Directorate-General for
Health & Consumers

Promoting actions for healthy indoor air (IAIAQ)

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Chapter 0. Introduction: From EnVIE to IAIAQ

The IAIAQ project is in many ways a small scale extension and update of the EnVIE project (2003 – 2008). EnVIE developed a new robust modelling tool to evaluate the quantitative relationships between the indoor air quality (IAQ) related diseases and symptoms, indoor relevant exposure agents causing these diseases, indoor and outdoor sources of these indoor exposures and the impacts of policies to control these sources. The assessment tool is in effect a four dimensional linear matrix. The task was simplified by selecting one common metric for all four dimensions, the WHO supported 'disability adjusted life year' (DALY).

IAIAQ project critically assessed and in some cases omitted or amended the diseases, agents and sources of the EnVIE tool, re-evaluated the matrix coefficients, and combined the model with a new 26 (31) country European model input database, which greatly improved the comprehensibility and eased the use of the modelling tool.

The EnVIE-IAIAQ modelling tool was first used to quantify the total current European IAQ related burden of disease (BoD) and to attribute it on the diseases, exposure agents and sources included in the model. (Chpt 1.2.)

The given and main focus of IAIAQ was on assessing the public health impacts, i.e. achievable reductions to the above modelled IAQ BoD, of some current European IAQ policies and to predict the potential impacts of some alternative and future IAQ policy scenarios, which in a broad sense were defined in the EAHC tender. (Chpt 3.1 and 3.2.)

IAIQ made also some attempts to assess the impacts of some EU funded IAQ data compiling projects on indoor air relevant EU legislation and respectively on the potential health impacts of such legislation, as well as on the impacts of some EU funded indoor air research projects (new data generating projects) on the results of the EU funded data compiling projects (pre-normative projects), and further on the health impacts of the IAQ relevant EU legislation. These assessments are by necessity based on highly simplifying and thus much weaker assumptions than the policy assessments, and should, therefore, be interpreted even more critically and cautiously than the risk and policy assessments. (Chpt. 3.3.)

Concerning this whole exercise, the reader should stay aware of the fact that the focus of this exercise is clearly the breadth of the assessment (to quantitatively and comparably link together a hugely complex network of health, pollution, source, building and policy issues using data of highly variable quality from 26 countries) rather than the depth of an analysis of, e.g., the emission and dispersion of and exposure to NO_2 in kitchen while cooking with a gas stove. Consequently the authors readily admit that a breadth-taking amount of corners had to be and were cut to make this assessment possible within the ca. 10 month overall project execution time. We believe, however, that the results present mostly realistic levels, are properly related to each other and give correct guidance for IAQ policy development and targeting.

Chapter 1. Description and analysis of current Health Impacts of Indoor Air Pollution within the EU- 26

People spend 60 – 90 % of their life indoors – be it at home or in other public or private indoor environments, such as schools, cafés and restaurants. Having clean air indoors is very important for the health of the population as a whole and it becomes particularly important for vulnerable groups like babies, children and the elderly or people already suffering from, e.g., respiratory or allergic diseases. The health effects of "cocktails" of different indoor pollutants, their concentrations and their public health significance are being studied worldwide. Already today, for many pollutants, scientific evidence shows a serious impact on the health of the population. Various indoor air pollutants are responsible for or exacerbate respiratory diseases, allergies, intoxication and certain types of cancer (e.g. asbestos, radon, environmental tobacco smoke (ETS), combustion products, volatile organic compounds, biological pollutants etc.).

Because of the continuous air exchange, i.e. replacement of spent indoor air with fresh outdoor air, indoor air quality depends largely on outdoor air quality, but it depends also on a number of other variables including emissions form the building and its equipment, such as construction and surfacing materials, furnishings, heating and ventilating equipment, emissions from the use of consumer products for cleaning, preparation of food etc., and other occupant actions, e.g. smoking, opening/closing of windows as well as various hobbies and DIY activities.

Improving indoor air quality is a specific action of the Action plan (Action 12, Improve indoor air quality. See European Parliament views and midterm comments in the end of this section) with two key elements: addressing environmental tobacco smoke (ETS) and developing networks and guidelines on other factors affecting indoor air quality by using research and exchange of best practice.

As a result of the adoption of the Action Plan, a considerable research effort has been funded by the Commission. The current work is deeply founded on the results and methods of the DG Sanco funded IndEx (2002-2005), PM-IndEx and IndEx UPRIC (2008-2010) and the DG Research funded EnVIE (2004-2008) projects, as well as the expertise of the key individuals and European institutions involved in them.

1. Upgrade of the EnVIE risk modelling tool

In the DG Research funded Coordination Action on Indoor Air Quality and Health Effects, EnVIE, a robust modelling tool was developed to quantify the most important health risks attributable to IAQ (allergic and asthma symptoms, lung cancer, chronic obstructive pulmonary disease, airborne respiratory infections, cardiovascular morbidity and mortality, odour and irritation (SBS)), and to assign these health risk to a short list of exposure agents (tobacco smoke, [other] combustion particles, carbon monoxide, radon, dampness, mould & bioaerosols, and (S)VOCs incl. indoor chemistry products) and to the main sources of these exposures (outdoor air, building/equipment/ventilation, consumer products and occupant behaviour). Using this model and expert elicited source control coefficients for a variety of alternative policy actions, also maximum potential health benefits of these policies were assessed. The common unit for all the different burden of disease (BoD) assessments was DALY/year (disability adjusted lifeyear), developed and supported by WHO, for the quantification and comparison of a wide variety of health effects (Murray *et al.* 1996, Prüss-Üstün *et al.* 2003 and 2006). WHO estimated national BoDs for diseases and symptoms in DALYs (http://www.who.int/healthinfo/global_burden_disease/estimates_country/en/index.html) were used as the underlying baseline values for the diseases and symptoms caused and/or aggravated by indoor exposures.

In the current project the EnVIE model has been thoroughly reviewed and updated into the IAIAQ model:

- SBS symptoms were removed from the assessment because there are no data across the European countries on their incidence or causes, and no basis for assigning DALY severity coefficients for them.
- Allergy, asthma and respiratory infections were reorganised to asthma caused and/or aggravated by bio-aerosols of ambient origin and home dampness, and respiratory infections caused by home dampness.
- Instead of performing the assessments, as in EnVIE, only for those countries which had sufficient data for all data categories and scaling the overall assessment for EU-27 by population ratios, the new IAIAQ modelling tool uses all data from 26 EU countries (no indoor exposure data were found for Malta), and replaces each missing data point by population weighed average from those countries for which such data exist. Any new and updated data which could be found enters into the assessment and its results by simply entering it into the source data table.
- All source data have been reviewed and updated by the latest published materials and according to expert opinions collected by questionnaires distributed among the DG Sanco IAQ Expert Group and the additional invited IAQ experts.

2. Analysis of the Health Impacts for diseases from, exposures to and sources of indoor air pollution within the EU-26

The assessment method can best be understood as a four dimensional matrix. The dimensions are diseases, exposure agents, sources and policies. A change in the implementation of a policy is assumed to induce (a) proportional change(s) in the release(s) of one or more of the sources, respectively (a) proportional change(s) in the level(s) of one or more exposures, and finally (a) proportional change(s) in the level(s) – attributable to IAQ – of one or more of the disease(s). All impacts are estimated as DALYs per year in each of the 26 assessed European countries (EU-27 minus Malta. No IAQ data were available from Malta) assuming that the attributable impact is linearly proportional to the exposure all way to zero exposure from the source. This assumption is realistic and testable for some sources, such as tobacco smoke and indoor combustion equipment, but unrealistic and non-testable for some others, e.g. bio-aerosols of fine PM originating from outdoor air. Yet, it serves well for the purposes of comparison of the magnitudes of the various impacts of interest. The baseline is the absence of any policies in 2004 (± 3 years).

In line with the EnVIE assessment, the IAIAQ assessment begins with the most important *diseases* which have been associated with (caused or aggravated by) indoor air exposures. These are:

- asthma (and asthma like symptoms),
- lung cancer,
- cardiovascular diseases (CVD),
- chronic obstructive lung disease (COPD),
- (upper and lower) respiratory infections/symptoms and
- acute toxication.

The exposure – health relationship models, which link the diseases/symptoms to the exposures are presented in Table 1. below.

Table 1. The exposure – health relationship models used in IAIAQ.

Disease/symptom	Exposure agent	Model
• Allergy & asthma	bioaerosols, PM, VOCs, (ETS)	*attributable fraction*
• Lung cancer	radon PM of ambient and indoor combustion origin, (ETS)	*dose/response* *attributable fraction*
• CVD	PM of ambient and indoor combustion origin, ETS	d*ose /response*
• COPD	PM of ambient and indoor combustion origin, (ETS)	*attributable fraction*
• Respir. infections	home dampness, (ETS)	*attributable fraction*
• Intoxication	CO	*incidence*

The *exposure agents* which are taken into consideration are bioaerosols from outdoor air, building dampness, VOCs and (mainly combustion generated) fine particles (PM) as causes/aggravators of asthma, radon and fine PM as causes of lung cancer, fine PM as causes/aggravators of both CVD and COPD, building dampness as causes/aggravators of respiratory infections/symptoms, and carbon monoxide (CO) as the cause of acute toxication. The main sources of indoor exposure data from across Europe are

National surveys:

- German Environmental Survey (GerES I…IV), 1985-2006
- French IAQ Observatory (OQAI), 2003-05

EU Projects:

- EC FP-3, Audit study, 1993-94
- EC FP-4, EXPOLIS, 1996-98
- EC/JRC, Macbeth,1998; People, 2002-04; AirMex, 2003-07

EU Data surveys:

- DG-SANCO: THADE, 2002-03
- DG-SANCO/JRC: IndEx, 2002-04, PM IndEx and IndEx update 2008-10
- EC FP-5, EnVIE WP-2 (Exposure), 2004 -08
- JRC: Radon mapping http://radonmapping.jrc.ec.europa.eu/index.php?id=36

Table 2. summarises the typical and high end levels of some indoor air contaminants and the contributions of the indoor sources to both the typical and the high end indoor air exposure levels in mainly West-European conditions, and compares the levels to the WHO (I)AQ Guidelines (WHO 2000 and 2006a).

Table 2. Typical and high end levels of some indoor air contaminants and the contributions of the indoor sources to both the typical and the high end indoor air exposure levels in Europe, and comparison to WHO (I)AQ Guidelines (WHO 2000 and 2006a).

Agent	**Long term (I)AQG** (µg/m³)	**Typical** (µg/m³)	**Indoor source** (%)	**High end** (µg/m³)	**Indoor source** (%)
PM2.5 (PM10/2)	10	10 – 40	.. 30	100 – 300	> 90
CO (*	10	1 – 4	0	100 – 200	> 99
NO2	40	10 – 50	.. 20	100 – 200	> 75
Formaldehyde	30 (**	20 – 80	> 90	200 – 800	> 99
Benzene	5	2 – 15	.. 40	- 50	> 75
Naphthalene	10	1 – 3	.. 30	- 1000	> 99.9
Radon (Bq/m3)(***	200	20 – 100	> 90	- 100 000	> 99.9

The *sources of exposure* which are taken into consideration – and are assumed to be manageable by buildings and IAQ related policies – are:

- ambient outdoor air quality,
- building materials,
- fixed heating and combustion equipment/appliances
- water systems, leaks and condensation,
- furnishings, decoration materials and electric appliances,
- cleaning agents and other household products, and
- underlying soil (incl. the building characteristics which influence the radon entry from the soil).

The *policy dimension* of the matrix is covered in chapters 2 and 3.

The impact of environmental (passive exposure to) tobacco smoke is excluded in following three attributions of the IAQ associated EU-27 BoD to the different diseases, exposures and sources. The reason is that tobacco smoke is, when present, so dominant that even small differences in the assessment of numbers of smokers, how much and where they smoke will destabilise all other assessments. The impact of smoking is, therefore, covered in a separate assessment and respective chapter.

Attribution of the health impacts of IAQ to the different diseases and symptoms

The total calculated burden of disease attributable to IAQ in EU-26 is ca. 2 million DALYs per year, i.e. two million years of healthy life is lost annually. This equals about 3 % of the total BoD due to all diseases from all causes in Europe. Not all of this loss is preventable, even in principle, partly because all exposures cannot be reduced to zero (e.g. radon, fine PM or bio-aerosols from outdoor air), and partly because the dose/ response and attributable risk coefficients are derived from epidemiological data around the current exposure levels and may not be valid at lower exposure levels (the D/R may be S-shaped or exhibit a threshold). Note the dominating 60 % proportion of CV-diseases, followed by the 35 % proportion of the respiratory diseases, asthma, lung cancer, upper and lower respiratory infections and COPD. For comparison, the contributions of these two categories to the total BoD (in DALY/year) in EU-27 are 19 % for CV-diseases and 9 % for the respiratory diseases.

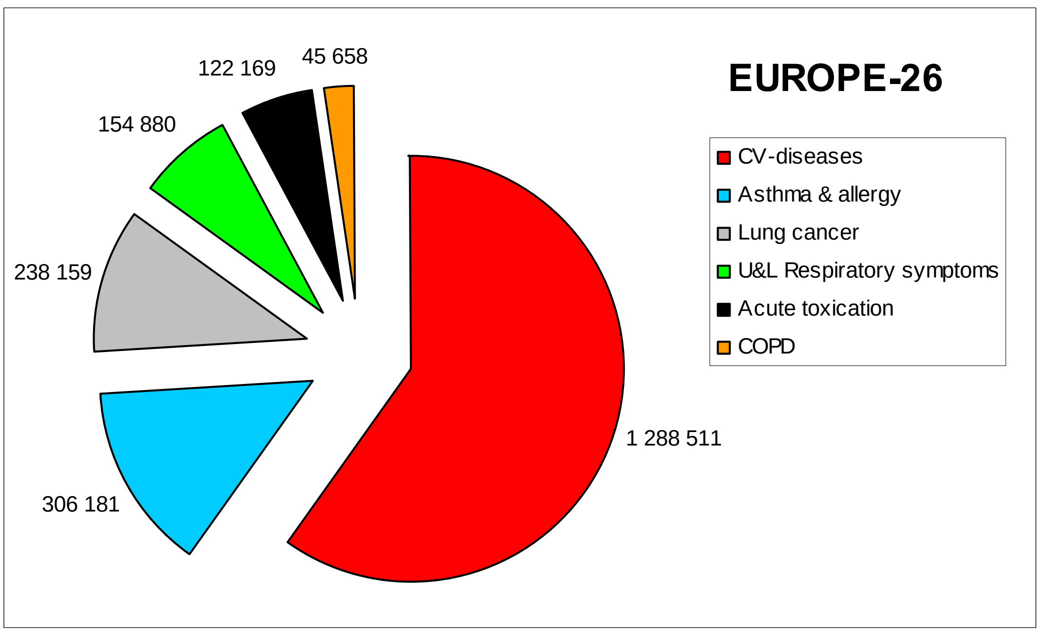

Figure 1. The IAQ associated BoD attributed to the key health outcomes. The total BoD for the EU-26 is 2 MDALY/year.

Attribution of the health impacts of IAQ to the different exposure agents

A whole 2/3 of the IAQ associated BoD is caused by exposure to fine PM (best represented by $PM_{2.5}$). Indoor air exposure to fine PM originates mostly from outdoor air and indoor combustion of solid fuels for cooking and heating, if present. Also the outdoor air fine PM originates mostly from combustion sources, local and distant, in particular where the levels exceed rural background. Fine PM exposure is mostly responsible for the CV-diseases but also for COPD and lung cancer. The other significant exposures are

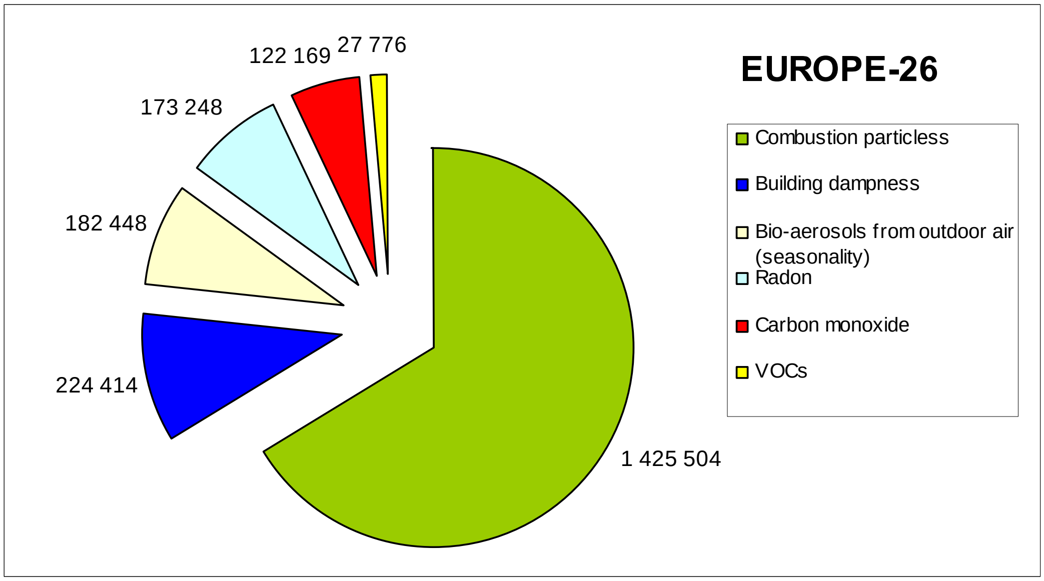

Figure 2. The IAQ associated BoD attributed to the key exposure agents.

building dampness (11 %) and bioaerosols from outdoor air (8 %). The impacts of both are assessed by their association to both induction and aggravation of asthma and dampness also by its association with respiratory diseases and symptoms. 9 % of all lung cancer cases in Europe are attributable to Radon (8 % of IAQ DALYs). Indoor exposure to carbon monoxide from indoor combustion sources (6 % or more) ranks among the highest causes of acute lethal toxication around Europe. In spite of the fact that in the case of CO poisoning the cause of death or non-lethal toxication is rather easy to diagnose, CO-toxication statistics are largely missing (18/26), highly diverse (8/26) and poorly comparable across Europe. The given estimate represents only lethal toxications and is certainly an underestimate of the total CO associated DALYs in EU-26.

The relatively small estimated role of the VOCs is counterintuitive, needs some explanations and should be reflected against three issues:

- Firstly, we have epidemiological data about specific disease dose/response which can be credibly extrapolated to indoor air levels for only very few VOCs, benzene, naphthalene and formaldehyde (Kotzias et al. 2006, INDEX report). For the other VOCs we have experimental toxicological data on animals and volunteering humans mostly at very much higher than common indoor air levels. Some VOC mixtures have in some laboratory experiments been shown to be much more potent than the sum of individual VOCs. High indoor air TVOC levels have also been associated with sick building syndrome and reduced learning in schools or productivity at workplaces, and, furthermore, interventions to reduce such levels by increased fresh air exchange, case by case, have been shown to reduce the symptoms and improve performance. Such interventions, however, are not specific for the VOCs, but dilute the levels of all contaminants generated indoors. No theory for causality or D/R model exists to link the common indoor air levels of dozens of VOCs to population level burden of disease.

- Secondly, population representative indoor air VOC exposure data exist only for two countries, Germany (GerES I … IV) and France (OQAI), and a number of cities studied in the EXPOLIS, MACBETH, AIRMEX and PEOPLE projects.
- Thirdly, the health problems of VOCs appear mostly in new, newly renovated of refurbished buildings, which – at any time – represent only a few percent of the total building stock occupied by the population. Therefore, even if significant health impacts were found in such buildings, the impact on the national BoD remains relatively small in comparison to e.g. indoor exposure to fine PM of outdoor origin which affects most of the urban populations, or to ETS which still affect majority of the population in many European countries.

Consequently, the public health role of the VOCs is certainly underestimated and should not be ignored. Besides, this role is highly relevant for the quality, safety and liability of European building products and materials and daily household products, and, thus, for a smoothly functioning European common marketplace.

The common results of the current assessment compare surprisingly well with another, independent and differently performed environmental BoD assessment of the 6 country EBoDE study (http://en.opasnet.org/w/EBoDE, Hänninen *et al*. 2011. Finland, Flanders/Belgium, France, Germany, Italy and the Netherlands). For fine PM EBoDE gave 4000, IAIAQ 2900 DALY/year*million. For radon EBoDE gave 420 and IAIAQ 340 DALY/year*million. Considering that EBoDE looked at the total and IAIAQ only indoor exposures, and that the IAIAQ country base was much larger, these results agree as well as they could ever be expected to.

Attribution of the health impacts of IAQ to the sources of exposure

Ambient outdoor air is the source of the indoor air contaminants (mostly fine PM and bioaerosols, but also some VOCs), which are responsible some 2/3 of the total BoD from indoor air exposures. Heating and combustion equipment, most importantly cooking and heating with solid fuels (14 %), water systems, water leaks and condensation (11 %), and underlying soil (as source of radon, 8 %), are the other important sources for the IAQ associated BoD.

In comparison the roles of furnishings, decoration materials, household products and building materials appear small, but the points in the discussion about the VOCs in the previous chapter should be taken into consideration here, too.

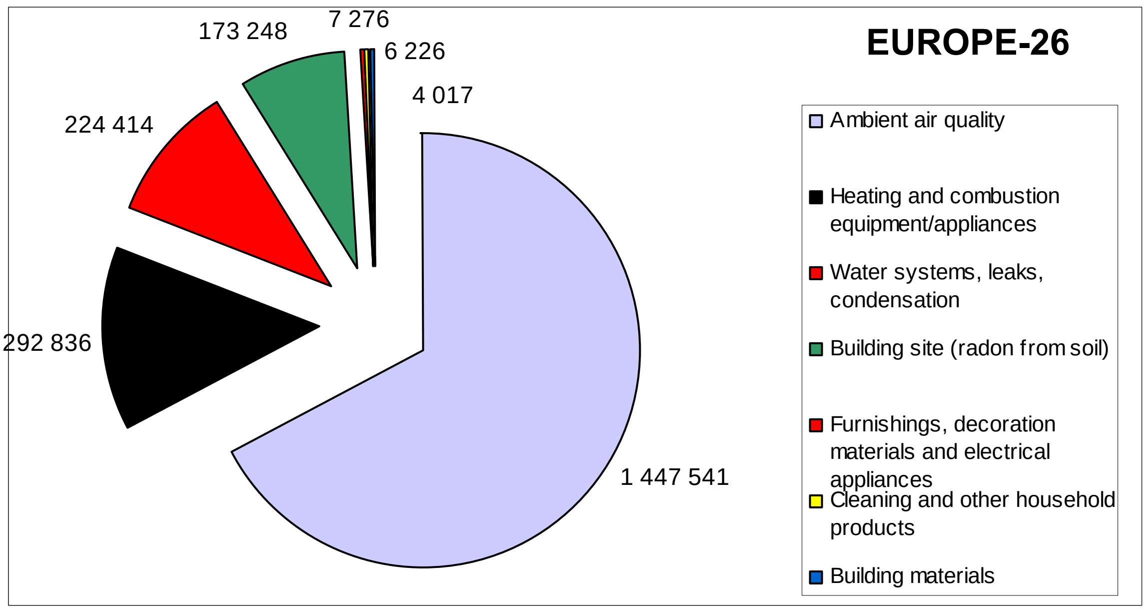

Figure 3. The IAQ associated BoD attributed to the key sources of exposure.

As a general discussion about the three previous chapters, the roles of indoor sources to the typical and high end exposures in Table 2 appear to be high, and, yet, we have demonstrated that the external environment of the building, both ambient outdoor air and the underlying soil dominate the total BoD impact. Do we have a contradiction here? Not really:

- First, in all recent assessments the total public health impact of ambient air fine PM far exceeds all other environmental health risks. What is often not acknowledged is that although the ambient $PM_{2.5}$ levels are monitored in outdoor air, over 90 % of our exposure to this monitored pollution occurs indoors, and, therefore logically also the respective health impact is mostly due to indoor air. The main reasons why this exposure should not be excluded from the health assessment of IAQ is that this exposure can be independently controlled both outdoors (by emissions reduction and urban planning - zoning) and indoors (by filtration in the building envelope and the ventilation systems), and the latter exposure control alternative has strong implications on and synergies with the urban greenhouse gas reduction and energy conservation policies.

- Secondly, the fact that the BoD impact of the fine PM of ambient origin is huge (it reduces the average life expectancy in Europe by several months) does not make the impacts of other exposure agents small, e.g., the 46 000 DALY/year lost in Europe via COPD from indoor air exposure or the 30 000 DALY/year from VOC exposure from building materials, furnishings, decoration materials. In magnitude these numbers equal e.g. the total European BoD from upper respiratory infections or hepatitis C.
- Thirdly, up to this point the assessment has ignored the BoD from indoor exposure to tobacco smoke, which in many European countries is still the most important preventable source of indoor air pollution.

Figure 4 presents the IAQ associated BoD in the EU-26 countries separating the contribution from outdoor air and from indoor sources (the latter includes radon). The list is rank ordered by the contribution from indoor sources.

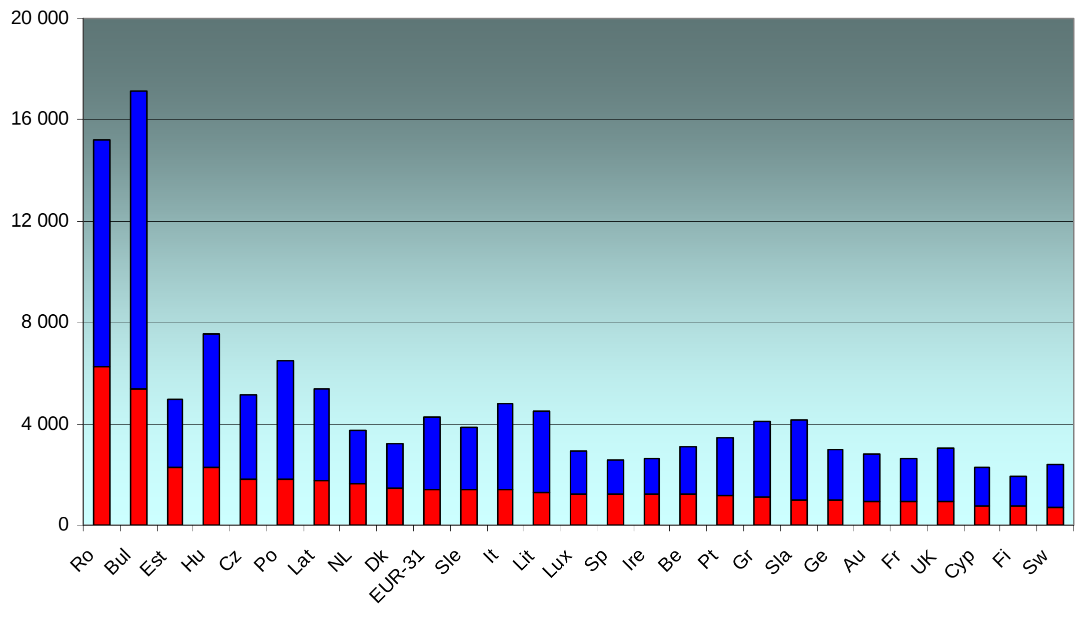

Figure 4. IAQ associated DALYs in 26 Europan countries (2005+/-5 years). Blue: national BoD in DALY(year*million from indoor exposure to pollution originating from outdoor air. Red: contribution from all indoor sources

The overall IAQ-BoD levels in and differences between specific countries in Figure 4 need to be interpreted very cautiously. The underlying public health data are robust and comparable, but the indoor exposure data are more or less incomplete, often non-representative and both quantitatively and qualitatively poorly comparable. We are, however, confident about the general observations that:

- the inter-European differences in IAQ and, respectively, its public health impacts are huge, and
- the greatest problems in IAQ occur in some Easter European countries.

Figure 5 presents the same information concerning the BoD caused by exposures from indoor sources on the map, colour coded for the DALY quartiles. It shows also the assessment results for some non-EU countries the general dominance of the East European and Balkan countries at the high end and Western and Northern countries in the low end of the BoD estimates.

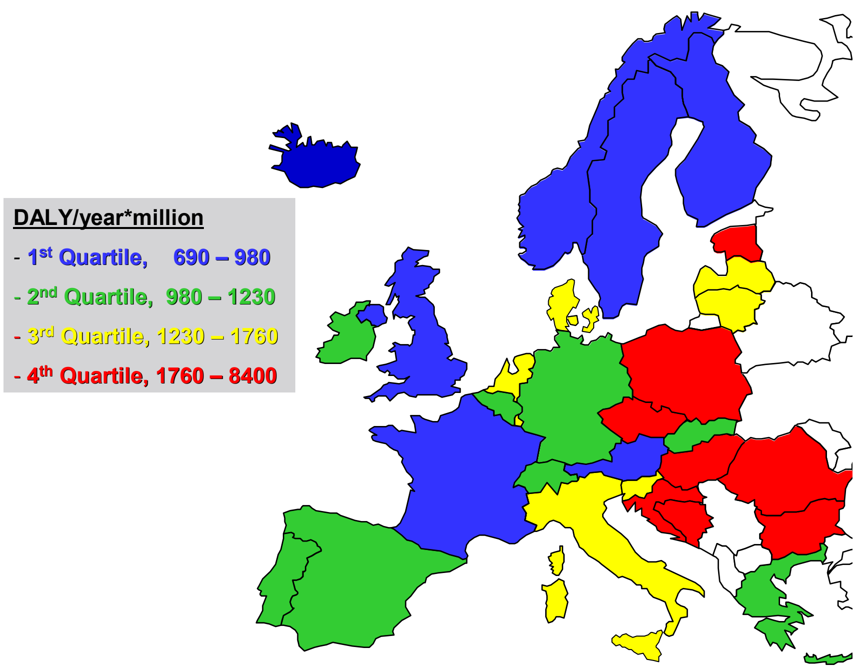

Figure 5. European countries divided into 4 quartiles according to BoD caused by exposures from indoor sources.

Health impact from indoor exposure to tobacco smoke

Most of the health effects of smoking – arguably the biggest preventable cause of disease and death in Europe – occur to the smokers themselves. Smoking regulations, smoking prevalence and smoking behaviour, all vary across Europe. The following assessment, however, only considers the health impacts of environmental tobacco smoke, i.e. not the impacts on smokers, and ignores the differences in the behaviour of smokers across Europe in their consideration of the non-smoking population.

Smoking restrictions have developed and expanded slowly in Europe over the decades after WW-2, with the first steps towards stricter restrictions in public transport, theatres, schools and workplaces emerging in the 70's. WHO Framework Convention on Tobacco Control, WHO FCTC, 2005 and EC Green Paper: Towards a Europe free from tobacco smoke: policy options at EU level, COM (2007)27 have been the two key documents guiding the most recent European tobacco policies. The first [strictly enforced] general smoking ban in all public indoor environments took effect in Ireland in 2004 and many countries have followed the suit since then. The public health benefits of a public smoking ban are manifested in many different diseases, both in the short term and over many years. The current estimate, however is based on only short term reduction of acute cardiovascular incidences which were demonstrated in Rome after the public smoking ban took effect in Italy in 2005 (Cesaroni *et al.* 2008). It is assumed that the impact on the similar implementation of a public smoking ban in any other country is directly proportional to the underlying prevalence of smoking and to the total BoD of CV-disease, both relative to Italy in 2005. Thus, the current assessment certainly underestimates the total BoD from indoor exposure to tobacco smoke and consequently the public health benefits from public smoking restrictions, which include also asthma reduction on children, lung cancer reduction and long term cardiovascular benefits.

Figure 6 presents the estimated BoD from environmental tobacco smoke and the benefits in DALY/year*million of the different levels of public and workplace smoking restrictions in place in 26 European countries in 2010, assuming that the starting point in each country would be the same as in Rome in 2005. For simplicity a full public smoking ban as in Ireland in 2004 is assumed to reduce non-smokers [non-residential] exposure to tobacco smoke by 90 %, a ban with provisions to designated smoking areas in restaurants, public transport and/or workplaces by 75 %, and enforced smoking restrictions in workplaces, schools, non-smoking areas etc. by 50 %. While non-voluntary exposure to tobacco smoke has truly almost disappeared in many countries and is still, indeed, unavoidable in others, the presented scaling between these extremes is admittedly rough.

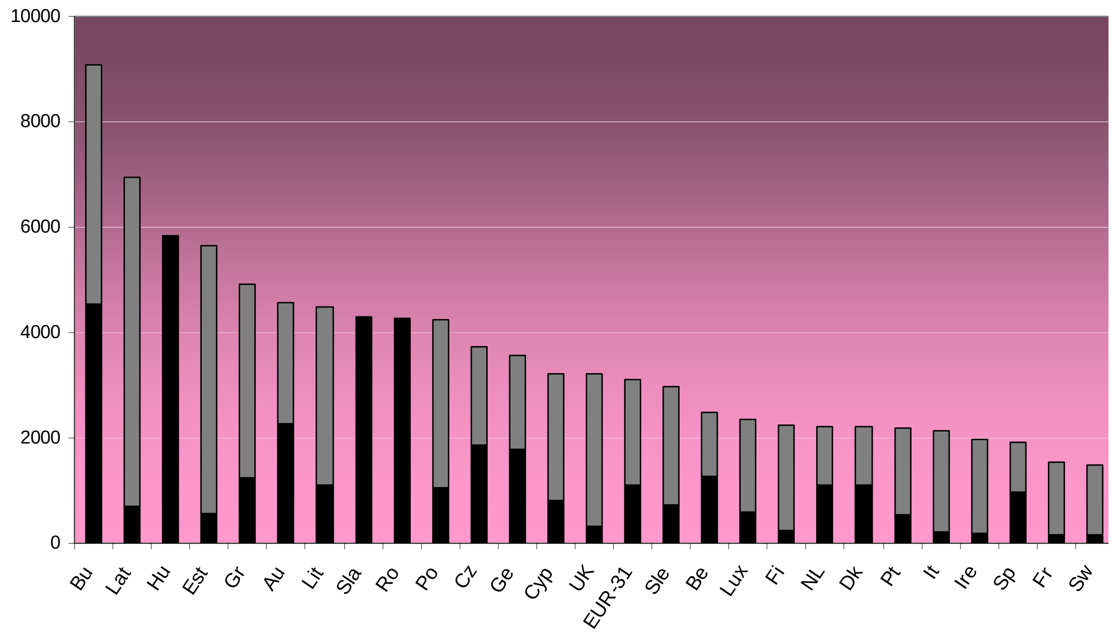

Figure 6. BoD in DALY/year*million from environmental tobacco smoke exposure beginning from poorly or non controlled conditions to the conditions mandated in the 2010 legislation.

According to this assessment the public smoking policies in the EU-26 countries have by 2010 reduced the total BoD from acute CV-incidences caused by indoor exposure to tobacco smoke in public places from 1.6 to 0.6 million DALY/year, or from 312 to 122 DALY/year*million. The current estimate is rather an assessment of the public health impact of a given policy – to reduce tobacco smoke exposure in public indoor spaces – than a comprehensive assessment of the total public health impact of passive tobacco exposure. This is highlighted by the estimate of WHO experts for the EBoDE study that in Europe the total BoD, including all health effects from tobacco smoke exposure including private residences has simultaneously been reduced to ca. 515 DALY/year*million. (Hänninen *et al*. 2011)

All these estimates, naturally, include large quantitative data uncertainties, but there is no question neither about the very large public health benefits already gained nor those still to be reached by further reduction of tobacco smoke exposures, in particular the exposures of children in their homes.

Chapter 2. Assessment of the EU Indoor Air Quality actions from 2004 to 2010

3. EU Policies with IAQ relevance

The health benefits from 2004 to 2010 [DALY/year in EU-26] of these policies are assessed by (i) considering the sources and exposures [and the respective underlying health effects] which they are designed and implemented to affect, (ii) the maximum indoor exposure reduction which they are estimated to achieve in the long term, (iii) the annual penetration of the impact (e.g. replacement rate of buildings) and (iv) the number of years which the policies have been in effect since 2004. After the description of each policy the applied values for these variables as well as the estimated BoD reduction are given. The uncertainties for these estimates are large and variable, but we expect that the magnitudes are comparable and realistic.

Regulation (EC) no 1907/2006 concerning Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

The purpose of REACH regulation is to protect human health and environment. It states that it is manufacturers', importers' and downstream users' responsibility to ensure that substances in use do not adversely affect human health or environment. It follows the precautionary principle.

The substances that are the biggest concern, the substances of very high concern (SVHC), include:

- carcinogenic, mutagenic or toxic to reproduction;
- persistent, bio-accumulative and toxic (PBT) or very persistent and very bio-accumulative (vPvB);
- other substances identified by scientific evidence as causing probable serious effects to human health or environment.

A chemical safety assessment (CSA) is required about all substances that are manufactured or imported ≥10 tonnes/year. This is done to determine risks related to manufacturing and use of a substance. If a substance is classified as dangerous, PBT or vPvB, then the CSA shall also include an exposure assessment and a risk characterization. If necessary, substances can be banned from market.

Exposure sources affected	1. Building materials, 2. furnishings, decorations and electrical appliances, 3. cleaning and other household products
Max. long term exposure reduction (% of current)	1. 30, 2. 30, 3. 50
Annual impact penetration (% of remaining)	25
Number of years implemented 2004… 10	2
Estimated BoD reduction 2004-10 in DALY/year in EU-26	3 100

Recast of Council Directive 92/75/EEC on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances.

This directive is referred to as the "Energy Labelling Directive" or "ELD". The aim of this recast is to extend its scope, currently restricted to household appliances, to allow for the labelling of all energy-related products including the household, commercial and industrial sectors and some non-energy using products such as windows which have a significant potential to save energy once in use or installed. In doing so, it follows the overall objective to ensure the free movement of products and improve their energy efficiency performance, thereby contributing to the Community objectives of strengthening the internal market, innovation, EU's competitiveness, protecting the environment and combating climate change. This would complement existing environmental policy, such as, with regard to energy use, the energy and climate package adopted by the Commission in January 2008. By the summer of 2010 this recast has not yet been implemented.

Exposure sources affected	Fixed heating and combustion equipment /appliances, electric appliances
Max. long term exposure reduction (% of current)	30
Annual impact penetration (% of remaining)	10
Number of years implemented 2004… 10	0
Estimated BoD reduction 2004-10 in DALY/year in EU-26	

Construction Products Directive (CPD), 89/106/EEC

This directive covers very broadly the finished building, as well as its components and equipment and the construction materials. It also concerns their impacts on IAQ, thermal comfort and indoor noise and health, respectively. The main concern of the directive has been dwellings, but it is not limited to those, but applies to all constructions that are fixed to the ground. Construction products are defined as materials that are permanently part of the construction work and removal and replacement involve construction activities.

Exposure sources affected	1. outdoor air, 2. building materials, 3. water systems, leaks and condensation
Max. long term exposure reduction (% of current)	1: 10, 2: 30, 3: 20
Annual impact penetration (% of remaining)	1.8
Number of years implemented 2004… 10	7
Estimated BoD reduction 2004-10 in DALY/year in EU-26	27 000

General Product Safety Directive (GPSD), 2001/95/EC

This directive covers all consumer products. A special attention is given to products that are used by children and elderly. The directive requires that products, that are available in market, are safe. This includes also composition and package. Product's interaction with other products, that it is likely to be used with, should be safe.

The GPS directive covers only risks to human health and safety. Risks to environment, plants and animals are not included.

A product is considered as safe when it and its use do not cause a threat to health in normal use. The safety requirement covers whole economically reasonable working life. A product is not considered as unsafe just because there are also safer products available, or that it can be made safer.

The producer should give the consumer all information needed in evaluating risks involved to the product and its use. Warning signs do not free the producer from responsibility of product's safety. The producer should follow up the safety of the product also after it is released to consumer market.

Exposure sources affected	1. fixed heating and combustion equipment/appliances 2. furnishings, decorations and electrical appliances, 3. cleaning and other household products
Max. long term exposure reduction (% of current)	1: 10, 2: 75, 3: 75
Annual impact penetration (% of remaining)	20
Number of years implemented 2004… 10	7
Estimated BoD reduction 2004-10 in DALY/year in EU-26	16 000

Energy Performance of Buildings Directive (EPBD), 2002/91/EC

From its 1st article "The objective of this Directive is to promote the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness.

The EPBD lays down requirements as regards:

- the general framework for a methodology of calculation of the integrated energy performance of buildings;
- the application of minimum requirements on the energy performance of new buildings;
- the application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation;
- energy certification of buildings; and

- regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old".

It is clearly started that the fulfilment of indoor climate requirements are objectives of the Directive. However nothing is specifically indicated on how to achieve that. Here, there is an opportunity for tackle the problem of IAQ. Portugal is the only Member State to include the IAQ assessment in the procedure of assessing the energy performance according to the Directive.

The EU commission is revising this directive, and published a recast directive in November 2008. It still includes the requirement for good indoor climate and still does not specify any actions to guarantee this goal. The recast directive emphasizes the energy certificates, but does not require any information on indoor air climate. It also proposes the directive to be applied to all building regardless of the size including private houses.

Based on this directive specific regulations are prepared for 30 preselected product categories, many of them affecting IAQ as potential sources.

Exposure sources affected	1. outdoor air, 2. fixed heating and combustion equipment/appliances 3. water systems, leaks and condensation
Max. long term exposure reduction (% of current)	1: 30, 2: 70, 3: 30
Annual impact penetration (% of remaining)	1.8
Number of years implemented 2004… 10	7
Estimated BoD reduction 2004-10 in DALY/year in EU-26	90 000

EC Green paper on tobacco smoke, COM (2007)27, based on WHO FCTC, 2005

FCTC is the first treaty negotiated under the auspices of WHO. It reaffirms the right of all people to the highest standard of health, represents a paradigm shift in developing a regulatory strategy to address addictive substances and was developed in response to the globalization of the tobacco epidemic. The core demand reduction provisions in the WHO FCTC are contained in articles 6-14, and include non-price measures to reduce the demand for tobacco, such as:

- protection from exposure to tobacco smoke;
- education, communication, training and public awareness;

which are directly relevant for IAQ policies. The WHO FCTC has signed and ratified by the EC.

EC Green Paper: Towards a Europe free from tobacco smoke: policy options at EU level is described here in more detail because it presents also at generic level an overview of the different optional policy levels that are available for European Union for regulating any environmental or public health issue.

COM(2007)27 is a logical follow up of the EC signing the WHO FCTC. It is not a policy or even a draft for a policy, but a pre-normative step towards a EU wide policy on tobacco. It presents a range of policy alternatives in the order of increasing legally binding capability, recognises that they are not mutually exclusive, and does not make a recommendation as to which one of the alternative routes to take.

No change from the status quo: Continuing the current work on ETS via different community programmes and relying on the member states implementation of FCTC. The work on IAQ, including ETS, will continue as a follow up to Action 12 of the EHAP. It is foreseen that smoking restrictions and ETS free spaces will expand also under this alternative.

Voluntary measures: This option would encourage stakeholders to adopt voluntary guidelines. Sectoral approaches (e.g. restaurants) and corporate social responsibility could be used as basis of development. European social partners, e.g. employers and trade unions would be encouraged to negotiate autonomous agreements on workplace smoking, based on Article 138 of the treaty. In practice, however, experience on such voluntary measures to restrict ETS exposure has not been encouraging.

Open method of coordination: Member states would be encouraged to converge their anti ETS policies via sharing experiences and best practices of smoke free policies at national and local level, agreeing on common EU targets and guidelines based on such experiences within and outside the EU, and reporting and periodic reviewing of each Member State's success. Commitment would remain voluntary and there would be no sanctions for non-compliance.

Commission or Council recommendation: This option would encourage Member States to adopt national smoke free legislation steered by a comprehensive Commission or Council Recommendation on smoke-free environments based on Article 152 EC. Such a recommendation would be a clear statement that action should be taken to eliminate passive smoking in Europe. It would bring the issue onto the political agenda at a high priority level and provide support for national actions. Yet, a Member State might choose not to act at all.

Binding legislation: On one hand this option would impose comparable, transparent and enforceable basic level of protection from the risks of ETS throughout the Member States, and ensure formal consultations and thorough negotiations involving all parties. On the other hand the legislative route is likely to be lengthy and the end result difficult to predict, as demonstrated by the experiences from some EU-countries. A simpler shortcut to legally binding EU level ETS policies could be based on revision of the existing Framework Directive on workplace safety and health (89/391/EEC) by extending the scope of the Carcinogens and Mutagens Directive 2004/37 to cover ETS, strengthening the requirements for the protection of workers from tobacco smoke in Directive 89/654/EEC, and/or amending the Dangerous Substances Directive (67/548/EEC) 91 to classify ETS as a carcinogen. The impact of such legally binding policies, however, would not cover all non-voluntary ETS exposures. The impact would be strongest on workplaces – including restaurants and bars - in countries where workplace smoking is not banned already.

As a summary, on one hand global, EU level and national foundations have been laid for the restriction and eventual banning of tobacco smoking in workplaces and indoor public spaces where non-voluntary exposure could occur, on the other hand, however, realistic options to protect the most vulnerable population, children at home have not even been suggested.

Exposure sources affected	1. outdoor air, 2. tobacco smoke
Max. long term exposure reduction (% of current)	1: 5, 2: 75
Annual impact penetration (% of remaining)	10
Number of years implemented 2004… 10	3
Estimated BoD reduction 2004-10 in DALY/year in EU-26	420 000

Evidence of success by 2010

Since 2004, starting from Ireland and soon followed by Italy, both outright public smoking bans and less comprehensive restrictions have been rapidly expanded and implemented across the European countries. A new wave of significantly tighter restrictions have taken effect since 2008, and since some earlier restrictions did not materialise in practice, their full impact on ETS reduction cannot, yet, be fully evaluated. Assuming that the current policies are fully implemented, their public health impact in Europe is huge, 1 million DALY/year saved via reduced acute CV-incidences alone. According to the WHO estimation for the EBoDE project, the health benefits achievable via total elimination of all non-voluntary ETS exposure – including that of children in private premises – would be three times larger. (Hänninen *et al*. 2011)

The development and expansion of the public and workplace smoking restrictions in many of the EU-countries, however, did not begin in 2004, but have evolved progressively over decades. Therefore, only a part, possibly between a quarter and a half, of the total ETS exposure and risk reduction can be attributed to the development from 2004 to 2010 and COM(2007)27. Yet, even this part is highly significant.

4. Contribution to the development of the WHO Guidelines for IAQ

For over two decades the Commission has supported the work of WHO for the development of Air Quality Guidelines for Europe, and the Indoor Air Quality Guidelines (under work in 2010). The Air Quality Guidelines for Europe referred to air pollution exposure and, thus, were not restricted to outdoor ambient air only. They influenced, however, the European policies mainly via the EU Ambient Air Quality Standards and the CAFÉ process, and were felt already before 2004.

The development of the WHO Guidelines for IAQ, on the other hand, is still work in progress, and their impacts on European IAQ policies, exposures and health lie still in the future.

5. DG Sanco IAQ Expert Group

In order to co-ordinate possible actions, the Commission established in October 2006 an expert working group to follow up the opinions of the Scientific Committee. The expert group (composed by external independent experts and representative of the EU Member States, NGOs and Industry) has been mandated to provide a forum for the exchange of best practice and information, to advise the Commission on EU programmes and policies related to indoor air quality and to give opinions on actions aimed at reducing relevant pollutant concentrations. The working group will have to follow main recommendations of relevant projects (such as the DG JRC INDEX report) and the opinion of the SCHER committee. The Expert group has issued a working plan. This is based on three main themes:

Information and education to the public on practice to improve indoor air quality;

Guidance for EU MS and exchange on best practices to lower/reduce pollutants concentration of priority compounds;

Linking different EU strategies relevant to the field of indoor air quality.

The IAQ Expert Group has met seven times since 27/10/2006. The Group has no decision authority, and consequently, has not created, let alone implemented any IAQ policies. Its role can be seen indirectly in the many IAQ projects which have been initiated and funded by DG Sanco in the recent years, which include the *IndoorExpo, IAIAQ* and most recently *Air Quality in School and Childcare Settings* projects. Of these the first two will be completed by the end of 2010 and the last in 2012, and, therefore, will make their impacts felt after 2010.

6. IAQ data compiling pre-normative EU projects

We consider the reports of these six projects as the scientific backbone for all EU-level IAQ related regulations. In the case of each regulation, of course, only the reports already available at the time of its finalisation could have been used, which, of course, enhances the importance of the earliest reports, THADE and IndEx. Similarly the earlier research findings and results have had a larger impact on the IAQ data compiling and assessing projects, and further on the regulatory processes. This can be easily seen in the numbers of references to each project.

None of these six projects has any direct regulatory authority, but we assume that any impacts of any new data generating research projects (Chpt. 2.5.) into actual European IAQ regulation (Chpt. 2.1.) and practice has been and will be transmitted via the reports of these projects. Consequently we have ranked the relative impacts of these projects by how many times they are quoted or named in these five reports. The method is rough, but probably robust and sufficient for the purpose.

THADE

The THADE project ("Towards Health Air in Dwellings in Europe"), co-ordinated by the European federation of Asthma and Allergy (2001-2003), investigated the association among indoor air pollutants and respiratory diseases. Several recommendations have been formulated for international, national and local level to improve air quality in dwellings. The results of this project confirmed that air pollution in dwellings is a relevant health problem. It is a complex problem that must be addressed at European and international levels, and it involves the medical profession, scientific societies, patients' organizations, lawmakers, architects and the building industry.

The report is available at the EFANET Website:
http://www.efanet.org/activities/documents/THADEReport.pdf

IndEx

The **INDEX** project (3) ("Critical appraisal of setting and implementation of indoor exposure limits in EU"), coordinated by the General Directorate Join Research Centre (2002-2004), identified a list of "priority compounds" on the basis of health impact criteria. Five compounds (formaldehyde, carbon monoxide, nitrogen dioxide, benzene and naphthalene) have been identified as high priority and suggestions and recommendations on potential exposure limits and actions have been formulated.

The report is available at the JRC/IHCP Website:
http://ec.europa.eu/health/ph_projects/2002/pollution/fp_pollution_2002_frep_02.pdf

SCHER Opinion on IAQ (2007)

In 2005 DG SANCO mandated the Scientific **Committee on Health and environmental Risks (SCHER)** to deliver an opinion on a possible risk assessment strategy to support policy on the indoor air issue, to identify potential areas of concern in relation to the different pollutants and to consider risks associated with the use of air fresheners. The SCHER issued a separate opinion on air fresheners on 27 January 2006. With regard "Risk Assessment on Indoor Air Quality", the Committee issued an opinion in 2007.

The report is available at:

http://ec.europa.eu/health/ph_risk/committees/04_scher/docs/scher_o_055.pdf

EnVIE

The EnVIE project "Indoor Air Quality and Health Effects", co-ordinated by IDMEC (Portugal) (2004- 2008), has been supported under the 'Scientific Support to Policies' programme. EnVIE interfaced science and policy making in the field of indoor air quality and collected and interpreted scientific knowledge from ongoing research, in particular from EU funded projects and the Joint Research Centre's activities. *The EnVIE approach* differed radically from most of the previous studies on IAQ and human health: Instead of searching for health effects for certain observed indoor exposures, EnVIE searched for exposures responsible for certain observed indoor associated health conditions. EnVIE started by first estimating the magnitudes of some key health impacts (BoD in DALY units) which have been associated with indoor air quality, then attributed these BoDs to the most important indoor exposures, further to sources of exposure and finally assessed the potential BoD reductions achievable by different policies, see Figure 7.

It should not be surprising that the different approach led to different prioritisation of the indoor air problems, as well. The EnVIE approach and modelling framework form the basis also for the IAIAQ assessments.

The Final Activity report of EnVIE is available at:
http://paginas.fe.up.pt/~envie/finalreports.html

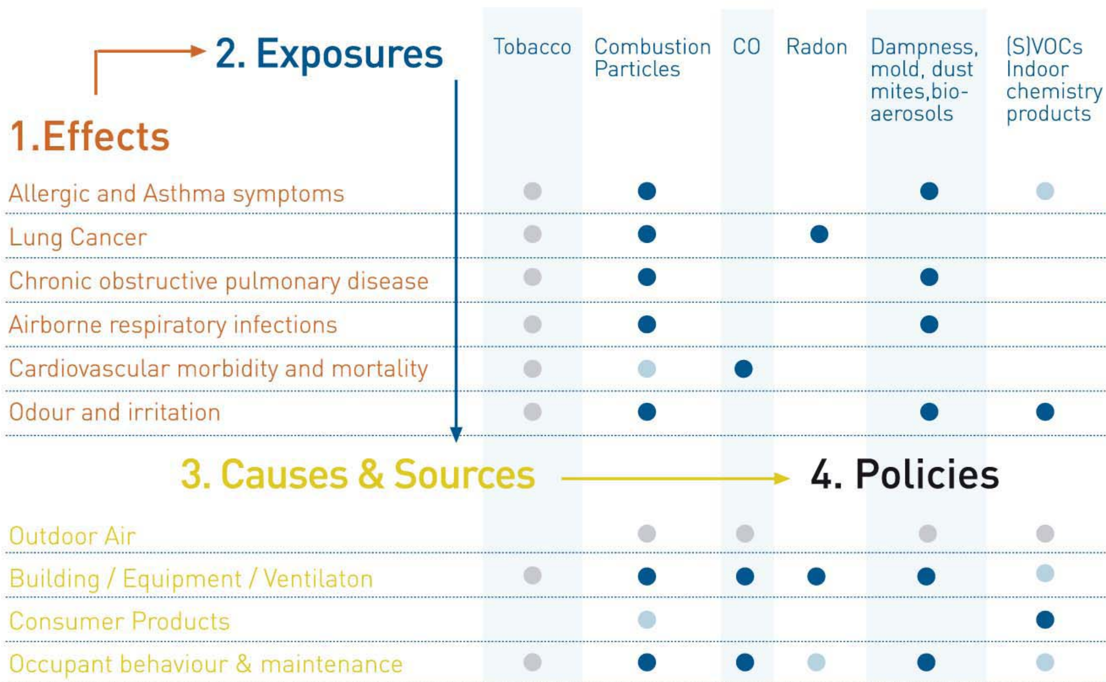

Figure 7. The EnVIE approach, see text.

IAQ ranking/VITO

The "*Ranking indoor air health problems using health impact assessment*" -study was coordinated by the VITO Institute (Belgium). This study has performed a review of exposure data for indoor air pollutants (2004-8).

The report is available at: http://www.vito.be/VITO/Search.aspx

7. New IAQ data generating EU projects

The following EU funded projects have generated new IAQ data. They are shortly described below and rank ordered according to how many times they have been named and/or quoted in the reports of the six IAQ data compiling and assessing projects (Chpt. 2.4.). The assumption is that the data on indoor air contaminants, their levels, sources and health effects are first generated in original research, then critically reviewed and formulated into recommendations in the IAQ data compiling and assessing projects, and finally formulated into policies by Member State and EU authorities according to these recommendations. Admittedly this approach is somewhat naïve and simplifies the matters, but as it reflects the due course of action and can be followed through, we rely on it for rank ordering, if not quantifying the impacts of the projects.

EXPOLIS

121 quotations in the six IAQ data compiling and assessing project reports (chpt. 2.4.): THADE (2004), INDEX (2005), EnVIE (2008) & PM-INDEX (2010) and VITO Ranking indoor air health problems…(2007) Reports, and SCHER Opinion (2007)

The EXPOLIS project (Jantunen *et al.* 1998.) was an air pollution exposure study performed among the populations of six European cities in 1996 - 8, and monitoring PM2.5, VOCs, CO, time-activity and other questionnaire data in personal, residential indoor, residential outdoor and workplace air. The results and numerous analyses thereof have been published in dozens of original articles and conference presentations already before 2004, provided unique new data and have therefore been quoted extensively in data the compiling and assessing reports.

More information can be found at: http://www.ktl.fi/expolis/

2. MACBETH*, *PEOPLE and AIRMEX

9, 3 and 10 quotations respectively in the six reports

The **Macbeth** (Population exposures, indoor and outdoor concentrations of BTEX in 6 EU cities, 1997-1998, Cocheo *et al.*), **PEOPLE** (Population exposures, outdoor and indoor concentrations of benzene in 6 EU cities, 2002-2004, Ballesta *et al.* 2005) **AIRMEX** (Exposure to air contaminants in schools, day-care centres and public buildings in 11 EU cities, 2004-8, Kotzias et al, 2005, 2009) project (6) ("European Indoor Air Monitoring and Exposure Assessment Project"), funded by the General Directorate Join Research Centre (2003-) aims at: (i) identifying and quantifying the main air pollutants in public buildings, including schools and kindergartens; (ii) identifying the main sources of these pollutants; and (iii) estimating people's exposure and evaluating possible health effects due to chronic exposure to these pollutants, especially for children.

3. EC AUDIT Study

14 quotations in the six reports

The aim of the study was to develop assessment procedures and guidance on ventilation and source control, to help optimize energy use in buildings while assuring good indoor air quality. In nine countries, six or more office buildings were selected and studied to identify pollution sources and quantify pollution load from occupants, activities and ventilation systems. The investigation included physical and chemical measurements, questionnaires, assessment of the perceived air quality and measurement of outdoor air supply.

4. EU RadonMapping

6 quotations in the six reports

This project compiles all the spatial indoor air radon data from across Europe, and, combined with the Darby *et al.* (2005) meta-analysis of radon epidemiology and radon risk assessment for Europe, provides the sole basis for the radon health risk assessment in the current project.

5. HESE & HESEInt

1 quotation in the six reports

The **HESE** project (5) ("Health Effects of Schools Environment"), coordinated by the University of Siena (2002-2005), highlighted the high presence of particulate, moulds, and allergens related to poor ventilation, which appears to be extremely common in European classrooms. Poor ventilation is likely to increase airway inflammation and the risk of asthma in allergic children and could even increase the risk of sensitization in healthy schoolchildren. **HESEInt,** *Interventions on Health Effects of Health Environment,* aims is to contribute to improve healthy growth and development of European children by improving the quality of the school environment and increasing the awareness and preparedness of European schools to cope with indoor air quality and with the special care required by children with asthma.

6. HOPE

3 quotations in the six reports

BUMA, HealthyAIR, GERIE, RADPAR, HITEA, INTARESE (WP-3.2 Housing), HEIMTSA (IAQ case study) and IndoorExpo

All these projects are still ongoing, they have not yet been quoted in any of the six IAQ data compiling and assessing reports, and their impacts will, therefore, be felt at some time after 2010.

The relative impacts (numbers of quotations) of the indoor data generating EU projects on the data compiling pre-normative EU projects are summarised in Table 3.

Pre-normative data compiling EU projects on IAQ	year	AUDIT 1995	EXPOLIS 1998	MACBETH 2000	PEOPLE 2005	HESE(INT) 2005	HOPE 2005	AIRMEX 2008
ECA Report 18 Evaluation of VOC…flooring materialls	1995							
ECA Report 21 European Interlab…VOCs…products	1998							
ECA Report 23 Ventilation, Good IAQ & Rational use of Energy	2003	3						
THADE	2004	2	5				3	
INDEX (INCL Update)	2005		62	6				2
WHO AQG	2005		6					
VITO IAQ Ranking	2007		19	2	2			6
SCHER Opinnion	2007		12					
DG Sanco IAQ Expert Group	2007							
EnVIE	2008	4	5	1	1			1
PM-INDEX	2009	5	12			1		1
WHO IAQGuiodelines, Dampness & Mould	2009							
Total quotations		14	121	9	3	1	3	10
Relative impact		0.087	0.752	0.056	0.019	0.006	0.019	0.062

Table 3. Numbers of quotations and relative impacts of 7 indoor data generating EU projects on 12 pre-normative indoor EU projects.

Chapter 3. Assessment of the potential impacts of new actions

The full potentials of strictly implemented tobacco smoke exposure control policies from public smoking ban to total indoor smoking ban including also homes and private automobiles with little children were assessed already in Chpt. 2.1. subchapter ***EC Green paper on tobacco smoke, COM (2007)27, based on WHO FCTC, 2005.*** While it is important to realise and acknowledge that this potential is both bigger and less costly than that of any other conceivable IAQ policy, this issue will not be dealt with again in the current chapter.

8. Potential impacts of the EnVIE suggested policies

All policy assessments in Chapter 3 are based on the assumption of all else remaining equal. All else refers to population and its behaviour, activities and underlying health status, the outdoor environment, the buildings and the products used in them, i.e. the only change is the one directly induced by the policy being assessed. This assumption is reasonable for the early stages of policy implementation when the changes are still small. Big changes change also human behaviour in response, people smoking outside near the door when indoor smoking is forbidden is a good example. Other policies require decades to be thoroughly implemented across the building stock, and the assumption that all else remains unchanged for, e.g., 30 years is not reasonable. While some changes over time are rather predictable, e.g., demographics, others are not, e.g., the way mobile telephones have changed our behaviour in the past 30 years. For the purposes of our policy assessments, all these changes are ignored, and it is assumed that they do not fundamentally favour certain policies and punish others.

The first look at the BoD reduction potentials of other IAQ policies can is generated by evaluating the potentials of the policies already evaluated in the EnVIE project, but using the updated IAIAQ database and modelling framework. These ten policies, slightly modified from EnVIE are:

General policies

- Integrate IAQ into the EPBD procedure (3.6 %/a)
- Develop and apply European harmonised protocols for IAQ testing, reporting and labelling of building materials, equipment and products (5 %/a) **– Scenario 4**
- Provide systematic documentation and operating, inspection and maintenance manuals for each building and all installations which may damage the building, deteriorate IAQ or cause health risks. Assign for each building a sufficiently qualified and trained person with control of all building documentation and responsibility for all building related tasks (10 %/a)
- Mandate radon safe construction for all new buildings (1.8 %/a)

Outdoor air pollution penetration policy

- Apply tight building envelopes, balanced ventilation and air cleaning for all new/renovated buildings when ambient air quality does not meet EU air quality directives or WHO AQGs (1.8 %/a)

Heating and combustion installations policy

- Ban all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandate CO detectors and regular maintenance/inspection for all combustion devices (10 %/a) **– Scenario 5**

Ventilation and air conditioning policies

- Develop health based ventilation guidelines to control exposure to pollutants from indoor and outdoor sources, indoor moisture and ensure comfortable indoor temperature (3.6 %/a)
- Mandate regular inspection and maintenance for all ventilation and air conditioning systems (10 %/a)

Water systems and dampness control

- Develop moisture control guidelines for building design and maintenance to prevent persistent dampness and hidden and visible mould growth (5 %/a)
- Provide kitchens, bath- and laundry rooms with controlled extract ventilation, bath- and laundry rooms also with waterproofed surfaces (5 %/a)

These and other IAQ policies differ in many ways other than their impact on public health, which have significant impacts on their feasibility and effectiveness, such as:

- **Time and cost:** Some policies can be implemented quickly and cheaply, while others require decades and are very expensive – except when implemented along normal renewal and renovation schedules. Policies which provide only marginal health benefit may still be quite cost effective.
- **Invasiveness:** Some policies affect only certain product manufacturers, while others set requirements on every citizen.
- **Interdependence:** Estimated policy benefits cannot be summed because they – more or less – overlap, depend on and sometimes even contradict each other.
- **Individual vs. population:** The current assessment focuses solely on Europe wide public health issues. Policies that appear marginal for public health may be critical for individual risks – and vice versa.

In addition to cost and invasiveness, the time scale of the implementation is critically important. Policies which can be implemented overnight by posting a sign, such as **NO SMOKING**, are likely to be much more efficient than policies which require rebuilding of the entire building stock. A policy of the former kind is also fast and cheap to repeal or change, if found to be erroneous (not likely for smoking bans). A policy of the latter kind may bring significant long term health benefits, but it will take decades – until the whole building stock has been replaced or renovated – before the benefits materialise in full. Hardly any specific building construction, management or IAQ policy will stay in effect sufficiently long.

- Policy which is implemented in only new or extensively renovated buildings exerts its influence at 1.8 – 3.6 %/a
- Policy which is implemented on furnishings, carpets, paints, etc. exerts its influence at 5 – 10 %/a
- Policy which is implemented on household chemicals, behaviour, etc. may exerts its full influence in less than one year, i.e. at 100 %/a

To conduct a meaningful comparison of the policies we have estimated for each an annual impact penetration percentage, and the health impact of each is assessed at the 10th year of its implementation.

The exposure and health impact of any policy is estimated using the IAIAQ Modelling Framework and estimating by an expert panel how much each particular policy could reduce the indoor air contamination released from each of the source categories at the time of its full implementation through the entire building stock, and then by modelling the impact ion the 10th year as explained above.

Figure 8 presents the health benefits in EU-26 in DALY/year which according to our modelling exercise could be achieved in the 10th year of implementation of each of the ten policies

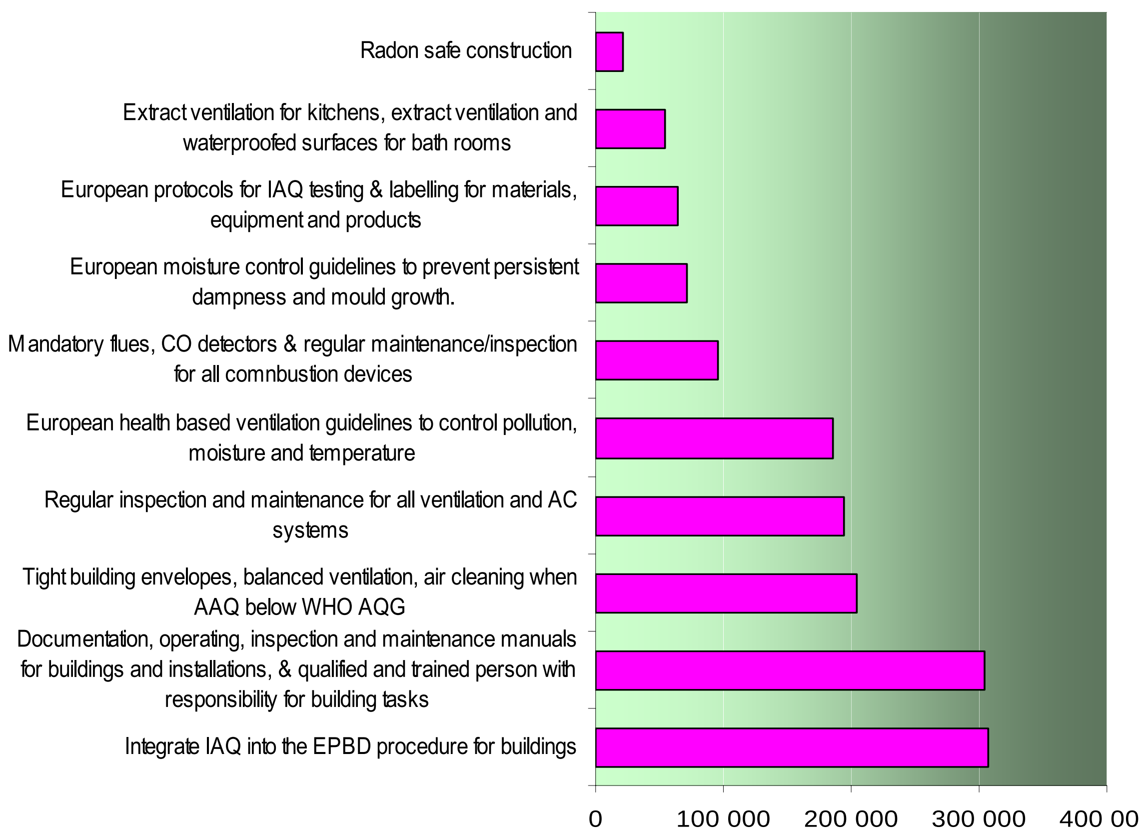

Figure 8. Potential DALY/year benefits at the 10th year of implementation of 10 IAQ policies in EU-26 (for DALY/year*million, divide by 484 [million inhabitants], i.e. 400 000 DALY/year corresponds to ca. 2000 DALY/year*million)

As explained, some of the policies are broad others focused, some are procedural others technical, etc. Much more than mere numbers should enter into policy comparisons. All these factors need to be taken into account when evaluating, selecting and implementing the policies.

An interesting European perspective into the policy assessment can be created by looking at the distributions of the health benefits normalised for one million inhabitants (DALY/year*million) between different countries. Figure 9 presents this comparison by showing the national minima, 1st quartiles, medians, 3rd quartiles and maxima of the BoD reductions achievable by the 10 policies within the 484 million citizens of the 26 EU countries. While it is logically obvious that the benefits are larger in the fourth than in the first quarter, it is still surprising that this difference can approach an order of magnitude for many of the policies.

As one could expect, the countries with the highest benefit potentials are the countries in Eastern and South-Eastern Europe (see Figures 4 and 5) which currently exhibit the poorest housing conditions, highest ambient air pollution, and highest use of solid fuels for cooking and heating. Radon exposure produces smaller differences between countries but huge differences within countries. The fact that we observed only small country differences provided by dampness control policies is more due to poorly comparable dampness statistics than real absence of such differences.

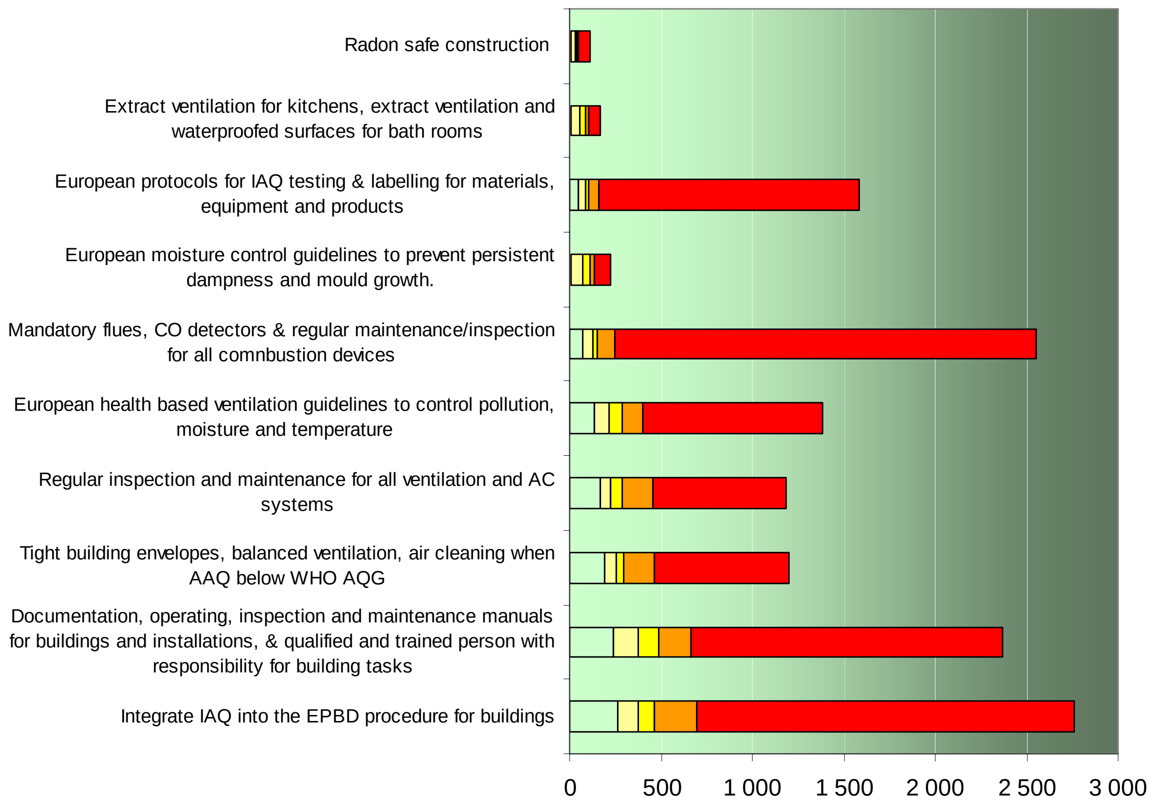

Figure 9. Distributions of the national public health benefit potentials of the 10 assessed policies in the 10th year of implementation (DALY/year*million) within the EU-26 countries. Levels from left to right: min – 1st quartile – median – third quartile – max.

9. Health benefits of the IAIAQ Policy Scenarios 2000 - 2020

First, the potential public health benefits of the seven IAIAQ policy scenarios were assessed using the modified EnVIE IAQ & Health Impact assessment tool.

Two of the policy scenarios,

> **Scenario 4:** Develop and apply European harmonised protocols for IAQ testing, reporting and labelling of building materials, equipment and products
>
> **Scenario 5:** Ban all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandate CO detectors and regular maintenance/inspection for all combustion devices.

were already assessed and presented in Chpt 3.1

> **Scenario 3**: Prepare EU future action on IAQ, linking to WHO IAQ Guidelines

is not assessed quantitatively.

In Chpt 3.1. impacts of the EnVIE proposed policies were evaluated at the 10th year of implementation. In the current chapter, instead, the impacts of the IAIAQ defined scenarios and related policies are assessed for selected calendar years from 2000 to 2020.

In Chpt 2.1., the total BoD in EU-26 due to exposure to contaminants in indoor air was estimated to be ca. 2 MDALY/year, or in average ca. 4 000 DALY/year*million. The potential reductions of these risk levels analysed for individual policies/regulations and IAIAQ policy **scenarios, 1,2,4, 5, 6 and 7**, are presented in Table 4. These risk reductions could be achieved in years 2005…2020, and at the time in the more distant future when each of these policies has been completely implemented throughout the entire building stock of EU-26.

Needless to say, health benefits of no policy will begin to materialise before the policy is enacted and implemented. The annual rate of implementation of building related policies ranges from 2 %/year or less for policies on building constructions and materials up to 100 %/year (e.g. smoking bans). For other building and indoor air policies the annual implementation rates fall between these two extremes. For existing policies the first implementation year was assumed to be the year following the legislation. All assessed future policies are assumed to be implemented from year 2011 onwards, because we have no basis for selecting any other year, or different years for the different policies.

When reading and interpreting the data on Table 4, it is important – once again – to keep in mind that the health benefits of different and in particular of alternative policies cannot be summed. The sum effect of any multiple policies is in all likelihood greater than the higher individual policy effect but smaller than their sum.

The table demonstrates on one hand how slow most of these processes are – only few policies could reach as much as half of their potentials by 2000, and others would reach only one fourth – and on the other hand that more than half of the DALYs lost today due to indoor air exposures could ultimately be prevented by the assessed policies.

Existing or proposed EU-regulation and respective IAIAQ Scenario	Start year	Annual health benefit in DALY/million in year					
		2 000	2 005	2 010	2 015	2 020	∞
CPD (89/106/EEC Construction Products), Scenario 1	2 000	0	35	70	100	120	400
GPSD (2001/95/EC General Product Safety), Scenario 1	2 002		2	5	6	7	9
EPBD (2002/91/EC Energy Performance of Buildings), Scenario 1	2 003		60	190	300	400	800
REACH (EC/1907/2006 Chemicals), Scenario 1	2 007			5	10	13	17
REACH implementation with focus on IAQ, Scenario 2	2 011				10	15	30
CPD+GPSD+ Integration of IAQ impacts of indoor combustion equipment into CPD&GPSD, Scenario 2	2 011				100	180	600
European harmionised protocols for IAQ lbling of building & indoor materials & products, Scenario 4	2 011				60	120	300
Ban on unflued combustion, CO detectors, regular maintenance&inspectiuon, Scenario 5	2 011				100	180	300
EPBD + Integration of IAQ into EPDB recast Scenario 6	2 011				160	350	1 200
Integration of IAQ into EU Climt Act & Renwbl Enrg Pckg & Recast of Energy lbl. Scenario 7	2 011				300	600	2 000

Table 4. Temporal increase of the annual public health benefits of the alternative IAIAQ policy scenarios in EU-27 as the implementation of the different policies slowly saturate the building stock.

- ***Baseline: No new EU actions***

Scenario 1**: Current actions continued at 2010 level**.

Four current policies are included in this scenario. Even in the absence of any new developments, their public health benefits would continue to increase far into the future and could reach significant levels.

The impacts of GPSD and REACH appear to be quite small in comparison to CPD and EPBD. GPSD and REACH focus on specific chemicals rather than air pollutants from indoor combustion and outdoor sources, mostly other exposure pathways than indoor air and safety as much as health issues. Besides, the benefits are limited to the use of certain new building equipment and household products, i.e. only a fraction of the buildings at any given time. Their overall public health benefits, however, are expected to be significant with indoor air playing only a marginal role in the total impact.

The impact of EPBD, on the other hand, appears particularly large. The health benefits are expected to come from reduced outdoor air pollution, reduced penetration of outdoor pollution indoors and reduced or eliminated emissions from indoor combustion equipment, i.e. they affect IAQ in all or most buildings, and target the most harmful sources and contaminants. The impacts of CPD and EPBD are not additive, they overlap significantly.

The assessment does not take into account the – quite real and poorly predictable – risks from increasing the energy performance by reducing ventilation, changing building physics, and relying on new products and increasingly complex technologies, which neither builders, nor building managers or occupants may properly understand. Such risks were the source of much of the infamous IAQ problems of the 1980's, and although much has been learned since then, their re-emergence can in no way be ruled out.

***Scenario 2*: Current IAQ Action Plan continued from 2010 onwards**

This scenario, which is still based on current policies, points out how the benefits of REACH, CPD and GPSD can be increased by enhancing the IAQ point of view and targeting also the impacts of indoor combustion equipment in their formulations and applications. It also points out the benefits of broad integrated IAQ policies.

- ***New activities focused on IAQ & health issues***

***Scenario 3*: European future action on IAQ**

This is not a scenario in the same sense as the others, and its public health or risk reduction benefits cannot be modelled like those of the other scenarios. The future actions should be based on a comprehensive and balanced understanding of the IAQ and public health community and help the decision makers to move forward in the development of IAQ policies, and – maybe more importantly – to appropriately consider IAQ in the formulation and implementation of other policies which would have the potential of either improving or deteriorating IAQ. EPBD and the EU Climate Action and Renewable Energy Package are prime examples of such policies, but also a variety of other policies relating to issues ranging from fire protection to pest control may exhibit such potentials.

***Scenario 4*: Integration of European harmonised protocols for IAQ labelling for building materials, equipment and products into CPD**

This scenario assesses the additional benefits of one specific IAQ policy, which would require the testing and labelling of all building materials, equipment and products, and integrate this requirement into CPD. The estimated additional health benefits would essentially double the public health benefits of CPD,

***Scenario 5*: Integration of EU wide regulation on indoor combustion equipment into CPD and GPSD**

This scenario defines a ban on all unflued / unvented indoor combustion equipment, and for all indoor combustion equipment a Europe wide testing and approval procedure, a mandatory and scheduled inspection and maintenance programme, and installation of a CO-detector/alarm. The scenario is expected to reduce both ambient and indoor air pollution, and virtually eliminate the risks of CO poisoning in the home. Because combustion is a major source of indoor air contamination, and parts of the policy could be implemented quite rapidly, this scenario would provide significant public health benefits relatively quickly.

- ***Coordinated actions involving health and other relevant sectors***

***Scenario 6*: Integration of IAQ into the EPBD**

This scenario defines that EPBD is revised and IAQ is considered at every step in the revision. Its public health benefits materialise at the rate the buildings are replaced, renovated and their heating units are replaced. The scenario would reduce direct indoor emissions from combustion equipment (and building materials), improve ambient air quality via reduced fuel combustion, better, lower emission combustion units and cleaner fuels, and reduce penetration of outdoor pollutants indoors by advanced energy recycling ventilation technologies, i.e. it is expected to significantly influence the most common sources of the highest risk indoor contaminants, fine particulate matter and other combustion products. Consequently its benefits would not build up very rapidly, but could ultimately become very important.

It is assumed that this scenario would also avoid the risks discussed in the context of Scenario 1.

***Scenario 7*: Integration of IAQ into the EU Climate Action and Renewable Energy Package [6], and Recast of the energy labelling directive**

This scenario is defined as an enhanced variant of the previous scenario (6), with drastic improvements on urban ambient air quality, outdoor pollution filtration and elimination of indoor emissions from heating and cooking equipment. It has a potential of ultimately reducing the BoD from indoor air contaminants by half. For this potential to materialise, however, IAQ and human health needs to be considered at every step of the implementation of the EU Climate Action and Renewable Energy Package.

Without such consideration, (i) straightforward energy conservation actions, such as further insulation of the buildings, reduced ventilation, smaller residences, more concentrated cities, (ii) single minded actions to reach the ambitious renewable energy targets by increasing domestic wood burning, and (iii) rushing towards the 20-20-20 objectives without adequate research, development and field testing programmes, the outcome could be a significant increase and not a decrease in the BoD due to contaminated indoor air.

10. Potential impacts of the selected data generating and pre-normative IAQ related EU projects on public health in the EU-26 until 2020

In the following sub-chapters the impacts of 7 EU financed new indoor data generating projects (AUDIT, EXPOLIS, MACBETH, PEOPLE, HESE(INT), HOPE and AIRMEX), 12 EU financed data compiling pre-normative projects/programmes (ECA Reports 18, 21 & 23, THADE, IndEx, WHO AQG 2005, VITO IAQ Ranking, SCHER Opinion, DGSanco IAQ Expert Group, EnVIE, PM IndEx, and WHO IAQG Dampness & Mould) via the implementation of six (of the seven) policy/regulation scenarios are assessed. The assessments are based on the following modelling assumptions, all of which more or less simplify the reality**:**

- A data generating project influences public health only by 1) being referred to in a pre-normative data compiling EU-project, which 2) precedes the formulation of an EU-regulation dealing topically with the issues covered in the pre-normative project.

> *This is a gross simplification because (i) a data generating project may influence pre-normative projects already before its final report and further results are published, (ii) because a pre-normative project may influence the implementation of an earlier regulation, and (iii) a data generating project may influence a regulation and its implementation also directly, bypassing the pre-normative project reports.*

- The relative weigh of the influence of a data generating project on a pre-normative project is proportional to the number of times the former is referred to in the final report of the latter

> *This approach is rather close to the 'citation index' and shares its simplicity and limitations.*

- The relative weigh of influence of a pre-normative EU-project on a regulation is 1 (one) if it precedes and is topically linked to the regulation, and otherwise it is 0 (zero)

> *This definition is reasonable for the zero case, but a gross simplification for all other cases because it ignores the real differences between them, which should range 0 … 1 – see the identical assessment results in Table 7. This judgement, however, should be based on expert elicitation process, and would still be difficult.*

- On one hand, it is clear that all public health benefits that can be assigned to EU policies/regulations affecting IAQ, cannot be attributed to a limited set of pre-normative EU-funded IAQ projects, and its is equally clear that all health benefits that could be attributed to these pre-normative IAQ projects, cannot be further attributed to the limited set of original data generating EU-funded IAQ projects which are quoted in their reports. On the other hand it is fair to assume, that both of these attributable benefits are significant. We have no way to analyse or predict the actual attribution of each projects health benefits to each following step, we arbitrarily assume that:

-- All of the listed data generating EU-projects combined are responsible for [a maximum of] 1/2 of the impact of the pre-normative projects

- -All of the listed pre-normative EU-projects combined are responsible for [a maximum of] 1/2 of the public health impact of any regulation

> *These impacts are assumed to be significant, different for different data generating and pre-normative projects, difficult to quantify, but surely less than 1.0. The selected value of 1/2 is arbitrary.*

<u>Table 5</u> presents the estimated maximum public health benefits of the pre-normative data compiling EU projects via the IAIAQ policy scenarios, assuming complete long term implementation of only those policies in effect in 2005, in 2010 and in 2015, e.g. in the column titled ‘Policies of 2010’ the benefits apply for a much later year, when these policies have been completely implemented through the entire building stock, but no new policies are enacted after 2010.

According to our assessment logic the 7 included indoor data generating EU-projects influence the policies and their benefits via the 12 data compiling projects. It is therefore possible to also assess the respective potential benefits of the data generating projects. These results are presented in table 6, below.

Project max impact at full implementation DALY/year*million		
Project	Policies of 2010	Policies of 2015
AUDIT	150	300
EXPOLIS	350	700
MACBETH	14	30
PEOPLE	7	17
HESE(INT)	5	10
HOPE	25	50
AIRMEX	13	35

Table 6. Potential annual health benefits in EU-26 of the 7 evaluated data generating EU-projects full long term (saturation) implementation 4 existing and 5 proposed EU policies/regulations.

As explained before, the evaluation (Table 5) of the policy impacts and – via the policies – the potential public health impacts of the pre-normative EU projects is very rude, based only on the timing and the presence or absence of topical connection between the policy and the project. Consequently one should only expect a low level of impact differentiation. At the high end are ECA Report 23, the THADE, INDEX and EnVIE reports and the WHO Air Quality Guidelines. The other EU-projects are estimated to exhibit lower impacts either because of their too late appearance to influence earlier policies, narrow topical coverage or focus on issues which do not have the highest public health significance in relation to indoor air.

The assessment logic of the impacts of the original data generating EU projects on public health via the pre-normative EU-projects and EU policies/regulations can is similar to the one above, but instead of yes/no impact the actual number of references to project N divided by the number of references to all of the seven projects can now be used to estimate the impact of each data generating EU-project on each pre-normative EU-project. The first step of this assessment, from the data generating EU-projects to the pre-normative EU-projects is found earlier in Table 3. The full chain assessment from the data-generating EU-projects to estimated public health impacts (Table 6) points out much larger differences within the data-generating EU-projects than within the pre-normative EU-projects. Most of this increased differentiation is due to the assessment logic.

The AUDIT and EXPOLIS projects have the advantage of having been reported in 1995 and 1998 respectively. Consequently the have been able to influence the development of many more policies than, e.g., PEOPLE and AIRMEX, reported in 2005 and 2008. EXPOLIS also covered all indoor air contaminants of interest, except radon and bioaerosols, analysed their sources and developed exposure models – therefore resulting in quotations in the context of most diverse IAQ interests (Table 3).

Public health impact assessments of 12 data compiling pre-normative EU projects on IAQ		EU IAQ related policies/regulations CPD	GPSD	EPDB	REACH	REACH + IAQ	CPD+GPSD + Comb ctrl + IAQ	EPDB + IAQ	Clim Pol 20-20-20 + IAQ	Project impact in DALY/year*million at full implementation the policies enacted by the year of …		
Policy impact DALY/year*million		400	9	800	17	25	600	1 200	2 000			
Projects	year	1989	2001	2002	2006	2011	2011	2011	2011	… 2005	… 2010	… 2015
ECA Report 18 Evaluation of VOC…flooring materialls	1995		1		1	1	1	1		0.3	30	70
ECA Report 21 European Interlab…VOCs…products	1998		1		1	1	1	1		0.3	30	70
ECA Report 23 Ventilation, … IAQ & ...Energy	2003						1	1	1			150
THADE	2004				1	1	1	1	1		30	160
INDEX (INCL Update)	2005				1	1	1	1	1		30	160
WHO AQG	2005				1	1	1	1	1		30	160
VITO IAQ Ranking	2007					1	1					25
SCHER Opinnion	2007					1	1		1			110
DG Sanco IAQ Expert Group	2007					1	1	1				70
EnVIE	2008					1	1	1	1			160
PM-INDEX	2009						1	1	1			150
WHO IAQGuiodelines, Dampness & Mould	2009							1				50

Table 5. Impact of 12 pre-normative indoor air data compiling EU projects on public health in EU-26 via 4 existing EU-regulations and 5 expansions of these regulations for stronger than present consideration and advancement of indoor air quality. Value 1 indicates that the project precedes the policy and is relevant to it. The existing policies included are:

CPD (89/106/EEC Construction Products) **– Scenario 1**

GPSD (2001/95/EC General Product Safety) **– Scenario 1**

EPDB (2002/91/EC Energy Performance of Buildings) **– Scenario 1**

REACH (EC/1907/2006 Chemicals) **– Scenario 1**

and the proposed ones are:

REACH + IAQ = REACH implementation with focus on IAQ **– Scenario 2**

CPSD+CPD + Comb = CPSD+CPD+ Integration of IAQ impacts of indoor combustion equipment into CPD&GPSD – **Scenario 2**

EPDB + IAQ = EPBD + Integration of IAQ into EPDB recast **– Scenario 6**

20-20-20 + IAQ = Integration of IAQ into EU Climate Act & Renewable Energy Package & Recast of Energy labelling – **Scenario 7**

11. New projects

National and international studies on the health effects of indoor air quality and related preventive measures exist but are still few in number compared to the wide range of substances that may cause health problems for occupants.

Studies should be performed on the relationship between IAQ and health, on the efficacy of the remedial actions in reducing the health effects. Similarly, more research is required to determine the effects and costs of preventive and remedial measures.

Below are listed the areas in which more data are required in order to make an accurate analysis of the effects of preventive/remedial measures:

1. Assessment of the health effects of short- and long-term exposures in indoor environments, especially at home and in the schools. Epidemiological studies should be performed on the relationships between health and measured indoor levels, taking into account exposure time and exposure variability and also vulnerable groups. Studies are needed on the effects of new emerging risks such as the products which emit contaminants that can react in indoor air (e.g. terpenes), on the possible effects of fine and ultrafine particles, and of man-made nanoparticles in indoor air. Clinical studies (including biochemical markers of effect) are needed to clarify the effects due to the exposure to microbiological agents. Research is needed on the effects due to combined exposure to indoor air pollutants and on the objective methods for their evaluation, including development of validated modelling tools.
2. New studies should be started to assess exposure patterns (short and long term in different environments) to indoor air pollutants, and identify relevant exposure indicators.
3. Source attribution techniques should be applied for the characterisation of pollution sources in buildings and assessment of the technologies to control the sources and their effects on health and well-being. Special emphasis should be given to the assessment of chemical emissions from consumer products used or stored indoors.
4. More research is needed on ventilation rates and energy use in different types of existing buildings and the respective impacts on indoor air quality and climate, health and well-being.
5. Research is needed on the optimal balance between improved control of indoor sources, ventilation rates and air cleaning, and to develop efficient and reliable control systems based on outdoor and indoor air quality.
6. Research is still needed on the durability, reliability, and robustness of the alternative air cleaning technologies for ventilation systems. There is also a growing need for low energy ventilation technologies for better indoor air quality, e.g. via improvements in air distribution and air quality based intelligent controls.
7. Research is needed to develop and test urban planning tools to model – from short term to life cycle - the population exposures, energy requirements and pollution loads of alternative plans – from an individual building to entire urban areas.

8. There is a need to promote the development of robust design tools for sustainable and energy efficient buildings, including life cycle analysis, environmental impact assessment and appropriate performance goals. Guidance for building commissioning and management should be integrated into these tools. This requires:
   - comprehensive criteria and tools to assess the holistic performance of buildings,
   - integrated tools assessing the compromise between good IAQ and energy efficiency and requirements for management and control strategies.

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