differences across patients and thus represent *ceteris paribus* real values.

- Estimated COI using Markov model: More rarely used, it computes the cost of a chronic disease by first defining mutually exclusive different disease states that have clinical meaning (from mild to death, for instance). Then, transition probabilities are assigned to moves between these states as well as average monetary cost by state. An overall estimate of the cost of an average state is then computed, generally through Monte Carlo simulations. The values obtained are thus based on a probabilistic model for transition and actual medical costs by state, and are considered as constructed (i.e. not actually observed) values.

4.2. Economic values chosen

[7] Indeed, dealing with COPD, Ramsey and Sullivan (2003) explain that « individuals with COPD often have more comorbidity than age- and sex-matched persons without COPD because of the impact of smoking on developing coronary artery disease, cancers and other illnesses. In addition, persons with COPD may come from different socioeconomic groups than those without the disease, because smoking is disproportionate among those with lower socioeconomic standing and in certain racial and ethnic groups. To estimate the impact of COPD on burden-of-illness or CEA studies, these factors must be controlled for. »

To estimate an annual average cost of a CD patient, we consulted studies providing costs for the three chronic diseases via a structured literature search with keywords in Scopus database and a systematic review of abstracts (or full-text) for all studies realized in the OECD (studies from developing countries were excluded). The studies analyzed in this section to compute the unit economic values of the chronic disease onsets cover both COI (for direct costs and total costs) and WTP (for intangible costs) for the computations. **The values chosen are** summarized in Table 4 and are **not country-specific due to missing data**. However, it is possible to obtain country-specific values by adjusting the annual average cost of a CD patient according to GDP/Capita measured at PPP in each country, or according to average cost of hospitalization.

To estimate the average exacerbation costs, we use several sources of information. Besides studies from the literature for direct costs, we also use country-specific data from Official Diagnosis-Related Groups (DRG) (Health-Related Groups (HRG) in UK), personal communications from members of the Aphekom project, and average lengths of stay in hospital specific to each of the three chronic diseases (source, OECD Health Data, 2010). Indirect costs account for losses of production through country-specific gross wage loss per day. **Table 4 provides the population-weighted average exacerbation costs for the three relevant chronic diseases, and Table 5 presents the corresponding direct, indirect and total costs for each of the 12 countries.**

As mentioned in Section 2.1., we suggest a +/- 33% range around the cost estimates, to account for uncertainties specific to the economic valuation. The Low and High estimates for the sensitivity analysis are then obtained by multiplying the costs respectively by 0.66 and 1.33.

Table 4 Summary of the unit values for WP4 (in €2005, all costs rounded to the nearest ten)

Chronic diseases	Health outcomes	Direct costs	Indirect costs	Intangible costs	Total costs[(a)]
Asthma	Annual average cost of asthma onset due to traffic	1,000	90	1,000	2,090 (1,390 – 2,790)
	Full asthma exacerbation cost[(b)]	1,600	670	-	2,270 (1,510 – 3,030)
	For joint valuation: asthma exacerbation cost in asthma onset due to traffic	1,100	630	-	1,730 (1,150 – 2,310)
COPD	Annual average cost of COPD onset due to traffic	2,200	70	770	3,040 (2,030 – 4,050)
	Full COPD exacerbation cost[(b)]	3,070	100	-	3,170 (2,110 – 4,230)
	For joint valuation: COPD exacerbation cost in COPD onset due to traffic	1,840	60	-	1,900 (1,270 – 2,530)
CHD	Annual average cost of CHD onset due to traffic	5,000	280	1,500	6,780 (4,520 – 9,040)
	Full acute myocardial infarction exacerbation cost[(b)]	2,630	90	-	2,720 (1,810 – 3,630)
	For joint valuation: acute myocardial infarction exacerbation cost in CHD onset due to traffic	1,560	30	-	1,590 (1,060 – 2,120)

[a] Figures in brackets represent the Low and High values. [b] Country-specific full exacerbation costs are provided in Table 5.

Table 5 Average lengths of stay, hospitalization costs, work loss, direct and total hospitalization cost per patient.

Country	Average length of stay in days in 2005 [a]			Average cost per day (€ 2005)		Direct average hospital. cost[d] (€ 2005)			Average cost of work loss [d] (€ 2005)			Total average hospital. cost[d] (€ 2005)		
	Asthma	COPD	AMI	Hosp. all causes[b]	Work loss[c]	Asthma	COPD	AMI	Asthma	COPD	AMI	Asthma	COPD	AMI
Austria	5.1	8.4	8.4	319	83	1,627	2,680	2,680	847	114	114	2,474	2,794	2,794
Belgium	6.5	13.1	8.7	351	98	2,282	4,598	3,054	1,274	211	140	3,556	4,809	3,194
France	4.1	9	6.6	366	83	1,501	3,294	2,416	681	123	90	2,182	3,417	2,506
Greece	4.6[c]	6	7	389	48	1,789	2,334	2,723	442	47	55	2,231	2,381	2,778
Hungary	6.7	8.3	8.3	59	18	395	490	490	241	25	25	636	515	515
Ireland	3.2	10	10.5	349	81	1,117	3,490	3,665	518	133	139	1,635	3,623	3,804
Italy	4.8	8.9	8.2	379	62	1,819	3,373	3,108	595	90	83	2,414	3,463	3,191
Romania	4.6[c]	8.5[c]	7.4[c]	57	6	262	485	420	55	8	7	317	493	427
Slovenia	4	9.8	9.9	240	34	960	2,352	2,376	272	55	55	1,232	2,407	2,431
Spain	6.5	9.2	9	321	55	2,087	2,953	2,889	715	83	81	2,802	3,036	2,970
Sweden	6.1	10	7.8	427	92	2,605	4,270	3,331	1,122	151	118	3,727	4,421	3,449
UK	2.7	6.4	5.3	581	116	1,569	3,718	3,079	626	122	101	2,195	3,840	3,180
Mean[c]	**4.6**	**8.5**	**7.4**	**373**	**73**	**1,601**	**3,069**	**2,630**	**672**	**102**	**89**	**2,273**	**3,171**	**2,719**

Sources: [a] OECD Health Data (2010); [b] CEC (2008), annex 7, cost/bed/day corr; [c] population-weighted average. [d]As explained in the text, we suggest a +/- 33% range around these cost estimates, to account for uncertainties specific to the economic valuation.

4.2.1. Asthma-related costs

The asthma-related costs for children aged 0-17 present *a priori* three major differences with respect to the corresponding costs observed in the general population:
- the severity of asthma is considered lower, hence the medical costs should be lower,
- the indirect costs are also lower as the loss in production is limited to adults (generally parents) who stop working to care for their children,
- a special care needs to be taken in computing intangible costs for children. Indeed, several studies consider this issue from a general valuation perspective (US-EPA, 2003; PEP, 2004; OECD, 2006, 2010) or on specific issues (Leung and Guria, 2006; Hammitt and Haninger, 2010; Liu et al, 2000; or Dickie and Messman, 2004). A crucial question is what WTP values should be used: based on parents', children's own or general population preferences? We consider that parents are the right people to estimate the intangible costs borne by their children.

4.2.1.1. Annual average cost of an asthmatic patient

It is, then, likely that the average annual cost per child aged 0-17 is lower than the average annual cost computed over the whole population. However, the literature review does not yield clear answers, mainly due to the definition of the costs included in the computations. Hence, Bahadori et al. (2009) report that "Younger age was found to be a significant predictor of higher costs in seven studies" but that "seven studies reported "older age" to be significantly more likely to have higher costs" and that in seven other studies "costs of asthma to be increased as patients' age increased". Moreover, a cohort study found that adolescents (15–19) "had both lower inpatient and outpatient (…) costs than either younger or older patients" whereas a second "found extremes of age (<10 yrs and >60 yrs) to be significantly predictive of higher asthma-related costs".

A literature review on asthma yields to 20 original studies plus 2 literature reviews that in total provide the results of 80 studies between 1984 and 2010 computing an average annual cost of asthma per patient. Among them, 71 are COI studies (either standard or using differences in average costs), one uses a matching approach, one follows a Markov approach, 6 are WTP studies, and one tries to estimate the economic value of a new asthma case over a 10-year period.

Only three of the studies examined the annual average direct and indirect costs of an asthma patient under 18, and are detailed below.

Ungar et al. (2001) compute the direct and indirect costs for 339 asthmatic children (1-15) in Ontario. They find a direct cost of € 949, and an indirect cost due to loss of production by the parents of € 124 (25% of the parents take an average of 4.8 working days off to care for their asthmatic child). Note that when the same authors applied the same methodology to 940 asthmatic adults, they found a direct cost of € 1,124 and an indirect cost of € 1,116 (due to higher loss of productivity among adults).

Lozano et al. (1999) estimate the difference in health care expenditures between 667 asthmatic children and 911 non-asthmatic children in the US. They find a € 1,029 difference, accounted for by both specific asthma expenditure and expenditure due to the fact that asthmatics more often suffer from pulmonary infections and have a higher risk of developing certain comorbidities than other patients.

Stock et al. (2005) study the cost of illness with asthma in Germany by retrospectively analyzing routine health insurance data. They find an average cost per patient of all ages of € 6,035, with € 1,509 for direct costs and € 4,526 for indirect costs (loss of production due to sick leave, early retirement and premature death). The hospitalization costs represent 6.9% of the average annual cost (20.7% of the direct cost), with an average cost of € 1,032 per hospitalization. Note that this cost is lower for age classes 0-5 (€ 641), 5-15 (about € 280), and 15-17 (about € 400).

Due to these lower hospitalization cost, mainly linked to the less severe nature of asthma in children, **we consider a direct annual cost of € 1,000 as a reasonable value for child(ren) aged 0-17**. Indirect costs are irrelevant for child(ren) aged 0-17 themselves. However, because the parents of a asthmatic child may support loss of production, **we consider an indirect annual cost of € 90.**[8]

Regarding intangible costs, two studies specifically ask parents for WTP to avoid symptoms in their asthmatic children. Brandt et al. (2008), in 250 households of asthmatic children aged 5-11, find an annual WTP ranging from € 564 to € 676 to get ride of all symptomatic days. Blomquist et al. (2011) for 192 parents of asthmatic children aged 4-17 find an annual WTP in the range € 1,819 – 3,463 for asthma control using an improved asthma therapy.

We choose to estimate intangible costs at € 1,000.

The direct and indirect annual costs related to an asthma onset attributable to traffic proximity in children aged 0-17 amount to € 1,090, the intangible annual costs to € 1,000, yielding a total annual cost per asthma onset of € 2,090.

Although the other studies in the literature review deal with asthma in adults or in the general population, the following brief summary of the values obtained is intended as a reliability check (see also Figure 7):
- 24 studies provide estimates of direct (medical and non-medical) annual costs per patient, with extremes of € 225 and € 6,004. Most estimates are in the range € 700 – € 1,600 and the mean is € 1,527.
- 17 studies provide estimates of indirect annual costs per patient, with extremes of € 67 and € 5,878. Most estimates are in the range € 200 – € 2,000 and the mean is € 1,377.
- 27 studies provide estimates of total (i.e. direct and indirect) annual costs per patient, with extremes of € 243 and € 7,560. Most estimates are in the range € 560 – € 2,800 and the mean is € 2,159.
- Finally, 6 contingent valuation studies provide 10 estimates of intangible costs per patient, with extremes of € 564 and € 3,463. The mean is € 1,764.

Thus, the value chosen to compute the annual economic burden of a case of asthma in child(ren) aged 0-17 seems in line with the values observed in the literature, being slightly lower than for adults because the illness is less severe.

[8] Ungar et al. (2001) find that 25% of parents take an average of 4.8 working days off to care for their asthmatic child, hence an average 1.2 days per child and per family times the average gross production loss per day in Table 2: € 73 x 1.2 days = € 88, rounded to € 90.

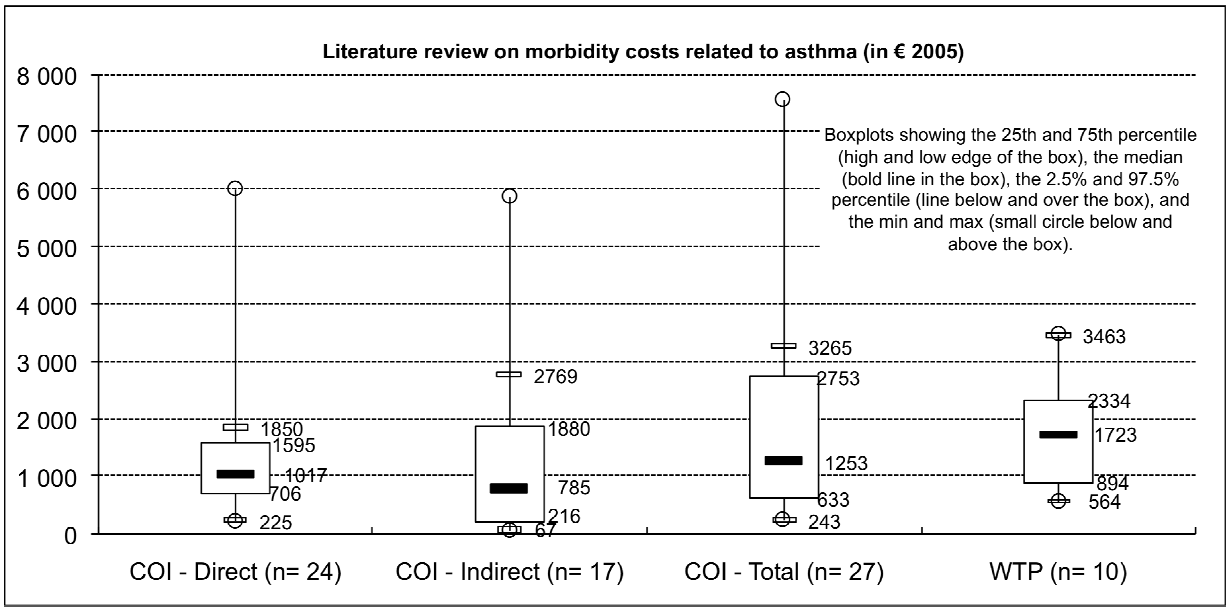

Figure 7: Boxplots on the literature review on morbidity costs related to asthma (€ 2005)

4.2.1.2. Asthma exacerbation cost: asthma hospitalization

A) Full average asthma exacerbation cost

We present below the direct medical costs obtained from the literature and from personal communications.

In Austria, the average duration for an asthma hospitalization in patients under 54 is 3.7 days, leading to an average cost of hospitalization of € 2,119 (source: direct information from Hanns Moshammer in October 2010, based on the Austrian system of hospital financing data).

In France, Com-Ruelle et al. (2002) report an average cost of hospitalization in the range € 2,520 - € 5,639 on 1,793 patients, depending on the severity of their asthma.

In Spain, the average cost for an asthma hospitalization (without complications) in patients under is € 1,787 (national Spanish Health System website, www.msps.es/fr/estadEstudios/estadisticas/inforRecopilaciones/anaDesarrolloGDR.htm). In Bilbao, it is € 2,262 (direct information from Marina Lacasana in November 2010, based on DRG) and € 1,871 in Andalousia (direct information from Teresa Martínez-Rueda in November 2010, based on DRG).

In Stockholm (Sweden), the average cost of an asthma hospitalization (without complications) in patients of all ages is € 2,461 (source: personal communication, Bertil Forsberg, November 2010, based on DRG).

In addition to these average costs, the direct costs for each of the twelve countries are computed in Table 5 by multiplying average country-specific length of stay in hospital for asthma (source, OECD Health Data, 2010) and average country-specific hospitalization cost per day (source ECE, 2008). The country-specific hospitalization costs range from € 262 for Romania to € 2,605 for Sweden, with a population-weighted average of € 1,601.

Consequently, a valuation of € 1,600 is chosen for the full average cost of a child's asthma hospitalization.

Regarding indirect costs, because the losses of production for children's families should be accounted for, we assume an average number of days off work equals twice the average length of hospitalization for each country. By applying the country-specific average gross production loss per day, we obtain a population-weighted average indirect cost of 4.6 days x 2 x € 73 = € 672, rounded to € 670 (see Table 5).

In total, the average direct and indirect costs of an asthma hospitalization for non-traffic-onset asthmatic children can be estimated at € 2,270.

B) Partial average asthma exacerbation costs for joint valuation

In cases of joint valuation, and to avoid double-counting, a specific value will be applied to exacerbations of CD onset due to traffic (blocs C and D), as detailed in Section 412.

We need to identify the fraction of the annual average cost per asthma that is due to hospitalization. Two studies on children find that hospitalization costs account for respectively 51% (Lozano et al., 1999) and 48% (Ungar et al., 2001) of direct costs. Note that studies in the general population (or in adults) find lower figures: between 15% (Cisternas et al., 2003) and 36% (Com-Ruelle et al., 2002).

We assume that the hospitalization component represents 50% of the costs for children aged 0-17. The cost of exacerbation of cases of asthma attributable to traffic proximity is equal to the full average exacerbation cost minus the fraction incurred by hospitalization in the average annual cost of an asthmatic child:

€ 2,270 - € 1,090 x 0.5 = € 1,725.

Hence, the average direct and indirect costs of an asthma hospitalization in traffic-onset asthmatic children can be estimated at € 1,730 in cases of joint valuation (as opposed to € 2,270 for separate valuation).

4.2.3. COPD-related costs

The COPD-related costs for adults over 65 present *a priori* two major differences with respect to the corresponding costs observed in the general population (see also Gerdtham et al., 2009):
- the severity of COPD is certainly greater, hence the evaluation of the medical costs may be higher,
- the indirect costs are lower since the average losses in production apply to working adults, whereas most adults over 65 are retired. Indeed, according to Aliaga and Romans (2006), only 8.2% of European citizens aged between 65 and 69 work in 2005.

4.2.3.1. Annual average cost of a COPD patient

It is therefore not clear whether the annual average COPD cost per adult over 65 is lower or higher than the annual average cost computed over the whole COPD population.[9]

The literature review yields to 37 original studies plus 2 literature reviews, which provide results of a total of 53 studies between 1990 and 2010 computing an average annual cost of COPD per patient. 35 are COI studies (either standard or using differences in average costs), 11 are WTP studies and 7 follow a Markov approach.

The costs obtained in the studies that deal with COPD in adults or the general population are presented below (see also Figure 8):
- 45 studies provide estimates of direct medical and non-medical annual costs per patient, with extremes of € 262 and € 8,885. Most estimates are in the range € 1,090 – € 2,700 and the mean is € 2,167.
- 19 studies provide estimates of indirect annual costs per patient, with extremes of € 49 and € 1,920. Most estimates are in the range € 520 – € 1,300 and the mean is € 891.
- 19 studies provide estimates of total (direct and indirect) annual costs per patient, with extremes of € 1,071 and € 5,435. Most estimates are in the range € 1,670 – € 3,403 and the mean is € 2,696.
- 10 contingent valuation studies provide 11 estimates of intangible costs per patient. Nine estimate a WTP to avoid a COPD throughout life (or a full to cure for COPD), and find values in the range € 20,154 - € 696,484, with a mean at € 193,200. Only one (Kleinman et al., 2010) estimates the annual WTP to get ride of the effects and symptoms of COPD for one year, and find a value of € 768 per year.

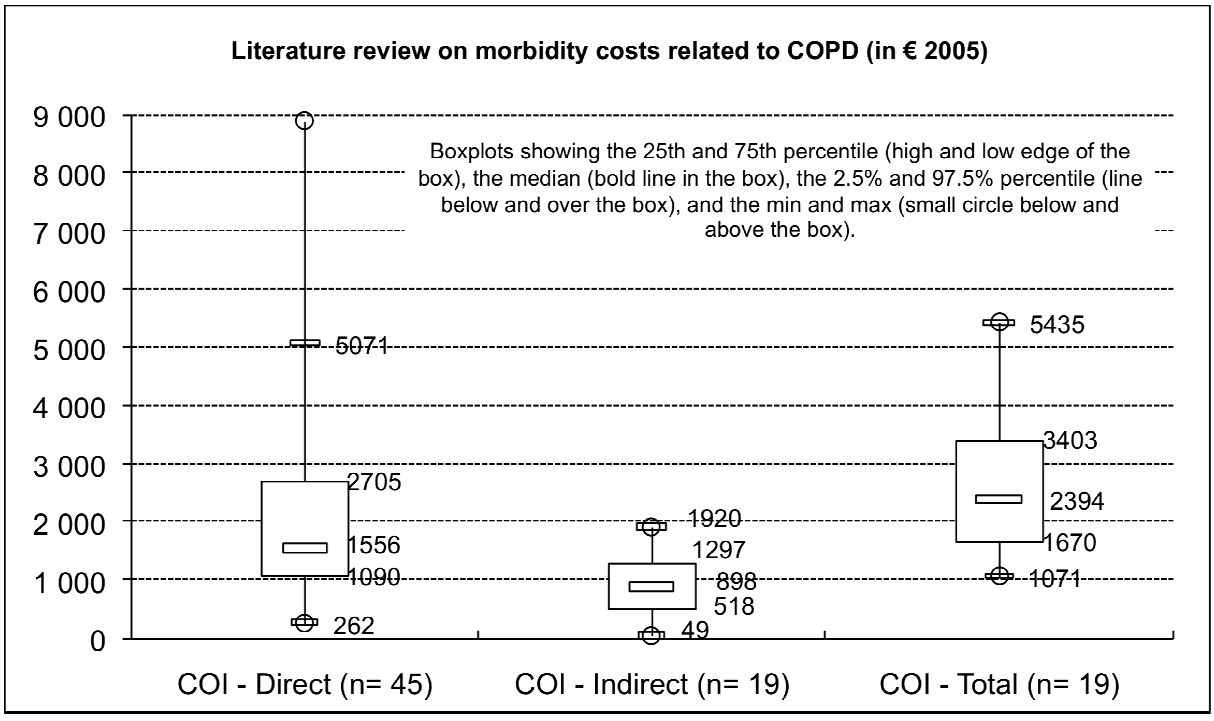

Figure 8: Boxplots on the literature review on morbidity costs related to COPD (€ 2005)

[9] According to de Miguel Diez (2008), for instance, there is a statistical significant positive relationship between age and cost for males, but not for females.

In line with the estimates observed in the literature, **we choose to set the direct annual cost of a case of COPD in adults over 65 at € 2,200, and the annual indirect cost at € 891x0.082 (the average probability of working after 65) = € 73.** This accounts for the fact that the COPD stages are certainly more severe than in all adults on average, the indirect costs linked to loss of production due to morbidity certainly lower and those linked to loss of production due to mortality comparable.[10]

The intangible costs are set at € 770 per year.

The direct and indirect annual costs related to a COPD onset attributable to traffic proximity in adults over 65 amount to € 2,270, the intangible annual costs to € 770, yielding a total annual cost per asthma onset of € 3,040.

4.2.3.2. COPD exacerbation cost: COPD hospitalization

A) Full average COPD exacerbation cost

We present below the direct medical costs obtained from the literature and from personal communications.

Rutten-van Mölken (2007), in Spain, uses an average COPD hospitalization of 8 days and an average cost per hospitalization day of € 368, hence yielding an overall average cost of € 2,944.

In Spain, the average cost of hospitalization (without complications) for COPD in patients over 65 is € 2,746 (source: national Spanish Health System website, www.msps.es/fr/estadEstudios/estadisticas/inforRecopilaciones/anaDesarrolloGDR.htm). In Bilbao, it is € 2,781 (direct information from Marina Lacasana in November 2010) and in Andalousia, € 2,459 (direct information from Teresa Martínez-Rueda in November 2010).

Viegi (2003), in Italy, gives the average COPD hospitalization as 9.4 days. The average cost per hospitalization day is € 379 in Italy (see table 2), hence yielding an overall average cost of € 2,415.

In Stockholm (Sweden), the average cost of a COPD hospitalization (without complications) in patients of all ages is € 2,402 (source: personal communication, Bertil Forsberg, November 2010).

In Austria, the average COPD hospitalization is 7.7 days, with an average cost of hospitalization of € 3,423 (source: direct information from Hanns Moshammer in October 2010, based on data for the Austrian system of hospital financing).

[10] An exact assessment of the respective importance of these three categories of costs in adults over 65 w.r.t. the general population deserves specific studies. However, it seems reasonable to consider that direct medical costs are certainly higher due to longer hospitalizations and higher costs of medication, that productivity loss due to morbidity is much lower due to age, and that productivity loss due to mortality might not strongly differ. For the latter, the higher death rate in COPD patients over 65 (w.r.t. the general population) is counterbalanced by the shorter life expectancy at death, which lowers the computed expected losses of production.

In France, the DGS (2007) estimates an average hospitalization cost of € 3,354 in the general population.

In addition to these average costs, the direct costs for each of the twelve countries are computed in Table 5 by multiplying average country-specific length of stay in hospital for COPD (source, OECD Health Data, 2010) and average country-specific hospitalization cost per day (source ECE, 2008). The country-specific hospitalization costs range from € 485 for Romania to € 4,598 for Belgium, with a population-weighted average of € 3,069.

A reasonable value for the average direct costs of a COPD hospitalization can thus be estimated at € 3,070.

Regarding loss of production, as stated earlier, only 8.2% of the 65-69-year-old-population work (and none above 70, except in Romania). Hence, if we assume an average productivity loss equal to twice the average duration of hospitalization, the population-weighted average indirect cost is 8.5 days x 2 x € 73 = € 1,241, rounded to € 1,240. Because the average employment rate in adults over 65 is 8.2%, the indirect costs are equal to 1,240 x 0.082 = € 102, rounded to € 100 (see Table 5).

In total, the full average direct and indirect costs of a COPD hospitalization can be estimated at € 3,170.

B) Partial average COPD exacerbation costs for joint valuation

We need to identify the fraction of the annual average cost per COPD that is due to hospitalization. Several studies apportion a share of direct costs to hospitalization costs: 35% in France (Fournier et al., 2005); 37% in Sweden (Jansson et al., 2007); 54% in UK (Britton, 2003); 55% in Australia (Australia Lung Foundation, 2008); 75% in Italy (Dal Negro et al., 2003) and 84% in Spain (Izquierdo et al., 2003). This leads to an average of 56%.

On average, we assume that the hospitalization component represents 56% of the direct costs of COPD. The cost of exacerbation in the cases of COPD attributable to traffic proximity is equal to the full average exacerbation cost minus the hospitalization component in the average annual cost of COPD:

€ 3,170 - € 2,270 x 0.56 = € 1,900.

Hence, the average direct and indirect costs of a COPD hospitalization for traffic-onset COPD can be estimated at € 1,900 in cases of joint valuation (as opposed to of € 3,070 for separate valuation).

4.2.4. Coronary-Heart-Disease-related costs

Coronary heart disease covers several diseases (cardiac arrest, myocardial infarction, angina, stroke), with various degrees of severity and whose costs strongly depend on the therapeutic approach used. Similarly to COPD, CHD-related costs present *a priori* two major differences with respect to the corresponding costs in the general population:
- the severity of CHD is certainly higher, hence evaluation of the medical costs may be higher,

- the indirect costs are lower since the average losses in production apply to working adults whereas most adults over 65 are retired.

4.2.4.1. Annual average cost of a CHD patient

It is not clear whether the annual average CHD cost per adult over 65 is lower or higher than the annual average cost computed over the whole CHD population.

The literature review is less homogeneous due to the diversity of the diseases covered. We found 17 original studies between 1990 and 2010 that compute an average annual cost of COPD per patient. 16 are COI studies (either standard or using differences in average costs), and one follows a Markov approach.

The costs obtained in the studies that deal with CHD in adults or the general population are presented below (see also Figure 9):
- 15 studies provide estimates of direct medical and non-medical annual costs per patient, with extremes of € 762 and € 11,444. Most estimates are in the range € 3,020 – € 6,920 and the mean is € 5,153.
- 6 studies provide estimates of indirect annual costs per patient, between € 1,550 – € 4,602, for a mean of € 3,372.
- 3 studies provide estimates of total (direct and indirect) annual costs per patient, between € 1,494 and € 8,168, for a mean of € 5,817.

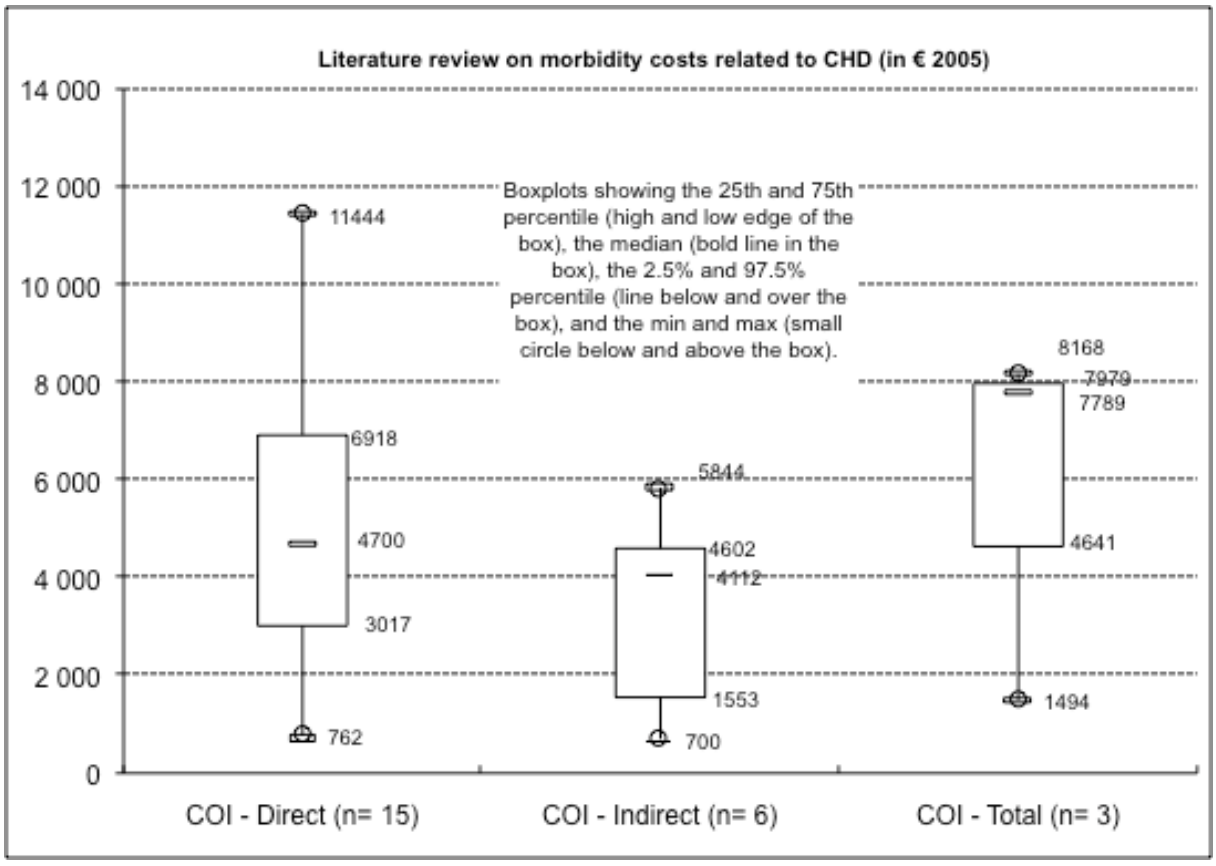

Figure 9: Boxplots on the literature review on morbidity costs related to CHD (€ 2005)

We did not find any studies that provide WTP to avoid one year of CHD. However, Groot et al. (2004) estimate a monetary equivalent variation to compensate for annual loss of welfare

due to cardiovascular disease for 65- and 75-year-old males and females (their Table 4, level "sufficient"). The gender-average equivalent variation is € 2,460 for a 65-year-old patient with CHD and € 817 for a 75-year-old patient. In the same spirit, Kartman et al. (1996) asked 402 Swedish angina pectoris patients (average age 68) their WTP for reduction by 50% in angina pectoris attacks. Based on their results, for a 3-month reduction, the corresponding annual WTP is between € 1,348 and € 1,604.

In line with the values observed in the literature, we choose **a direct annual cost of a case of CHD in adults over 65 of € 5,000 and an indirect annual cost of € 3,372x0.082 (the average probability of working after 65) = € 277.** As with the COPD valuation, it is reasonable to consider that direct costs and indirect costs differ between patients over 65 and the general population, but that the overall balance can result in a comparable annual cost evaluation.

The intangible annual costs are set at € 1,500 per year.

The direct and indirect annual costs related to a CHD onset attributable to traffic proximity in adults over 65 amount to € 5,280, the intangible annual costs to € 1,500, yielding a total annual cost per asthma onset of € 6,780.

4.2.4.2. CHD exacerbation cost: Acute Myocardial Infarction (AMI) hospitalization

A) Full average CHD exacerbation cost

We present below the direct medical costs obtained from the literature and from personal communications.

In Stockholm (Sweden), the average direct medical cost of a Myocardial Infarction hospitalization (without complications) in patients of all ages is € 2,714 (direct information from Bertil Forsberg based on DRG data, November 2010).

According to Lamotte et al. (2006) and based on official DRG data, the cost of myocardial infarction is € 1,665 in UK, 5,978 in Spain and € 4,387 in Italy.

In Bilbao, it is € 4,991 for patients over 65 (direct information from Marina Lacasana based on DRG data, November 2010) and € 4,293 in Andalousia, (direct information from Teresa Martínez-Rueda based on DRG data, November 2010).

In France, according to Montagne et al. (2000) and based on DRG data, the direct cost of a fatal myocardial infarction is € 4,453 and that of a myocardial infarction without complications is € 6,485.

In Belgium, according to Lamotte et al. (2006) and based upon DRG data, the direct cost of a fatal myocardial infarction is € 3,881 and that of a non-fatal myocardial infarction is € 4,733.

In addition to these average costs, the costs for each of the twelve countries are computed in Table 5 by multiplying average country-specific length of stay in hospital for acute myocardial infarction (source, OECD Health Data, 2010) and average country-specific hospitalization cost per day (source ECE, 2008). The country-specific hospitalization costs

range from € 420 for Romania to € 3,665 for Belgium, with a population-weighted average of € 2,630.

Regarding loss of production, as for COPD, only 8.2% of the 65-69 year-old population work (and none over 70, except in Romania). Hence, if we assume an average productivity loss equal to twice the average duration of hospitalization, the population-weighted average indirect cost is 7.4 days x 2 x € 73 = € 1,080. When the average employment rate of 8.2% is applied to this amount, the indirect costs are equal to € 1,080x 0.082 = € 89, rounded to € 90.

Hence, the full average direct and indirect costs of an acute myocardial infarction hospitalization can be estimated at € 2,720.

B) Partial average CHD exacerbation costs for joint valuation

We need to identify the fraction of the annual average cost per CHD that is due to Myocardial infarction hospitalization. According to Leal et al. (2006) and based on the average figures for EU-25, 43% of the costs of CHD are due to hospitalization for CHD, including acute myocardial infarction. In New Zealand, hospitalizations for AMI total a share of 50% of all coronary heart disease in 2005 (Chan et al., 2008). This share is also estimated on the basis of discharge rate statistics by diagnostic category (source: OECD Health Data; 2010), and is equal to a population-weighted average of 46% in 2005, for the 12 countries involved (except Romania, missing data).

On average, a hospitalization for AMI represents about 0.43 x 0.5 = 0.215, i.e. 21,5% of the direct annual costs of CHD. The cost of exacerbation in the cases of CHD attributable to traffic proximity is equal to the full average exacerbation cost minus the hospitalization component in the average annual cost of CHD:

€ 2,720 - € 5,280 x 0.215 = € 1,590.

Hence, the average direct and indirect costs of an acute myocardial infarction hospitalization for traffic-onset CHD can be estimated at € 1,590 in cases of joint valuation with the costs of CHD onset (as opposed to € 2,720 for separate valuation).

5. Specific features of the economic valuation in WP6

The WP evaluates mortality effects for implementation of a regulation on sulphur dioxide content in diesel fuel (see Aphekom Deliverable D11, 2011). It can be observed that the effects on mortality start before the regulation is actually implemented. However, this is probably due to rational behavior in anticipation of an increase in the cost of a tonne of SO2 (due to desulphurization). In fact, some major users of sulphured fuel before 1994 presumably switched to natural gas prior to the implementation of the regulation.

The regulation has two potential effects on mortality: short-term and long-term. It has been decided that, to take a conservative standpoint, mortality effects will be considered as short-term effects. Consequently, we use a VOLY similar to that proposed in WP5 (see section 3.2) to value short-term mortality. The economic evaluation thus constitutes a lower bound of the mortality effects of the regulation.

Although only mortality effects are accounted for in Aphekom, we should bear in mind that that sulphur dioxide emissions also generate effects on morbidity, on crops (with a positive effect at low doses but a negative effect when doses increase), visibility or acid rains. We should be aware that what will be assessed are only partial benefits of the regulation. Note finally that Olsthoorn et al. (1999) provides a rough estimate of the cost of desulphurization, with an average cost of reduction by one tonne SO_2 ranging from € 176 to € 3,072, central value € 504 (expressed in euros 2005).

6. References

Akobundu E., Ju J., Blatt L. and Mullins C.D., (2006) Cost-of-Illness Studies, A Review of Current Methods. Pharmacoeconomics, 24 (9): 869-890.

Alberini A., and Chiabai, A. (2007). Urban environmental health and sensitive populations: How much are the Italians willing to pay to reduce their risks? Regional Science and Urban Economics 37 239–258.

Alberini A., Cropper, M., Krupnick, A., and Simon, N. (2004). Does the value of a statistical life vary with age and health status? Evidence from the US and Canada. Journal of Environmental Economics and Management, 48, 769-792.

Alberini A., Hunt, A. and Markandya (2006) A. Willingness to pay to reduce mortality risks: evidence from a three-country contingent valuation study. Environmental & Resource Economics, 33: 251–264.

Aliaga C. and F. Romans (2006), Statistics in focus, Population and social conditions 2006: The employment of seniors in the European Union, KS-NK-06-015-EN-N, 11 p.

Aphekom Deliverable D11 (2011), Health impacts and costs of a strategy already implemented to reduce air pollution in Europe, by Goodman P. et al., May.

Aphekom Deliverable D11bis (2011), Report on benefits associated with the implementation of the 1996 EC regulation on SO_2, by Chanel O., May.

Aphekom Deliverable D3 (2011), Guidelines of methods, by Perez L. and Künzli N., May.

Aphekom Deliverable D4 (2011), Integrating local-traffic pollution chronic effects in the air pollution health impact methodology - Case study, by Perez L. and Künzli N., May.

Aphekom Deliverable D4bis (2011), Integrating chronic effects of local-traffic pollution into air pollution health impact methodology: monetary assessment, by Chanel O., May.

Aphekom Deliverable D7 (2011), Health impacts of urban air pollution, by Declercq C. et al., May.

Aphekom Deliverable D7bis (2011), Health impacts of urban air pollution: assessment of the economic benefits, by Chanel O., May.

ASCC - Australian Safety and Compensation Council (2008), The Health of Nations: The Value of a Statistical Life, July, 194 p.

Australian Lung Foundation (2008), Economic impact of COPD and cost effective solutions, Report by Access Economics, October 16th, 85 p.

Bahadori K., Doyle-Waters M., Marra C., Lynd L., Alasaly K., Swiston J. and FitzGerald JM (2009), Economic burden of asthma: a systematic review, BMC Pulmonary Medicine 9 :24

Barnes P.J., Jonsson B., and Klim J.B. (1996), The costs of asthma, European Respiratory Journal, 9, 636–642.

Bickel P., Hunt A., De Jon G., Laird J., Lieb Ch., Lindberg G., Mackie P., Navrud S., Odgaard Th., Shies J., and Tavasszy L. (2006) HEATCO D5: Proposal for Harmonized Guidelines. Deliverable 5 of HEATCO (Developing Harmonized European Approaches for Transport Costing and Project Assessment).

Blomquist G., Dickie M., and O'Conor R. (2011) Willingness to pay for improving fatality risks and asthma symptoms: Values for children and adults of all ages, Resource and Energy Economics 33(2) 410-425

Brandt S., Vásquez F., and Hanemann M. (2008), Designing Contingent Valuation Scenarios for Environmental Health: The Case of Childhood Asthma, UDEC DT 11-09, Universidad de Conception, 35 p.

Britton M. (2003) The burden of COPD in the U.K.: results from the confronting COPD survey. Respir Med; 97: S71–S79

Burmaster DE, and Anderson PD. (1994) Principles of good practice for the use of Monte Carlo techniques in human health and ecological risk assessment. Risk Analysis 14: 477-81.

CAFE (2005a), Methodology for the Cost-Benefit analysis for CAFE: Volume 3: Uncertainty in the CAFE CBA. http://www.cafe-cba.org. Holland, M., Hurley, F., Hunt, A. and Watkiss, P.

CAFE (2005b) Methodology for the Cost-Benefit analysis for CAFE: Volume 2 – Health Impact Assessment. http://www.cafe-cba.org . F. Hurley, A. Hunt, H. Cowie, M. Holland, B. Miller, S. Pye and P. Watkiss.

CEC Commission of the European Communities (2008), Commission staff working document accompanying the Proposal for a Council recommendation on patient safety, including the prevention and control of healthcare associated infections – Impact assessment, SEC(2008) 3004 Brussels, December 15, 59 p.

Chan W C, C Wright, M Tobias, et al. (2008) Directions admissions and incidence can be in opposite hospitalisations in New Zealand: trend for explaining trends in coronary heart disease, Heart 94: 1589-1593

Chanel O. and Luchini S. (2010), Monetary values for air pollution risk of death: a contingent valuation survey, updated mimeo of working paper 2008-05, GREQAM.

Chanel O., Faugère, E., Geniaux, G., Kast, R., Luchini, S., and Scapecchi, P. (2004). Valorisation économique des effets de la pollution atmosphérique: Résultats d'une enquête contextuelle. Revue Economique, 55(1), 65-92.

Chanel O., Scapecchi P. and Vergnaud J.-C., (2006), How to correctly assess mortality benefits in public policies, Journal of Environmental Planning and Management, 49:5, 759-776.

Chestnut L. and P. De Civita, (2009), Economic Valuation of Mortality Risk Reduction, report available at http://www.policyresearch.gc.ca/doclib/2009-0012-eng.pdf.

Chilton S., Covey, J., Jones-Lee, M., Loomes, G., and Metcalf, H. (2004) Valuation of health benefits associated with reductions in air pollution. Defra publication PB 9413.

Cisternas M., Blanc P., Yen I., Katz, P., Earnest G., Eisner, M., Shiboski, S., and Yelin E., (2003), A comprehensive study of the direct and indirect costs of adult asthma. J Allergy and Clinical Immunology 111(6), 1212-1218.

Com-Ruelle L., Grandfils N., Midy F., and Sitta R. (2002), Les déterminants du coût médical de l'asthme en Île-de-France, CREDES n°1397, Novembre, ISBN: 2-87812-301-8, 120 p.

Cropper M., Aydede, S.K., and Portney, P. (1994), Preferences for saving life-saving programs: how the public discount time and age. Journal of Risk and Uncertainty, 8, 243-265.

Dal Negro R, Rossi A, Cerveri I (2003), The burden of COPD in Italy: results from the Confronting COPD survey. Respir Med ; 97, S43-50.

de Miguel Diez, Carrasco Garrido P., García Carballo M., Gil de Miguel A., Rejas Gutierrez J., Bellón Cano J., Hernández Barrera V. and Jimenez García E. (2008), Determinants and predictors of the cost of COPD in primary care: A Spanish perspective International Journal of COPD, 3(4) 701–712

Desaigues B, Ami D, Hutchison M, Rabl A, Chilton S, Metcalf H, Hunt A, Ortiz R, Navrud S, Kaderjak P, Szanta R, Seested Nielsen J, Jeanrenaud C, Pellegrini S, Braun Kohlova M, Scasny M, Maca V, Urban J, Stoeckel M-E, Bartczak A, Markiewicz O, Riera P, and Farreras V (2007) Final Report on the monetary valuation of mortality and morbidity risks from air pollution, Deliverable D6.7, NEEDS RS1b, February, European Union, 54 p.

Desaigues B., Ami D., Bartczak A., Braun-Kohlová M., Chilton S., Czajkowski M., Farreras V., Hunt A., Hutchison M., Jeanrenaud C., Kaderjak P., Máca V., Markiewicz O., Markowska A., Metcalf H., Navrud S., Seested Nielsen J., Ortiz R., Pellegrini S., Rabl A., Riera P., Scasny M., Stoeckel M.-E., Szántó R. and Urban J. (2010), Economic Valuation of Air Pollution Mortality : A 9-Country Contingent Valuation Survey of Value of a Life Year (VOLY), forthcoming Ecological Indicators.

Dickie M., and Messman, V.L., (2004), Parental altruism and the value of avoiding acute illness: Are kids worth more than parents? Journal of Environmental Economics and Management 48, 1146–1174.

Direction Générale de la Santé (2007), Etude épidémiologique sur la BPCO, Rapport final, Les Asclépiades – Thales, Novembre, 168 p.

Droste-Franke B. and R. Friedrich (2004), Air Pollution: Greensense Project; EC DG Research Project. European Commission, Brussels.

Eurostat (2003), Paternoster A. Annual Gross Earnings: Results from Member States, Acceeding and Candidature Countries, and Switzerland, Theme 3—25/2003, Statistics in Focus, EUROSTAT.

ExternE (1999) DGXII (JOULE Programme) Externalities of Energy, ExternE Project, Report Number 7, Methodology: Update 1998. Holland, M.R. and Forster, D. (eds.).

Ezzati M., Lopez, A., Rodgers, A., van der Hoorn, S., Murray, C.J.L. and the Comparative Risk Assessment Collaborating Group. (2002). Selected major risk factors and global and regional burden of disease, The Lancet, 360, 1347-1360.

Fournier M., Tonnel A.-B., Housset B., Huchon G., Godard P., Vervloet D., Huas D., Durand-Zaleski I., Chanal I., Pribil C. et le groupe SCOPE (2005) Impact économique de la BPCO en France : étude SCOPE, Rev Mal Respir 2005, 22, 247-56.

Gerdtham U.-G., Andersson F., Ericsson A., Borg S., S.-A. Jansson, Rönmark E. and Lundbäck L. (2009), Factors affecting chronic obstructive pulmonary disease (COPD)-related costs: a multivariate analysis of a Swedish COPD cohort, Eur J Health Econ 10:217–226

Groot W., Maassen van den BrinkH. and Plug E. (2004), Money for health: the equivalent variation of cardiovascular diseases, Health Econ. 13: 859–872

Guria J., Jones W., Jones-Lee M., Keall M., Leung J. and Loomes G. (1999), The values of statistical life and prevention of injuries in New Zealand, Report to the New Zealand

Transport Safety Authority.

Hammitt J. (2007), Valuing changes in mortality risk: lives saved versus life years saved. Review of Environmental Economics and Policy, 1, 228-240.

Hammitt J. and Graham J. (1999), Willingness to pay for health protection: inadequate sensitivity to probability?, Journal of Risk and Uncertainty, 8,33-62.

Hammitt J., and Haninger K., (2010), Valuing fatal risks to children and adults: effects of disease, latency, and risk aversion. Journal of Risk and Uncertainty, 40, 57–83.

Hammitt J.K., and Liu J.-T. (2004). Effects of disease type and latency on the value of mortality risk. Journal of Risk and Uncertainty 28 (1), 73-95.

Infras, CE Delft, M. Maibach, C. Schreyer, D. Sutter, H.P. van Essen, B.H. Boon, R. Smokers, A. Schroten, C. Doll, B. Pawlowska, M. Bak, (2008) Handbook on estimation of external costs in the transport sector, Internalisation Measures and Policies for All external Cost of Transport (IMPACT), Publication number: 07.4288.52, 336 p.

Izquierdo JL. (2003) The burden of COPD in Spain: results from the confronting COPD survey. Respir Med 97 (Suppl. C), S61-9.

Janke K., Propper C., and Henderson J. (2009). Do current levels of air pollution kill? The impact of air pollution on population mortality in England. Health Economics, 18(9), 1031-55.

Jansson SA, Ronmark E, Forsberg B, Lofgren C, Lindberg A, Lundback B (2007) The economic consequences of asthma among adults in Sweden. Respir Med, 101(11), 2263-70.

Jones-Lee M. (1992), Paternalistic Altruism and the Value of Statistical Life, The Economic Journal, 102, 80-90.

Kartman B., F. Andersson, and M. Johannesson (1996) Willingness to Pay for Reductions in Angina Pectoris Attacks Med Decis Making, August 1, 16(3): 248 – 253

Kleinman L., Kawata A., Harding G. and Ramachandran S. (2010), Patient Willingness To Pay For Specific Attributes Of Maintenance Medication For COPD, Am. J. Respir. Crit. Care Med.; 181: A2868

Kochi I., B. Hubbell, and R. Kramer, (2006), An Empirical Bayes Approach to Combining and Comparing Estimates of the Value of Statistical Life for Environmental Policy Analysis. Environmental & Resource Economics, 34(3): 385-406.

Krupnick A. (2007), Mortality-risk valuation and age: stated preference evidence. Review of Environmental Economics and Policy, 1, 261-282.

Krupnick A., Alberini A., Belli R., Cropper M. and Simon N. (1998), New Directions in Mortality Risk Valuation and Stated Preference Methods: Preliminary Results, Proceedings of PSAM 4: The International Conference of Probabilistic Safety Assessment and Management, New York, NY.

Krupnick A., Alberini A., Cropper M. and Simon N., with Itaoka K. and Akai M. (1999), Mortality Risk Valuation for Environmental Policy, Discussion Paper 99-47, August, 25p.

Krupnick A., Alberini, A., Cropper, M., Simon, N., O'Brien, B., Goeree, R., and Heintzelman, M. (2002), Age, health and the willingness to pay for mortality risk reductions: a contingent valuation survey of Ontario residents. Journal of Risk and Uncertainty, 24, 161-186.

Künzli N, Perez L, Lurmann F, Hricko A, Penfold B, and McConnell R. (2008) An Attributable Risk Model for Exposures Assumed to Cause both Chronic Disease and its Exacerbations. Epidemiology 19(2): 179-185, March.

Lamotte M., Annemans, L., Kawalec P., and Zoellner Y. (2006), A Multi-Country Health Economic Evaluation of Highly Concentrated N-3 Polyunsaturated Fatty Acids in Secondary Prevention after Myocardial Infarction, Pharmacoeconomics, 24 (8), 783-795

Leal J, Luengo-Fernandez R, Gray A, Petersen S, and Rayner M. (2006) Economic burden of cardiovascular diseases in the enlarged European Union. Eur Heart J., 27(13), 1610-1619

Leksell I., and Rabl, A. (2001), Air pollution and mortality: quantification and valuation of years of life lost. Risk Analysis, 21, 843-857.

Leung J. and Guria J. (2006), Value of statistical life: Adults versus children. Accident Analysis and Prevention 38 1208–1217

Lindhjem H., Navrud, S. and Braathen N.-A. (2010) Valuing lives saved from environmental, transport and health policies: A meta-analysis of stated preference studies, ENV/EPOC/WPNEP(2008)10/FINAL, 60 p.

Liu J.T., Hammitt, J.K., Wang, J.D., and Liu, J.L., (2000), Mother's willingness to pay for her own and her child's health: a contingent valuation study in Taiwan. Health Economics 9, 319–326

Lozano P, Sullivan SD, Smith DH, and Weiss KB (1999) The economic burden of asthma in US children: estimates from the National Medical Expenditure Survey. J Allergy Clin Immunol, 104(5) 957-63.

Miller B. and Hurley F. (2006), Comparing estimated risks for air pollution with risks for other health effects, IOM Research Report TM/06/01, March, 42 p.

Mitchell R.C. and Carson R.T. (1989), Using survey to valuate public goods: the contingent valuation method, Resources for the Future, John Hopkins University Press.

Montagne O., Chaix C., Harf A., Castaigne A. and Durand-Zaleski I. (2000) Costs for Acute Myocardial Infarction in a Tertiary Care Centre and Nationwide in France PharmacoEconomics, 17(6), 603-609.

Nellthorp J., Samson T., Bickel P., Doll C. and Lindberg G. (2001) Valuation Conventions for UNITE, UNITE (UNIfication of accounts and marginal costs for Transport Efficency), Contract: 1999-AM.11157, Funded by the 5th Framework RTD Programme, Leeds.

New-Ext (2004), New Elements for the Assessment of External Costs from Energy Technologies, final report to the European Commission DG Research, Technological Development and Demonstration, (Contract No : ENG1-CT2000-00129), produced by IER (Institute for Energy Economics and the Rational Use of Energy) et al.

OECD (2006), Economic Valuation of Environmental Health Risks to Children, 314 p.

OECD (2010), Valuation of Environment-Related Health Risks for Children, Alberini A., Loomes G., Scasny M., Bateman I. December 2010, ISBN 9789264068100, 150 p

OECD Health Data (2010), CD-ROM

Olsthoorn X., M. Amann, A. Bartonova, J. Clench-Aas, J. Cofala, K. Dorland, C. Guerreiro, J. Fr. Henriksen, H. Jansen and S. Larssen (1999), Cost Benefit Analysis of European Air Quality Targets for Sulphur Dioxide, Nitrogen Dioxide and Fine and Suspended Particulate Matter in Cities, Environmental & Resource Economics, 14, 333-351.

Ortiz R., Markandya, A. and Hunt, A. (2009), Willingness to Pay for Mortality Risk Reduction Associated with Air Pollution in São Paulo. Revista Brasila Economia, 63(1) 3–22.

Ostro B., and Chestnut, L. (1998), Assessing the health benefits of reducing particulate matter air pollution in the USA. Environmental Research Section A, 76, 94-106.

Ostro B.D. (1987). Air pollution and morbidity revisited: A specification test. J Environ Econ Manage 14, 87-98.

Ostro B.D., Tran, H., and Levy, J.I., (2006), The health benefits of reduced tropospheric ozone in California. Journal of the Air and Waste Management Association 56 (7), 1007-1021.

Pearce D., and Crowards, T. (1996), Particulate matter and human health in the United Kingdom. Energy Policy, 24, 609-619.

PEP - Transport, Health and Environment Pan-European Programme (2004), Transport-related Health Effects with a Particular Focus on Children, Economic Valuation, SIKA, June, 51p .

Pidgeon N. and Beattie J. (1997), The psychology of risk and uncertainty, in P. Calow (ed.) Handbook of environmental risk assessment and management, Oxford: Blackwell Science, 289-318.

Rabl A. (1999) Assessment of Uncertainty. In ExternE – Externalities of Energy, Volume 7 – Methodology 1998 Update (M. Holland, J. Berry and D. Forster. eds).

Rabl A. (2000) Uncertainty. Chapter 11 of Environmental External Costs of Transport (R. Friedrich and P. Bickel, eds). Springer-Verlag, Berlin.

Ramsey S.D. and Sullivan S.D. (2003) The burden of illness and economic evaluation for COPD Eur Respir J; 21: Suppl. 41, 29s–35s

Ready R., Navrud S., Day B, Dubourg R., Machado F., Mourato S., Spanninks F., and M. X. V. Rodriquez. (2004) Benefit Transfer in Europe: How Reliable Are Transfers Across Countries? Environmental & Resource Economics 29: 67-82

Röösli M., N. Künzli, C. Braun-Fahrländer and M. Egger (2005), Years of life lost attributable to air pollution in Switzerland: dynamic exposure–response model, International Journal of Epidemiology, 34:1029–1035

Rutten-van Mölken M., Oostenbrink J., Miravitlles M., and Monz B. (2007) Modelling the 5-year cost effectiveness of tiotropium, salmeterol and ipratropium for the treatment of chronic obstructive pulmonary disease in Spain, Eur J Health Econ 8, 123–135

Slovic P. (1987), Perception of risk. Science, 236, 280-285.

Soguel N. and van Griethuysen P. (2000), Evaluation contingente, qualité de l'air et santé : une étude en milieu urbain, Report IDHEAP 185/2000, Institut des Hautes Etudes en Administration Publique, Université de Lausanne, Lausanne, Switzerland, 162 p.

Sommer, H., Seethaler, R., Chanel, O., Herry, M., Masson, S., and Vergnaud, J.-C. (1999), Health costs due to road traffic-related air pollution, an impact assessment project of Austria, France and Switzerland, Economic valuation. WHO Technical Report TEH07, Bern.

Stock S, Redaelli M, Luengen M, Wendland G, Civello D, Lauterbach KW (2005) Asthma: prevalence and cost of illness. Eur Respir J 2005, 25(1), 7-53.

UK DH. (1999). Economic appraisal of the health effects of air pollution, Ad-hoc group on the economic appraisal of the health effects of air pollution. The Stationary Office, London.

Ungar WJ, and Coyte PC, (2001) Pharmacy Medication Monitoring Program Advisory B: Prospective study of the patient-level cost of asthma care in children. Pediatr Pulmonol, 32(2):101-8.

Ungar WJ, Coyte PC, Chapman KR, MacKeigan L, Pharmacy Medication Monitoring Program Advisory Board. (1998) The patient level cost of asthma in adults in south central Ontario. Can Respir J 1998(5), 463-471.

US-EPA (2003) Children's Health Valuation Handbook, EPA 100R-03-003, October, 184 p.

Vassanadumrongdee S., and Matsuoka, S. (2005), Risk perceptions and value of a statistical life for air pollution and traffic accidents: evidence from Bangkok, Thailand. Journal of Risk and Uncertainty, 30, 261-287.

Viegi G, (2003) Epidemiology of COPD: a European perspective, Eur Respir J, 22, suppl.43, 3s-7s.

Viscusi K., Hakes, J. and Carlin, A. (1997), Measure of mortality risks. The Journal of Risk and Uncertainty, 14(3), 213 – 233.

Viscusi K., Magat W. and Forrest A. (1988), Altruistic and private valuations of risk reduction, Journal of Policy Analysis and Management, 7, 227-245.

Wang H., & Mullahy J. (2006) Willingness to pay for reducing fatal risk by improving air quality: A contingent valuation study in Chongqing, China, Science of the Total Environment, 367, 50-57.

Watkiss P., S. Pye and Holland M. (2005). CAFE CBA: Baseline Analysis 2000 to 2020 Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE), Programme AEAT/ED51014/Baseline Scenarios, issue 5.

Weitzman M. (2001), Gamma discounting. American Economic Review 91(1), 260-271

WHO (2008), Boesch H.-J., Kahlmeier S., Sommer H., van Kempen E., Staatsen B., Racioppi F., Economic valuation of transport-related health effects: review of methods and development of practical approaches with a special focus on children, 159 p.

World Bank (2010), World Development Indicators database, http://databank.worldbank.org/

Appendix 1 Summary of unit economic values used in Aphekom for economic valuation (in € 2005)

Health outcomes (metric)	**Monetary value**	**Low estimate**	**Central estimate**	**High estimate**	**City-specific values?**	**WP involved**
Chronic mortality (premature deaths)	VSL (based on CV surveys)	1,090,000	**1,655,000**	2,220,000	No	WP5
Chronic mortality (years of life lost)	VOLY (based on CV surveys)	40,000	**86,600**	133,200	No	WP5
Acute mortality (premature deaths)	VOLY (based on CV surveys)	40,000	**86,600**	133,200	No	WP5, WP6
Respiratory hospitalization (cases)	Direct and indirect hosp. costs	2,560	**3,840**	5,120	Yes, see Table 2	WP5
Circulatory hospitalization (cases)	Direct and indirect hosp. costs	2,940	**4,410**	5,880	Yes, see Table 2	WP5
Asthma onset due to traffic (cases, annual cost)	Direct and indirect medical costs and intangible costs	1,390	**2,090**	2,790	Possible[(a)]	WP4
Full asthma exacerb. cost[(b)] (cases)	Direct and indirect hosp. costs	1,510	**2,270**	3,030	Yes, see Table 5	WP4
COPD onset due to traffic (cases, annual cost)	Direct and indirect medical costs and intangible costs	2,030	**3,040**	4,050	Possible[(a)]	WP4
Full COPD exacerb. cost[(b)] (cases)	Direct and indirect hosp. costs	2,110	**3,170**	4,230	Yes, see Table 5	WP4
CHD onset due to traffic (cases, annual cost)	Direct and indirect medical costs and intangible costs	4,520	**6,780**	9,040	Possible[(a)]	WP4
Full Myocardial infarction exacerbation cost[(b)] (cases)	Direct and indirect hosp. costs	1,810	**2,720**	3,630	Yes, see Table 5	WP4
Average cost of hospitalization (per day)	Direct hosp. costs	249	**373**	497	Yes, see Table 2	WP4, WP5
Average cost of work loss (per day)	Goss loss of production	49	**73**	97	Yes, see Table 2	WP4, WP5

[(a)] Country-specific values can be obtained by adjusting the relevant chronic disease annual average cost according to country's GDP/Capita measured at PPP or according to country's average cost of hospitalization. [(b)] In cases of joint assessment of chronic diseases onsets and exacerbations, use the specific unit monetary values proposed in Table 4.

Appendix 2 National consumer price indices (base 100 in 2005) and PPP exchange rates in € 2005 for the countries used in cost computations (including the literature reviews).

Year	UK	USA	Canada	EU-15	Sweden	Australia	Switzerland
1965	7.728	16.146	15.730	13.227	11.877	10.108	29.411
1966	8.030	16.629	16.318	13.664	12.637	10.409	30.816
1967	8.225	17.091	16.901	14.060	13.179	10.741	32.055
1968	8.614	17.812	17.591	14.439	13.435	11.026	32.829
1969	9.084	18.776	18.384	14.988	13.797	11.348	33.646
1970	9.662	19.883	19.003	15.693	14.765	11.791	34.862
1971	10.571	20.729	19.542	16.618	15.857	12.506	37.154
1972	11.320	21.414	20.475	17.632	16.810	13.240	39.628
1973	12.363	22.746	22.034	19.219	17.939	14.493	43.098
1974	14.329	25.256	24.428	21.679	19.717	16.683	47.307
1975	17.802	27.563	27.069	24.237	21.645	19.198	50.475
1976	20.745	29.144	29.102	26.685	23.870	21.794	51.341
1977	24.040	31.035	31.427	29.781	26.612	24.474	52.001
1978	26.015	33.408	34.228	32.282	29.253	26.414	52.550
1979	29.518	37.172	37.358	35.220	31.362	28.815	54.467
1980	34.822	42.193	41.162	39.481	35.659	31.733	56.657
1981	38.959	46.546	46.292	44.180	39.980	34.808	60.335
1982	42.306	49.413	51.293	48.907	43.407	38.688	63.747
1983	44.255	51.001	54.277	52.966	47.258	42.600	65.638
1984	46.447	53.202	56.632	56.780	51.068	44.283	67.549
1985	49.264	55.097	58.869	60.016	54.828	47.267	69.866
1986	50.953	56.121	61.326	61.697	57.152	51.562	70.384
1987	53.067	58.221	64.003	63.362	59.541	55.938	71.403
1988	55.671	60.555	66.578	65.137	63.018	59.984	72.748
1989	60.012	63.478	69.903	68.003	67.075	64.518	75.049
1990	65.699	66.904	73.234	70.451	74.097	69.210	79.086
1991	69.545	69.738	77.346	73.973	81.016	71.441	83.736
1992	72.140	71.850	78.511	76.414	82.864	72.145	87.120
1993	73.269	73.971	79.957	78.936	86.716	73.453	89.970
1994	75.084	75.899	80.105	80.988	88.623	74.845	90.743
1995	77.645	78.029	81.842	82.932	90.864	78.316	92.375
1996	79.546	80.316	83.127	84.674	91.292	80.362	93.131
1997	82.038	82.193	84.475	85.944	91.765	80.563	93.617
1998	84.842	83.469	85.316	87.061	91.640	81.251	93.633
1999	86.161	85.295	86.796	88.019	92.056	82.442	94.405
2000	88.683	88.176	89.156	89.779	93.011	86.131	95.862
2001	90.298	90.668	91.408	92.024	95.249	89.904	96.810
2002	91.774	92.106	93.472	93.864	97.305	92.604	97.432
2003	94.448	94.197	96.050	95.647	99.178	95.170	98.054
2004	97.248	96.719	97.834	97.847	99.549	97.401	98.842
2005	**100**	**100**	**100**	**100**	**100**	**100**	**100**
2006	103.195	103.226	102.002	102.400	101.360	103.538	101.060
2007	107.605	106.171	104.183	104.243	103.602	105.953	101.799
2008	111.903	110.247	106.653	108.517	107.163	110.565	104.265
2009	111.282	109.855	106.972	107.866	106.865	112.578	103.768
2010		111.691		109.700	108.651		
PPP exch. rate in 2005	**EUR/GBP 1.391**	**EUR/USD 0.907**	**EUR/CAD 0.720**	**1**	**EUR/SEK 0.094**	**EUR/AUSD 0.612**	**EUR/CHF 0.490**

Source: World Bank database (World Development Indicators and Global Development Finance), http://databank.worldbank.org/ddp/home.do, last update 28/09/2010