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ENVIE
Co-ordination Action on Indoor Air Quality and Health Effects

Publishable Final Activity Report

by

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Executive Summary

Background

People want to live longer, healthier, in an environment of low involuntary risks, and at an affordable cost. Urban environmental policies should, therefore, manage the determinants of health as far upstream as possible and improve citizens' quality of life'. People are exposed to a multitude of chemical, physical and biological stressors in their environment, some of which are apparently harmless, others of low health significance, and some incur significant risks to health, especially for vulnerable individuals. Human exposure to environmental contaminants occurs via various pathways (air, water, food...) and routes of entry (inhalation, ingestion and dermal). Exposure via air occurs outdoors and in different indoor microenvironments; e.g. home, workplace, transport. Knowing the relative contributions of these exposure pathways, routes of entry and microenvironments to total exposure is essential for effective risk management and resource allocation.

Roles of Buildings, Indoor Air and Ventilation in Air Pollution Exposures and Risks

Modern European citizens spend - on average - over 90% of their time indoors. Indoor air originates from outdoors, carrying outdoor air contaminants indoors with varying degrees of penetration: some are effectively transferred indoors (e.g. for $PM_{2.5}$ penetration ranges from 50-90%), others are adsorbed on indoor surfaces or readily react with indoor air co-pollutants (e.g. ozone). Also indoor environments contain sources of contaminants that, due to the low air exchange rates compared to outdoor environments can cause relatively high pollutant levels. Indoor environments have been widely studied for a range of chemicals and biological contaminants; in the presence of indoor sources, indoor contaminant concentrations are higher, sometimes 10 or 20 times higher (e.g. formaldehyde) than the respective outdoor air levels. The combination of the generally higher indoor concentrations and the overwhelming fraction of time spent indoors results in the overall domination of indoor air in air pollution exposures regardless of whether the sources are indoors or outdoors.

Radon is a natural and carcinogenic air contaminant, which is drawn into the indoor air by the air pressure gradient caused by the normally low indoor relative to outdoor air pressure. Indoor air radon concentrations often exceed outdoor air levels by 1, 2, or even 3 orders of magnitude.

Indoor exposures to allergens from outdoor sources - e.g. pollen – can affect sensitive individuals. The sources of other allergenic substances, e.g. moulds, are often found indoors. While the building – in particular when moisture persists in its structures - is the cause of the latter, it may, at the same time, significantly reduce the former exposures; such reductions can be significantly enhanced by the ventilation equipment, indoor space cleaning and occupant behaviour.

The function of ventilation is to ensure fresh indoor air with low levels of contaminants from any indoor sources (e.g. human metabolism, occupant activities, consumer products, furnishing, building equipment and materials). Yet, ventilation also draws in more or less polluted outdoor air, the ventilation system may itself be contaminated and a source of pollution, insufficient ventilation may cause moisture to condense and accumulate, *unbalanced ventilation results in uncontrolled air leaks and sometimes radon build-up, and excessive ventilation with no heat recovery wastes energy.*

Air Quality Policies & Indoor Air in Europe

European air quality policies have devoted most of their efforts to controlling urban outdoor air concentrations of regulated air pollutants derived from heat and power generation, industrial processes and traffic. Although there is no reason to relax society's preoccupation with these issues, it is now recognized that new policies should be focussed on indoor exposures to identify, control and eliminate the indoor sources of pollution, and also to reduce exposure to air pollutants of outdoor origin. For most volatile organic compounds, the focus should be on the indoor sources, building materials, consumer products and occupant activities. In the case of nitrogen dioxide and fine particulate matter, both indoor source control and filtration of the outdoor air may be considered. Exceedances of European and National outdoor air carbon monoxide standards are becoming rare, yet dangerous carbon monoxide exposures are still occurring and are currently caused almost exclusively by indoor combustion sources.

National air quality policies on indoor air have until recently consisted of scattered regulations on building materials and equipment, heating, ventilation, and air conditioning equipment, ventilation rates and concentration guidelines on a few chemicals (mainly formaldehyde and radon). New EU policies on chemicals (REACH; 2006/121/EC), consumer products (GPSD; 2001/95/EC), construction products (CPD; 89/106/EC) and energy performance of buildings (EPBD; 2002/91/EC) all refer to IAQ issues - suggesting that they could, and probably should, contribute to IAQ policy development.

Since 1987, indoor air issues in Europe have been broadly covered by the 26 reports of the European Concerted Action on "Indoor Air Quality and its Impact on Man" (renamed in 1999 "Indoor Air, Human Exposure and Urban Environment"). DG SANCO funded the JRC/IHCP coordinated INDEX project (2002-2005), which for the first time in Europe evaluated the indoor air chemicals for which exposure and health data were available in Europe, and recommended indoor air quality policies for a shortlist of chemicals consisting of formaldehyde, benzene, nitrogen dioxide, carbon monoxide and naphthalene.

Biological contaminants, radon and environmental tobacco smoke were not included in the EnVIE analysis, mainly because specific policies and regulations already exist for these pollutants. In 2006, WHO/Europe initiated the preparation of Indoor Air Quality Guidelines, expected for 2009-10.

Objectives and Approach of EnVIE

The aim of the EnVIE project is to increase the understanding of the Europe-wide public health impacts of indoor air quality by identifying the most widespread and significant indoor causes for these health impacts and evaluating the existing and optional building and housing related policies for controlling them. It addresses in particular how indoor air quality might contribute to the observed rise in asthma and respiratory allergy, together with other acute and chronic health impacts. The intention is not to conduct new experimental or field research, but rather to build on the broad scientific experience and the wealth of accumulated literature from the domestic and international indoor air research projects as well as the EU, WHO, ISIAQ and CIB committees and expert groups during the past 20 years.

Many previous indoor air quality and policy assessments have taken specific contaminants or indoor sources as the starting point. The logic behind this is the flow of molecules from *sources via the environment to exposure, whole body dose, target organ dose, and the consequent health outcome. EnVIE follows an opposite logic, starting from consideration of the most pronounced indoor air related health outcomes (which may have also other sources and causes), then identifying the most widespread indoor air exposures that are likely to cause these health outcomes and the most common sources which dominate the indoor air exposures. The intention was to focus from the start on those indoor air quality issues that have the highest Europe-wide health relevance. Having defined a shortlist of such "reverse" indoor health-exposure-source chains, the project evaluates the policy alternatives for minimising both unwanted health consequences, in terms of achievable public health benefits, and invasiveness, while taking into account political, legal, technological, economical and social feasibility. A further outcome is the identification of a set of highly advisable and feasible indoor air quality policy options for Europe. Europe-wide applicability brings the benefits of enhanced competition in a broader marketplace.*

Health Policy Gains from IAQ Policies

Although many IAQ policies depend on and/or overlap with others, the public health benefits that could be achieved by each policy are here each assessed individually. This assessment does not consider the costs or political feasibility of the policies, and it is assumed that each policy is fully implemented throughout the building stock. The assessment follows the EnVIE concept, beginning with the shortlist of health impacts. Likely public health gains, represented by DALY[*] reductions, which could be achieved by the selection of different general and specific indoor air quality policies, are calculated.

Recommendations on Policies

The recommendations on policies can be grouped and summarized as:

Policies concerning energy efficiency, building materials, products and maintenance.

- *Integration of IAQ into the EPBD procedure for buildings*
- *Development and application of European harmonised protocols for IAQ testing, reporting and labelling for building materials, equipment and products (common IAQ monitoring procedures) (REACH, GPSD)*
- *Providing for each building systematic documentation and operating, inspection and maintenance manuals for all installations and assigning a sufficiently qualified person with control of all documentation and responsibility for all building tasks*

Policies concerning the impacts of outdoor environment

- *Mandating radon-safe construction for all new buildings*
- *Applying tight building envelopes, balanced ventilation and air cleaning for all new/renovated buildings when ambient air quality is below WHO*

Policies concerning specific building constructions and equipment

- *Banning of all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandating CO detectors regular maintenance/inspection for all combustion devices (integrate with EPBD procedures);*

[*] *DALY –Disability-Adjusted Life Year

- *Development of health based ventilation guidelines to control exposure to pollutants from indoor and outdoor sources, including indoor moisture, and ensure comfortable indoor temperature;*
- *Mandating regular inspection and maintenance of all ventilation and air conditioning systems. (integrate to EPBD);*
- *Developing moisture control guidelines for building design and maintenance, to prevent persistent dampness and hidden and visible mould growth, and Keeping domestic hot water [tap water] temperatures above 55ºC;*
- *Providing kitchens, bath- and laundry rooms with controlled extract ventilation, bath- and laundry rooms also with waterproofed surfaces;*
- *Avoiding spaces, structures and materials that would not dry by convective airflows.*

Framework for a EU Green Paper on IAQ

The list of proposed policies clearly shows that to tackle IAQ there is a need for an integrative approach. Therefore, the justification for a Green Paper on IAQ was identified in order to, among other things: coordinate the proposed policies with other already existing and in preparation legislative tools and policies related to IAQ; promote an objective dialogue among all relevant stakeholders; and contribute to the holistic view needed for the management of the built environment.

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Project execution

1. Introduction

Buildings play a multitude of roles in air pollution exposure: (i) Depending on the national energy “mix”, climate zone, typology, quality and age of the building stock, ca. 40 % of the primary energy is used to heat, light and ventilate buildings and to run a variety of electrical equipment in buildings from elevators to personal computers. Consequently, buildings are directly and indirectly responsible for a similar proportion of air pollution from heat and power generation by burning conventional fossile fuels (ii) The building structure and materials as well as other sources in buildings - from invisible dirty air ducts and water damaged mouldy insulation materials to unflued combustion appliances, candle burning and the use of organic solvents, hypochlorite and ammonia containing cleaning agents, for example - contaminate the air inside the buildings where people spend most of the time (iii) 20 to 100% of the concentrations of outdoor air pollutants are transferred inside the buildings - depending strongly on the pollutant of concern and the ventilation or air conditioning system - and, consequently, most exposure to so-called outdoor air pollution occurs indoors. For traffic pollution, about half the total exposure, on average, occurs indoors and the other half while in transport or outdoors. In summary, buildings have a large impact on both outdoor and indoor air quality (IAQ) and, relative to outdoor air pollution; buildings may significantly increase or decrease people’s air pollution exposures. Buildings are, therefore, the most important factor in air pollution exposure and associated health effects.

EnVIE was a ‘European coordination action for IAQ and Health Effects’ (2004-2008) funded by the EC DG RTD in the context of the 6th Framework Research Programme. Its starting point was the Europe-wide public health effects of indoor air pollution and its aim was to identify the key policies - existing and new - to improve European IAQ and reduce the negative health effects of both, indoor and outdoor air pollution. Three specific EnVIE reports cover the health effects of indoor air pollution, exposures to indoor air pollution and indoor air sources. Two open dedicated Conferences and one Workshop allowed for exchange of views with experts beyond the circle of the twenty EnVIE partners. The current report evokes briefly the rational of the EnVIE method and focuses mostly on policies, both IAQ policies and other related policies that are important to manage and improve IAQ. The report first identifies and shortly describes some existing EU policies with broad implications for IAQ, then, issue by issue, identifies European and national, legal industrial and professional policies and suggests new policies where existing policies seem insufficient, uncoordinated or even contradictory.

The policies should be seen as elements of a coherent and holistic IAQ strategy, which has clear overall aims to improve IAQ and reduce the public health effects of air pollution. The policies should be accountable, i.e. - when they are specified for technical implementation - they should be (i) given measurable exposure and public health objectives, (ii) connected to respective success monitoring programmes and (iii) assigned to an authority that is responsible for reporting, improving and revising the policy according to the monitoring of the achievements *vs.* the objectives of each policy.

IAQ policies have to be developed and implemented within many boundary conditions (other policies) such as:

- respect for the privacy of private residences,

- coherence across the treatment of competing industries, technologies and materials, natural and man made,
- the need to manage rationally energy and other natural resources over the full life cycle of the building,
- consistency over time - buildings should, ideally, be built for centuries and renovated for decades,
- economic feasibility, including flexibility to adapt different strategies for good IAQ to new uses and requirements of both, old and new buildings,
- external and internal accessibility by the users, including physically challenged users of the building,
- safety in relation to risks of fire, flooding, accident, breaking-in, etc.

These policies may contradict each other, and when they do the order of priority of the conditions determines which conditions prevail and which are waived. A rigid and legally binding policy always has priority over a recommendation, regardless of its impact on IAQ. The priority of the IAQ policies relative to the other policies and conditions is, therefore, as important as the policies themselves.

2. Motivation

Different pathways from sources to humans lead to a broad variety of health outcomes that are attributable to the indoor environment (See Figure 1, Jantunen *et al*., 2000).

Building Related Illness (BRI) is a term referring to illness brought on by exposure to the building air, where a defined illness, directly linked to agents in the indoor environment, is diagnosed. Legionaire's disease and hypersensitivity pneumonitis are examples of BRI that can have serious, even life-threatening consequences. Some indoor pollutants are known or suspected carcinogens (radon, environmental tobacco smoke (ETS), asbestos, benzene) and add to the underlying cancer risk for European populations.

Also *hypersensitivity initiation, asthma and allergies* are sometimes associated with contaminated indoor air; various reports have linked indoor allergens with asthma and a whole range of allergic manifestations amongst building occupants.

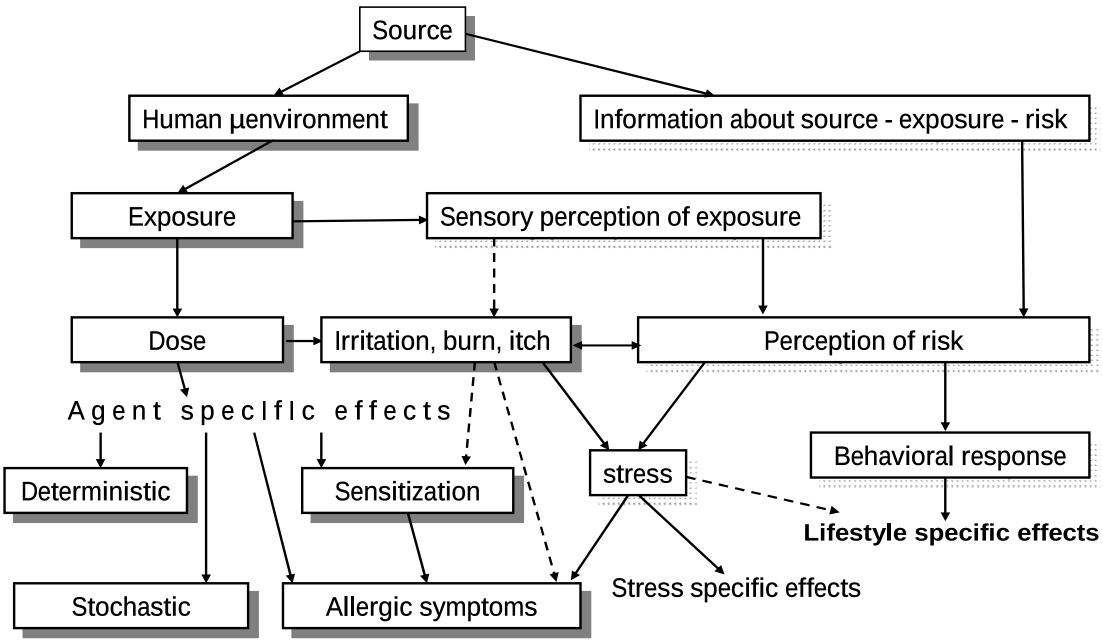


Figure 1. The entangled pathways from source to the different agent, stress and lifestyle related health outcomes (simplified from ECA report Nº 22, 2000)

The term *Sick Building Syndrome* (SBS) is used to describe cases in which an abnormally high proportion of building occupants experience acute symptoms and discomfort that are apparently linked to the time they spend in the building, but for which no specific illness or cause can be assigned. Thus sick building syndrome is not the diagnosis for an individual, but for the whole population of occupants of a building in relation to that building. Many different symptoms have been associated with SBS, including respiratory complaints, irritation, and fatigue. Sensory perception of odours and mucous irritation leads to perception of poor air quality and possible risks and consequently to *stress* or *behavioural responses* (opening a window, leaving the building). The highly variable symptoms of stress depend mainly on the host, rather than the cause of the stress. Other environmental stressors such as noise, vibration, crowding, ergonomic stressors and inadequate lighting can produce symptoms that are similar to those of poor air quality.

Finally, *discomforting information* about exposures and health risks, and job-related *psychosocial problems* may cause stress symptoms that are undistinguishable from those of sensory perceptions. Aside from its impact on health, information concerning risks to health and safety will also affect absenteeism, work productivity and - in the school - learning.

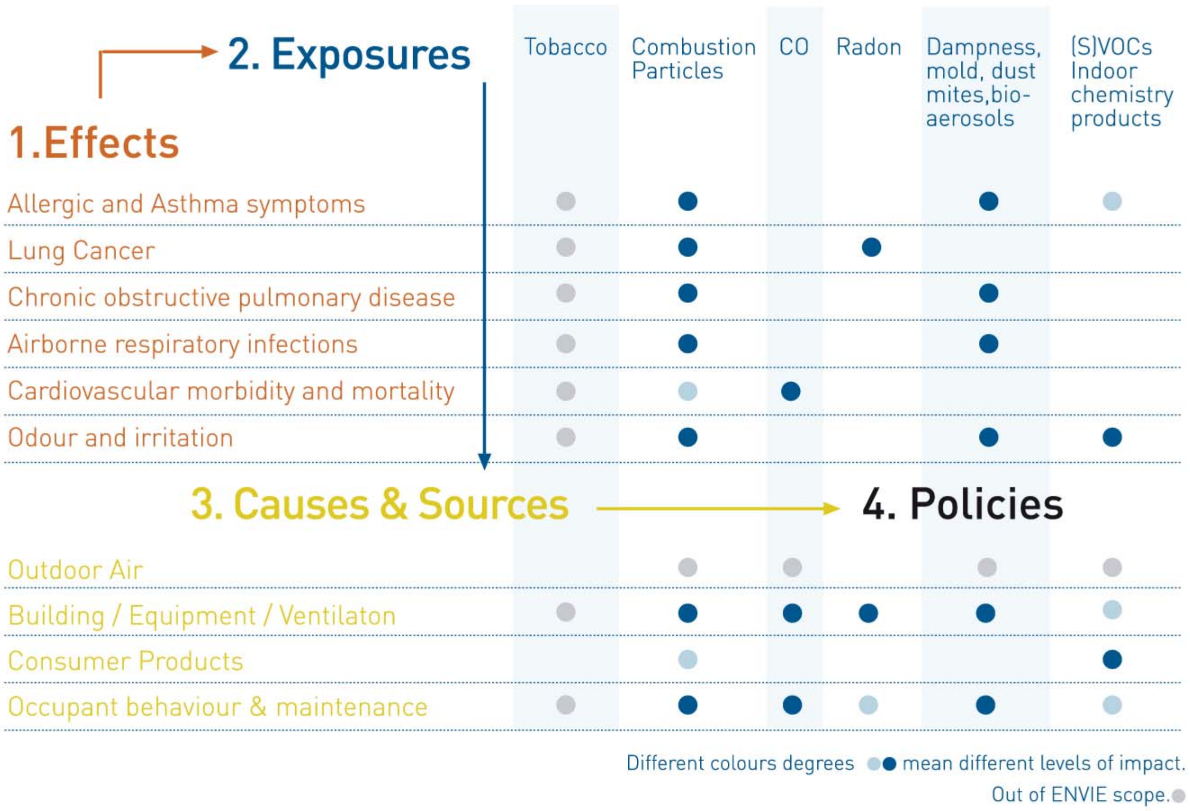
Figure 1 also highlights the targets for intervention to reduce and eliminate indoor related health risks. Eliminating the source of contamination, by removing or replacing or moderating it is the option of first priority. Cutting or restricting the pathway from the source to human indoor microenvironment by filtering the contaminant originating from outdoor source(s) in the ventilation system or by extracting the effluents from indoor sources away from human exposure is the option of second priority. Exposure can also be controlled by restricting the time spent in a particular contaminated space and, as the most general solution, by diluting with increased ventilation. Air fresheners are often used to mask or modify the sensory perception of exposure. This method, however, increases rather than decreases the overall exposure and is, therefore, not a recommended option. Risk perceptions and stress symptoms caused by information and sensory perceptions in various combinations should be dealt with by risk communication – a challenge in itself, not covered in the present report.

The complexity of indoor pollution sources, effects pathways and the multitude of parties responsible for generating and respectively controlling indoor air pollution make the coherent development of risk reduction strategies a challenge. To be effective, policies directed at improving IAQ need to be part of a comprehensive, internally and externally consistent management strategy involving governments, institutions, professional bodies and individuals. Plans need to be directed at both new and existing buildings and involve action at both local and national levels. Important considerations include outdoor climate and air quality, building materials and styles, knowledge and behaviour patterns of the occupants, energy and sustainability policies, and building system technologies. Requirements for the establishment of a successful strategy include prior justification, goal setting, appraisal of management options, and political willingness.

3. EnVIE Method

The selection of issues for and the structure of this report is based on the EnVIE concept (see Figure 2), starting from (i) the selected shortlist of high priority indoor air quality related public health concerns, identifying (ii) the key indoor exposures that are believed by most experts to significantly contribute to these health outcomes, (iii) identifying the sources which are known to significantly contribute to these indoor exposures and – finally, (iv) identifying and assessing the existing and missing policies to control these sources (and consequently the health outcomes) as well as the critical new research that would be needed to develop the missing policies. The first three issues are covered in the EnVIE WP1 (Carrer et al., 2008), WP2 (Jantunen et al., 2008) and WP3 (Oliveira Fernandes *et al*., 2008) Final Reports. The current WP-4 Report concentrates on the last issue, that is, the indoor air policies.

The ultimate outcome of the WP-4 report is a list of proposed IAQ policies. Most policies affect one or multiple indoor air pollution sources and activities. At first, however, the exposures and sources of interest, and policy assessment objectives are defined.



Explanatory note: Different degrees of colours mean different levels of impact and/or out of the scope in EnVIE. Tobacco smoke is not addressed here because of the recent bans and even more because, if considered it will tend to hide all other impacts. Outdoor air was not object of EnVIE because it is covered by actual existent European air quality policies that control urban outdoor air concentrations.

Figure 2. The EnVIE Concept

4. The State of Knowledge

4.1 Health Effects and Risk Assessment

Much work has been done to assess the exposure of individuals to particular indoor air pollutants and to evaluate the risks to health of such exposures. Such understanding is a prime prerequisite for policy formulation. Research of this nature involves monitoring indoor environments and assessing personal exposure; toxicological assessment of chemical hazards; monitoring health effects related to the indoor environment (either *in situ* or in experimental studies); and health impact assessment. The risk assessment process is crucial and involves the identification of factors that have an impact on health and well-being of occupants, quantification of human exposure to these factors, assessment of human responses to these factors, and characterisation of risk. Risk assessment can then lead to specific recommendations for control, mitigation and/or remediation, or more general policy recommendations for improving IAQ through identified management options.

Effective action is best achieved if it is based on good scientific evidence, but there are other important considerations in the establishment of indoor air policy, including the *precautionary principle*, the *principle of individual responsibility*, the *cooperation principle*, the *'polluter pays' principle*, the *'right to know' principle*, and the *limitations of action principle*.

Risk management for IAQ can involve regulatory or non-regulatory strategies. Examples of possible regulatory strategies include bans of chemicals or products, emissions limits, labelling requirements, exposure limits, building design standards, building operation and maintenance requirements, and ventilation standards. Non-regulatory approaches include the production of guidelines and guidance, labelling schemes, market and fiscal incentives, population information campaigns, training and education of involved parties, and support of sustainable non-polluting technologies.

A number of reports have been published that provide useful information and pointers on indoor air policy setting. These include '*The Right to Healthy Indoor Air*' (WHO, 2000b), '*Strategic approaches to indoor air policy-making*' (WHO, 1999), and the various publications of the European Collaborative Action on "Urban Air, Indoor Air and Human Exposure" (ECA reports 1-26) and the series of reports from the "*Pilot study on indoor air quality*" by the NATO Committee on the Challenges of Modern Society (e.g. NATO CCMS, 1994).

Millions of Europeans spend more than 90% of their time indoors - at home, in the office, factory, school, restaurant, theatre, etc. The combination of the generally higher indoor concentrations and the overwhelming fraction of time spent indoors results in the overall domination of indoor air in air pollution exposures and, thus, their respective health consequences. Indoor air pollution may impair productivity, cause or aggravate illnesses, increase mortality, and have major economic and social impacts.

The identification of the main health effects was achieved in the context of EnVIE through review of the literature and of the results of some of the most important European and International projects dealing with IAQ - namely ECA reports, the INDEX project (Kotzias *et al.*, 2005), SCHER opinion on indoor air (SCHER, 2007), THADE project (Franchi *et al.*, 2006), VITO report (De Brouwere *et al.*, 2007), US National Occupational Research Agenda on Indoor Work Environments (Mendell *et al*., 2002), and the WHO working group on IAQ guidelines (WHO, 2006a). The results of, and reference to, these and a large number of other studies were reviewed in the EnVIE WP1 Report on Health effects (Carrer *et al*., 2008).

Based on this review the following diseases have been prioritised as being caused or aggravated by poor IAQ: allergic and asthma symptoms; lung cancer; chronic obstructive pulmonary disease (COPD); airborne respiratory infections; cardiovascular mortality and morbidity; odour and irritation (SBS symptoms).

4.1.1 Allergic and asthma symptoms

Asthma, allergy and airway hyper-reactivity are increasing throughout Europe. Asthma affects between 3% and 8% of the adult population in Europe, and the prevalence is even higher in infants; the ISAAC study (International Study of Asthma and **A**llergies in Childhood) reported that in children of the European centres involved in the study the prevalence of asthma symptoms ranged from 2.5 to 37% (Beasley, 1998). Asthma places a high burden on the health care systems in many European nations. In the UK and Republic of Ireland, there are over 4 million primary health care consultations for asthma each year. In the Netherlands it has been estimated that the annual direct medical cost per person with asthma is about US$500, while in Switzerland there are over 40,000 hospitalizations for asthma annually, representing the largest category of direct medical expenses related to the disease.

Allergic diseases are believed to be caused by complex interaction between genetic factors and environmental exposures. Asthmatic patients are sensitive to allergens present in indoor environments and are often hyper-reactive to a number of gases and particles. Key agents in the indoor environment that may have a role in the development of allergy and asthma include microbial, chemical agents and particles:

Microbial agents – Agents that may have a role in the development of allergy and asthma include endotoxin of Gram negative bacteria, fungal spores and fragments, bacterial cells, spores and fragments and microbial metabolites, and allergens derived from house dust mites, pets (dog, cat) and fungi (Ahlbom *et al*., 1998). The evidence for a causal link between dampness and “mould” and risk of allergy and asthma is strong, but the causal links are yet to be determined.

Chemicals - Chemicals that may play an important role in triggering asthma symptoms include in particular formaldehyde. Aromatic and aliphatic chemical compounds, phthalates or plastic materials and indoor chemistry products resulting from ozonolysis of terpenes may also play a role, but the evidence is more limited (ECA, 2007).

Particles - **ETS** and indoor ultrafine particulate matter may play an important role in triggering asthma symptoms (Strachan DP, 2000), as well as wood or oil smoke, soot, or exhaust.

4.1.2 Lung cancer

In the EU, lung cancer is the most common cause of death from cancer. It is estimated that about 20% of all cancer deaths in the EU in 2006 were due to lung cancer and that 236,000 lung cancer deaths occurred (Ferlay *et al*., 2007).

The majority of the cases is due to active smoking, but a not negligible proportion of the disease also occurs in persons who have never smoked. Available data in the literature indicate the role of the following indoor pollutants:

Radon - Radon is considered to be the second most important cause of lung cancer. From the pooling of 13 residential radon epidemiological studies in 9 EU countries it has been estimated that about 9% of lung cancer deaths may be attributed to radon exposure in the home (Mc Laughlin and Bochicchio, 2007).

Environmental Tobacco Smoke (ETS) - ETS has been classified as a Group 1 carcinogen by IARC*[†]. Studies conducted in the '90s have elucidated the relationship between exposure to ETS from spouse and lung cancer risk. The derived relative risks (RR) are 1.36 for men and 1.22 for women; the proportion of lung cancer cases attributable to ETS is about 0.5% in males and 4.6% in females. The largest burden of attributable cases derives from Western and Southern Europe (Hackshaw *et al*., 1997; Boffetta *et al*., 1998).

Combustion particles **–** Epidemiological studies suggest that lung cancer incidence increases as a consequence of long-term, low PM levels. Estimates indicate that each 10 $\mu g/m^3$ elevation in $PM_{2.5}$ is associated with approximately a 14% increase in lung cancer mortality.

4.1.3 Chronic obstructive pulmonary disease

COPD is a chronic respiratory disorder responsible for a major burden to society worldwide. Current estimates indicate COPD as the fifth leading cause of global morbidity. WHO predicts that COPD will become the third leading cause of death worldwide by 2020 (WHO, 2004; Annesi-Maesano *et al*., 2006; de Marco *et al*., 2007).

Variable definitions and lung function criteria for COPD have made it difficult to quantify the prevalence of the disease around the world; moreover, a large proportion of patients with COPD in the community remain undiagnosed. The European Lung White Book (ERS, 2003) reports the prevalence of clinically relevant COPD in Europe to vary from 4 to 10% of the adult population.

Active smoking is the most important risk factor for COPD. It has been estimated that about 70% of COPD related mortality is attributable to cigarette smoking.

A not insignificant proportion of the disease also occurs in persons who have never smoked; the prevalence of COPD in never-smokers in studies performed in different European countries varied from 4 to 20%.

Available data in the literature indicate that the following indoor pollutants may be related to the presence of COPD or its development:

Environmental tobacco smoke - ETS exposure may increase the frequency of respiratory symptoms in adults, and that these effects are estimated to be 30-60% higher in ETS exposed compared to unexposed nonsmokers. Significant relations between ETS exposure and COPD development have been found in the elderly, too, with an OR range of 1.68-5.63.

Combustion particles - Particles from outdoor pollution and by wood and biomass combustion: the estimation of the risk by biomass use for COPD results in ORs of 1.8 (1.0-2.8) in males and 3.2 (2.3-4.8) in females

Mould/dampness - The exposure to mould/dampness is linked to higher risk for cough, phlegm, or dyspnea in adults (de Hartog *et al*., 2005; Alipour *et al*., 2006; Gea, 2006; Simoni *et al*., 2007).

[†]IARC - International Agency for Research on Cancer

4.1.4 Airborne respiratory infections

Microbiological contamination of indoor environment is common and can provoke infectious diseases, especially in susceptible people. The most common route of transmission is airborne - person to person or from a source, in particular from aquatic systems like cooling towers and humidifiers.

The infection diseases can include:

- well-known infections like Legionnaire's disease (the incidence of Legionnaire's disease increased from 360 cases in 2000 to 765 cases in 2005), tuberculosis, influenza and common cold,
- new threats like severe acute respiratory syndrome (SARS).

The symptoms of airborne infectious diseases can be aggravated by exposure to environmental tobacco smoke and combustion particles.

4.1.5 Cardiovascular morbidity and mortality

Cardiovascular disease (CVD) is the leading cause of death in the industrialized world: CVD accounts for over 4.35 million deaths (49% of all deaths) each year in Europe and over 1.9 million deaths (42%) in the European Union (EU). The pollutants are:

ETS - Reviews of epidemiological studies on the association between ETS and increased risk for CVD have concluded that the risk estimate for CVD related to ETS exposure is about 25-30 (He *et al.*, 1999).

Particles - Several studies have shown a link between outdoor particulate matter (PM) and gaseous pollutant exposure and cardiovascular disease mortality and morbidity (Brunekreef *et al.*, 2002). Short-term effects of PM_{10} exposure include an increase in overall cardiovascular mortality. Long-term exposure to $PM_{2.5}$ has been demonstrated to be independently related to cardiovascular mortality in general, and to mortality from ischemic heart disease, arrhythmia, heart failure and cardiac arrest in particular. Current evidence suggests a link between exposure to indoor PM and cardiovascular disease onset, but more research is needed. Also there is a need to identify the role of the ultrafine fraction.

CO - At CO levels typically encountered in indoor environments, cardiovascular health effects are most likely to occur in hypersusceptible individuals (i.e. patients already suffering from CVD or respiratory diseases). It has to be underlined that the health effects associated with inhaled CO vary with concentration and duration of exposure. Effects range from subtle cardiovascular and neurobehavioral effects at low concentrations to unconsciousness and death after acute exposures to high concentrations of CO (Raub *et al.*, 2002). Chronic exposures to low CO concentrations may pose a problem in term of risk factors for CVD or undiagnosed neuropsychological sequelae but there is not enough reliable information on these effects. Although the annual number of deaths due to indoor CO poisoning has decreased in Europe in the last decades, CO exposure still represents a major public health issue.

4.1.6 Odour – Irritation (SBS symptoms)

Indoor air pollutants can often cause unspecific effects. A multitude of biological mechanisms are involved at the same time in the responses to multiple exposures indoors, and only few objective measurements are available (Berglund *et al*., 1992; Dalton, 1999; Chao *et al*., 2003; Fanger, 2006).

The most frequent effects include acute physiological or sensory reactions, psychological reactions, and sub-acute changes in sensitivity to environmental exposures. The term Sick Building Syndrome (SBS) is used to describe cases in which building occupants experience acute symptoms and discomfort that are apparently linked to the time they spend in the building, but for which no specific illness or cause can be assigned (Fang *et al*., 2004). Many different symptoms have been associated with SBS, including respiratory complaints, irritation, and fatigue. Sensory perception of odours and mucous irritation lead to perception of poor air quality and possible risks thereof, and consequently to stress or behavioural responses (opening a window, leaving the building). Other environmental stressors such as noise, vibration, crowding, ergonomic stressors and inadequate lighting can produce symptoms that are similar to those of poor air quality. Recent studies have also shown negative effects of IAQ on office productivity and school learning (Wargocki *et al*., 2000; Seppänen and Fisk, 2004).

The fraction of the incidence/prevalence of reports of discomfort and symptoms that can be related to IAQ is not exactly known. However, in buildings without specific complaints of poor IAQ the prevalence is often close to zero and normally below 30% of the occupants. In affected buildings the prevalence often ranges between 50 and 100% of the occupants.

The relevant indoor air pollutants that can cause these effects are those which alone or in combination, can stimulate the senses or cause tissue changes, and include in particular volatile organic compounds, viable or non-viable microbial aerosols and particulate matter. The risk factors also include physical aspects such as ventilation and related air velocity, humidity and temperature.

4.2 Exposures of Interest

European indoor air pollution data is compiled from a multitude of sources. The EXPOLIS study (Jantunen *et al*., 1998) was performed simultaneously and with identical equipment and work protocols in seven European cities. The project had personal exposure as its main target, but in order to understand and develop modelling capability for personal exposures, residential indoor and outdoor and workplace concentrations of a wide selection of particulate and volatile air pollutants were also monitored.

The German Environmental Survey (GerES) (Seifert *et al*., 2000) and the French Indoor Air Observatory projects both provide nation-wide representative indoor air quality data. The German study has been repeated 4 times between 1985 and 2006, and, therefore, it provides a unique set of data over time for the assessment of indoor air pollution trends. The EC's Joint Research Centre has performed four exposures to VOCs studies in urban environments, which cover a range of European cities and have included residential indoor air monitoring of both, residential and public buildings. These studies are: MACBETH (Cocheo *et al*., 2000), AIRMEX (Kotzias *et al*., 2005), PEOPLE (Ballesta *et al*., 2006), and the European Parliament Pilot Project on "*Exposure to Indoor Air Chemicals and Possible Health Risks*" (Geiss *et al*., 2008). The EC Audit study (Bluyssen et *al*., 1996) focused on a small number of office buildings in 9 European countries, and the English ALSPAC indoor air study was a 3-years follow up of the homes of 170 pregnant women and new born babies in Avon, UK. In addition, there are a few studies which have not generated new data, but instead collated IAQ data from previous studies, surveys and databanks (THADE, INDEX, VITO, RADON). The results of, and reference to, these and a large number of other studies were reviewed in the EnVIE WP-2 Report on Exposure (Jantunen et al., 2008).

The EnVIE indoor air exposures of concern are drawn from the EnVIE concept and include also the high priority chemicals listed in the "Recommendations" chapter of the Final Report of the (DG SANCO funded and JRC/IHCP coordinated) INDEX project ("*Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits in the EU*") (Kotzias *et al*., 2005). The current exposures of interest cover also radiation (radon), mixtures (combustion particles) and microbes, not included in the INDEX project, which restricted its focus to chemicals not covered by specific policy regulations in the EU. The list below contains ETS, which overlaps with many of the other exposures. The justification for ETS is, naturally, its source, tobacco smoking, and respectively unique control options.

- particles, from indoor and outdoor sources,
- environmental tobacco smoke,
- carbon monoxide and nitrogen dioxide (from DG SANCO/JRC INDEX),
- radon,
- microbes, allergens,
- formaldehyde (from DG SANCO/JRC INDEX),
- benzene (from DG SANCO/JRC INDEX),
- naphthalene (from DG SANCO/JRC INDEX).

This is by no means an exhaustive list of indoor air contaminants and exposures, nor is it intended to be. It does, however, represent a list of high priority indoor air contaminants, effective control of the sources of which is likely to control a variety of other contaminants from the same sources.

4.2.1 Particles, including environmental tobacco smoke

Based on 14 studies in 12 European countries published since 1996, it can be concluded that indoor air PM levels (in the absence of indoor combustion and smoking) are normally somewhat lower than ambient air levels, containing more coarse mineral particles (from indoor sources) and less secondary and combustion particles (from outdoor sources) than outdoor air at the same location. The contributions of indoor sources to indoor PM levels vary from a few per cent to about one third, depending as much on the indoor sources [numerator] as the level of outdoor PM that penetrates indoors [denominator].

Based on these and 7 further studies, indoor smoking or other indoor combustion sources can increase the indoor source contribution to indoor PM levels by 50% or more - i.e., when present, ETS is usually the dominating source of indoor air PM. ETS is usually also the main contributor to indoor pollution levels of formaldehyde, benzene and polyaromatic hydrocarbons including nicotine.

Indoor air nicotine can be considered the most specific marker of ETS. In the absence of physical barriers, no substantial differences have been seen between designated smoking and non-smoking areas in restaurants and hospitals.

4.2.2 Carbon monoxide and nitrogen dioxide

In current day European cities ambient air CO levels are quite low, rarely coming even close to air quality standards or WHO Guideline values. The highest reported CO levels originate from indoor sources and have been observed in public or residential garages [and primitive kitchens when cooking with open fire, e.g. in Guatemala], the lowest concentrations in churches and schools with no indoor sources.

In the absence of indoor combustion sources the residential indoor CO levels vary in a narrow and low range even when comparing different countries and cities – according to 15 studies and including 7 European countries.

Short time peak indoor air concentrations of CO have been published in few cases only, and the results have varied over a wide range. Such concentrations originate from indoor combustion devices which are either unflued (e.g. gas fired hot water heaters and baking ovens) or the flue is shut before combustion process is terminated (e.g. fireplaces), or from exhausts gases of internal combustion engines of e.g. electric power aggregates. CO intoxications are mostly caused by such accidentally induced or repetitively generated high short term peaks – orders of magnitude higher than the monitored concentrations – which are hardly ever captured in direct measurement, but can sometimes be evaluated from blood haemoglobin levels.

NO_2 is an extensively studied (outdoor and) indoor air pollutant in Europe and elsewhere. Gas cookers and gas heaters without exhaust hoods are important sources of indoor air NO_2. Consequently the highest indoor exposures are usually experienced in kitchens rather than bedrooms and living rooms.

NO_2 concentrations show notable geographical differences – also indoors. This is mostly due to the different level of residential gas use, different standards for the gas appliances and different ventilation standards and practices. For instance, if exhaust duct of a gas heater is led to the outdoor air just under the window sill the combustion products easily re-enter the room resulting in high NO_2 level – let alone the multitudes of gas appliances that have no exhaust hoods or ducts at all.

Many of the reported short term indoor NO_2 values have been close to or exceeded the WHO annual average limit value (40 $\mu g/m^3$). Yet, because NO_2 is a reactive gas, indoor air NO_2 levels stay often below the ambient air levels even in homes with gas cookers and heaters.

4.2.3 Radon

Radon concentrations indoors vary hugely between European countries and between individual residences. The lowest national averages are found in Cyprus and the Netherlands (7-23 Bq/m^3) the highest in Sweden, Luxembourg, Albania, Estonia, Finland and the Czech Republic (108-140 Bq/m^3). The highest levels measured in individual residences, however, exceed 10000 Bq/m^3 in at least eight European countries, including some with very low average levels. Consequently a low (or high) national or even local average level is no proof of a low (high) residential level. The only method of predicting the radon level for a new building site is to measure soil radon concentration, and the only method of estimating the level in a building is to measure it.

Certain basic constructions, however, are more prone than others to high radon concentrations. Concrete slab against dry and porous mineral soil, and tight building envelope combined with depressurisation by mechanical extract ventilation may lead to high indoor radon level. Ventilated airspace between ground and the ground floor, a balanced ventilation system and, obviously, location of the rooms or residences at elevated levels of a multi-storey building usually lead to lower indoor radon levels.

4.2.4 Formaldehyde

Formaldehyde (HCHO) is another extensively studied indoor air pollutant. Unlike PM and NO_2 almost all indoor air HCHO is of indoor origin; outdoor levels are typically an order of magnitude lower than even low indoor levels.

Data for population representative indoor air formaldehyde measurements in European are quite scarce considering that formaldehyde is the indoor air pollutant which has been acknowledged and measured for decades across Europe. It remains one of the most common indoor air pollutants with verified acute and chronic health effects.

Building materials and furniture are the main sources of formaldehyde and the maximum values measured indoors vary extensively, as can be seen from the results from Germany (GerEs study, Seifert et *al.*, 2000) and France (French Indoor Air Quality Observatory-study, Kirchner et *al.*, 2006). Some of the maximum values exceed the occupational exposure limit (8 h average). Several of the maximum values exceed the LOAELs[‡] for less serious symptoms from acute and chronic exposure, possibly causing irritation to eyes and nose and memory problems. Exceedances of both the WHO (2000a) and INDEX (Kotzias *et al*., 2005) short term guideline values (respectively, 100 μg/m^3 and 30 μg/m^3 or ALARA[§]) appear to be quite common.

4.2.5 Benzene

Benzene is another extensively studied contaminant in indoor air and personal exposure across Europe. ETS is a highly dominating source, but even in its absence there are significant benzene sources in indoor as well as outdoor environments; excluding ETS typically less than half of benzene exposure originates from indoor sources. This proportion, however, varies greatly across European countries, possibly due to the uses of different building and furnishings materials and household chemicals. Indoor benzene exposure levels are almost always too low to cause any concerns other than those related to its carcinogenicity. Exceedances of the EC Air Quality Standard for benzene, 5 μg/m^3 as annual average, is quite common in residential indoor spaces, and in many cities even the average levels exceed 10 μg/m^3.

4.2.6 Naphthalene

Measured indoor naphthalene levels from a representative sample of residential indoor environments in Europe are available for only six EXPOLIS cities. The typical low levels of ca. 1 μg/m^3 usually originate from outdoor air, but the high levels, which may reach several hundred μg/m^3 originate almost exclusively from the use of crystalline naphthalene moth repellents. The INDEX long term guideline value for naphthalene, 10 μg/m^3, is hardly ever exceeded indoors in the absence of intentional naphthalene usage.

[‡] LOAEL - Lowest-Observed-Adverse-Effect-Level

[§]ALARA - As Low As Reasonably Achievable

4.3 Causes and Sources of Indoor Air Contamination

Many building materials release gaseous, vapour phase or particulate contaminants into indoor air. Both natural and man-made materials exhibit such releases. Examples include terpenes and formaldehyde from fresh wood and monomers and phthalate plasticisers from man-made polymers. Some releases are caused by inherent decay of the material, such as formaldehyde from chemically unstable urea-formaldehyde resins and vapour phase irritants from the slow oxidation of aging linoleum, while some result from moisture induced reactions, such as ammonia release from the degradation of wetted casein containing fillers. Releases are not necessarily inherent for a certain material, such as PVC tiles or latex paints; rather it is the quality of the specific product brand and batch - e.g. its monomer residue level or physical durability - that may critically determine the exposure of the occupants. The emissions from a material may not be due to the material itself, but instead to chemicals used to treat it, for example to reduce fire hazard (e.g. PBDE in furniture, carpets and appliances) or to prevent mould growth - i.e. for purposeful beneficial purposes in their own right. Releases from some building materials may decay in days or weeks, such as the smell of fresh wood or new carpet, while others may persist as long as the material is present. There are materials which exhibit inherently low emissions, such as stone, glass and stainless steel in the extreme, but these cannot be used for everything.

Some releases may be toxic, allergenic, and odorous or irritating, others are - so far as is known at present - harmless and innocuous at the levels to which we are presently exposed.

The huge qualitative and quantitative differences in the releases and their health effects (if any) set remarkable challenges for the regulators and industry concerning how to measure, test and report the releases, how to judge the data, and how to select and best use the materials considering both long and short term risk and benefits.

The focus here is on the sources that have been identified in the EnVIE concept and cover factors, from outdoor air quality to occupant activities that may affect the quality of indoor air with respect to the previously defined exposures of interest. The dividing line between building equipment and furnishings is rather imprecise; in the current report equipment is considered to be fixed into the building and serves its basic functions as a building while furnishing includes everything else, fixed or portable. Consumer products are considered transient sources as opposed to equipment which is more or less permanent.

These topics generate a quite exhaustive list of indoor air pollution sources and, respectively, control options. The connections of sources and exposures form a matrix, which can be seen at the lower part of Figure 2, and is presented in the level of detail of the current report in Table 1. The results of, and reference to, these and a large number of other studies were reviewed in the EnVIE WP3 Report on Sources (Oliveira Fernandes *et al*., 2008).

Table 1. Matrix of the links between the indoor air exposure agents and the sources contributing to these indoor exposures

Sources/controls for indoor air pollution	Considered exposure agents							
	ETS	Combustion PM	$CO\&NO_2$	Radon	microbes, allergens	HCHO	Benzene	Naphthalene
Outdoor air								
Implications for air cleaning needs & indoor pollution dilution		X	X				X	
Buildings / fixed equipment / ventilation								
Building materials				(X)		X	X	X
Ventilation and air conditioning systems	X	X	X	X	X		X	
Fixed household equipment/appliances		X	X		X			
Heating systems		X	X					
Water systems					X			
Dampness and mold					X	(X)		
Consumer products used in buildings								
Furnishings and electrical (computing & entertainment)		X				X	X	(X)
Cleaning and household products						X		X
Occupant behaviour								
Maintenance, ventilation practices		X	X	X	X			X
Smoking, cooking	X	X	X		X	X	X	

4.3.1 Emissions from building construction

4.3.1.1 Building materials

Emission of chemical substances from construction materials and products in buildings to the indoor air have been reported and reviewed (Gustafsson, 1992) for a wide range of substances, including those formed during secondary reactions causing complaints of irritation and odour.

Since materials in building structures, and especially those applied to indoor surfaces in large quantities, is permanently exposed to indoor air, it is crucial to have an understanding to what extent they contribute to indoor air pollution. The releases of chemical substances from building and interior surface materials have been measured in, and reported from, numerous laboratory investigations. Theoretical models for the process of release of substances from materials have been formulated. In order to be able to compare emission rates from different materials it is essential to measure them under controlled conditions in climate chambers (ISO 16000- 9-11).

Various materials have been reported as long-term emission sources in buildings, e.g. paints, products based on coal tar and different polymeric materials. In some cases, the emissions have been caused by moisture-induced degradation of materials. During the last few years practical examples of the development of various low-emitting materials have been demonstrated (Gustafsson and Jonsson, 1999).

There are a high number of different building materials and it is difficult to group them in classes, but in this report they will be grouped by function/type materials.

Synthetic materials **-** During the last two decades there has been increasing advances in construction technology that have caused a much greater use of synthetic building materials. Whilst these improvements have led to more comfortable buildings, they also provide indoor environments with contaminants in higher concentrations than are found outside. Polymeric materials are usually products based on petroleum hydrocarbons. The polymer itself is not volatile, due to its high molecular weight. Polymeric materials may emit various process solvents and residual monomers remaining from the raw materials for polymerisation (Gustafsson, 2007).

Long-term emission of volatile residual monomers have been reported from paint (ethylhexylacrylate), carpet (styrene), glass-fibre-reinforced polyester fabric (styrene) (Wolkoff and Nielsen, 1985), rubber floor covering (styrene) (Wolkoff, 1990) and plastic-laminated cork tiles (phenol). Plasticized products such as PVC are used as floor and wall covering materials and are recognized as sources of phthalate esters indoor (Afshari et *al*., 2004). There is some epidemiological evidence for associations between phthalates or and allergic symptoms in the airways (e.g. asthma), nose and skin. (Sundell *et al*., 2007). Various process solvents (dodecene, dodecylbenzene, TXIB® - 2,2,4-trimethyl-1,3-pentanediol diisobutyrate) have been reported to give rise to emission from, for example, vinyl floor coverings.

Materials based on natural raw materials - Wood and cork are now frequently used as a building product for floor coverings, because the material is often regarded as “natural” and “healthy”. However, industrial products even based on natural raw materials may contain a number of artificial ingredients and the chemical emissions will strongly depend on the type of additives and the manufacturing process.

Horn *et al*. (1998) have reported high emissions of furfural and acetic acid from composite cork products. From chamber experiments it was concluded that furfural is not present in natural cork. Both substances are produced under thermal stress from degradation of hemicelluloses. Acetic acid results from elimination of acetyl-groups, while furfural is formed from pentoses and hexoses under elimination of water. The high concentrations of acetic acid and furfural result from the manufacturing conditions. But the emissions of furfural and acetic acid are not exclusively limited to cork products, being also measured in considerable amounts (1000 $\mu g/(m^2h)$) during chamber studies on particleboard (Salthammer and Fuhrmann, 2000). This effect is attributed to increased temperatures during the manufacturing process.

Adhesives like urea-formaldehyde (UF) and phenol-formaldehyde resin binders are widely used as a major component in the production of building and furniture materials, such as medium density fiberboard (MDF), particleboard (PB) and plywood. However, decreasing the emission levels of formaldehyde fumes from PB manufactured using UF resins has now become one of the major concerns of the timber and wood adhesives industry, particularly in the case of adhesively bonded wood products (Kim *et al*., 2007).

Interior paints and varnishes **-** Modern interior paints are usually based on a polymeric binder. In order fulfil requirements for durability, etc., paints contain various functional chemicals. Water-borne paints usually also contains small amounts of approved [98/8/EEC] biocides. Polymeric binders with a very low content of residual monomers have been developed for paint (Gustafsson and Jonsson, 1999).

Some water-borne paints and varnish have been giving rise to long-term emissions even after the drying-phase. Examples on substances emitted during several months after the application of the paint are Texanol® (2,2,4-Trimethyl-1,3-pentanediol monoisobutyrate (Wolkoff *et al*., 1990; Lin and Corsi, 2007), butyl acetate (Schriever and Marutzky, 1990) and dibutylpthalate (Risholm-Sundman, 1981). Alkyd paint has been reported (Seifert and Ullrich, 1987; Ullrich *et al*., 1982) to emit hexanal and other aldehydes during the oxidative hardening process of the alkyd binder. The study conducted by Chang and Guo (1998) shows that the alkyd paint itself contained no aldehydes and indicated that the aldehydes emitted (mainly hexanal, propanal and pentanal) should be produced after the paint was applied to a substrate, formed as by-products from spontaneous autoxidation reactions of unsaturated fatty acids (in the applied paint) with atmospheric oxygen. In a similar way, linseed oil also hardens by the formation of cross-bonds between high-molecular acids. Paint with linseed oil as a binder, and also linoleum, therefore also forms volatile aldehydes during the oxidative hardening. Another indoor source for aldehydes is wood-based materials in furnishing (Wolkoff *et al.*, 1990).

Products based on coal tar - Coal tar is a viscous liquid formed from the carbonization of coal. Many commercially important substances are derived from coal tar. Coal tars are complex and variable mixtures of phenols, polycyclic aromatic hydrocarbons (PAHs) and heterocyclic compounds. In construction, coal tar products have previously been used as damp-proof membrane applied to concrete floors, roofing, road paving and as solvent for impregnating wood materials. Creosote is obtained by dry distillation of coal tar and is mainly composed of PAHs, but also contains phenols and cresols. For more than a century, creosote has been a common preservative for construction timber though it is nowadays forbidden (2001/90/EC) to use creosote-impregnated timber for residential buildings. Construction timber impregnated with creosote has also been an indoor source for naphthalene.

Damp-proof membranes containing coal tar have been reported to give rise to emission of naphthalenes in residential buildings (Brown *et al.*, 1990). As noted above, mothballs can be a potent indoor source of naphthalene (Edwards *et al.*, 2005). Coal tar has been used as solvent in preparations with chlorinated substances intended for impregnating and eliminating fungi in wood constructions and wood-derived materials in fibre boards, for example. Several volatile substances such as naphthalene and chloronaphthalene have been prevalent in the indoor air in various premises where this kind of preparation ("Xylamit") has been used (Deptula *et al.*, 2007).

4.3.1.2. Interactions in building materials

Moisture induced degradation of materials: Besides the release of substances into the indoor air by primary emission, damp building materials may give rise to volatile substances formed during secondary reactions.

Damp mineral wool in exterior walls and roofs can release aldehydes to the indoor air (van der Wal *et al.*, 1987). The aldehydes, ranging from pentanal to decanal, are probably formed by microbial growth. Linoleum can release aldehydes and odorous carboxylic acids, especially if incorrectly wet-washed by the use of excessively strong detergent, which damages the surface layer of the floor covering (Wolkoff *et al.*, 1995).

Self-levelling flooring compounds based on Portland cement and containing casein as a levelling agent may give rise to odorous substances when laid on a damp sub-floor. Casein breaks down to form volatile amines such as cadaverine (Karlsson *et al.*, 1989). Another breakdown substance of casein, ortho-aminoacetophenone, has a very unpleasant odour that can be recognised at concentrations as low as of the order of nanogram/m^3. It is formed as a result of the breakdown of the amino acid tryptophane in the casein. Portland cement based casein-containing self-levelling compound may also release ammonia, which is capable of discolouring oak parquet laid on top of it (Gustafsson, 1996).

Another example for the release of volatile products from rather non-volatile precursors is the release of halogenated compounds from phosphorous-organic flame retardants. 1-chloro-2-propanol, 2-chloro-1-propanol and 1,3-dichloro-2- propanol can appear in indoor air samples from hydrolysis of the common flame retardants tri(chloropropyl)phosphate (TCPP) and tris(dichloropropyl)phosphate (TDCPP), respectively (Salthammer *et al*., 2003b, Uhde and Salthammer , 2007). The later requires increased attention since 1,3-dichloro-2-propanol has been acknowledged as a carcinogenic substance.

A completely different indoor contamination source is glue based on urea-formaldehyde (UF). The stability of these UF polymers against water is low. Therefore, the presence of the unavoidable amounts of water leads to a hydrolysis of the N–O bond and, as a consequence, to the release of formaldehyde. Since UF glues are commonly used in the manufacture of both building materials and furniture the loading factor of such products can be quite high in housings and offices. Especially the application of water-based flooring adhesives on UF-bonded particleboard may cause high and long term emissions of formaldehyde (Uhde and Salthammer, 2007).

The increase of the humidity can also be an indirect factor on the emission of new compounds as they may cause an increase in biological agents as house dust mites, fungi and bacteria. It is known that some examples of building materials, when attacked by fungi, emit odorous VOCs, the so-called MVOC (Microbiologic Volatile Organic Compounds) that result from their metabolism (Norback, 1995; Smedje *et al*., 1996; Thogersen *et al*., 1993; Rocha *et al*., 1996; Clausen and Oliveira Fernandes, 1997). In a more recent paper, the formation of metabolites from biological materials has been reported in detail by Fiedler *et al*. (2001) that have identified about 150 MVOCs from 12 types of mould.

Chemical degradation of flooring materials on damp alkaline concrete: Moisture induced chemical degradation of vinyl flooring and floor adhesive may give rise to the formation of odorous alcohols (mainly C10 - C12) if laid on damp alkaline concrete. The phthalate plasticizer content in resilient vinyl floor coverings can amount to 30% of the weight of the material. The chemical degradation of the plasticizer is strongly accelerated by the presence of alkali. In addition, phthalate plasticizers can contain small traces of alcohol components.

The types of adhesives most commonly used for laying floor coverings are dispersion-based. This type of adhesive is often based on acrylate copolymers of ethylhexacrylate. 2-ethylhexanol is a feedstock material (an estering alcohol) for the manufacture of ethylhexylacrylate. As is the case with plasticizers, ethylhexylacrylate can be hydrolysed by damp alkaline concrete, reforming the odorous alcohol.

Vinyl floor coverings containing phosphorus plasticizer are used in premises with particularly stringent fire safety requirements. The hydrolysis of this type of plasticizer specifically gives rise to the formation of phenol and cresol (Gustafsson, 1992).

Indoor surface chemistry - Weschler and Shields (1997) resumed the indoor chemistry: ‘‘From a chemical perspective, the indoor environment is a reaction vessel with chemicals continually entering and exiting. Some of these chemicals can react with one another (or themselves) creating reaction products that might otherwise be absent from the indoor setting. Many of the resulting products are more reactive and/or irritating than their precursors’’. Indoor air contains many highly reactive molecules and radicals such as ozone (O_3), nitrogen oxides (NO_x), hydroxyl radicals (OH) and sulfur dioxide (SO_2), that are either introduced from the outside air or generated directly indoors by human activities (photocopiers, laser printers, gas cookers, UV lighting, etc.).

There have been several investigations of the interaction between O_3 and surfaces. The experimental investigations on the topic of indoor chemistry became known at the beginning of the 1990s by the work of Weschler *et al*. (1992) on aldehyde emission from carpet in the presence of ozone. They observed a significant decrease of compounds containing double bonds like styrene and 4-phenylcyclohexene, but also an increase of oxidation products like aldehydes. Morrison *et al*. determined that carpet exposed to a mean indoor concentration of 2.7 ppb O_3 could result in long-term (years) emissions of aldehyde and ketone species (Morrison and Nazaroff, 2000, 2002[a,b]). Secondary organic aerosols were measured as a product from ozone-initiated reactions with emissions from wood-based materials and a ''green'' paint (Toftum *et al*., 2008).

Another problem might become dominant when components of different materials can react with each other. Many building materials, furnishings and household products demonstrate emission of volatile organic compounds (VOCs) during usage (Uhde and Salthammer, 2007). Typical reaction products are aliphatic aldehydes, 2-ethyl-hexanol, MIBK and photoinitiator fragments, while acrylic monomers, reactive solvents, terpenes and diisocyanate monomers are reactive species. Especially such substances may affect humans due to low odour thresholds or low TLV-levels (Salthammer *et al*., 1999).

Another identified problem become from the use of cure- UV during manufacture of some building materials and the role of light in increase of secondary emissions (Uhde and Salthammer, 2007). In many countries, legal requirements regarding the consumption and release of volatile solvents have encouraged manufacturers of coating systems to introduce more and more UV-curable formulations. The technique reduces the amount of solvents required for the coating of metal, wood or other materials significantly and can even be utilized for powder-based systems. Photoinitiators start the curing process and are essential ingredients of UV-curable coating systems. However, photoinitiators are usually overdosed to avoid undercuring of the lacquer film and a certain amount of residual photoinitiator is left in the finished product after curing.

Recently, new photocatalytic paints have been launched on the market, which are claimed to have air-purifying effects. A study carried out by Auvinen and Wirtanen (2008) shows that photocatalytically active paints were able to decompose only more reactive VOCs (1-hexanol and nonanal), but at the same time they also generated, for instance, formaldehyde, acetaldehyde, and acetone that may cause adverse health effects in people.

***Release and sorption of semi-volatile organic substances* -** Semi-volatile organic compounds (SVOCs) are now receiving much more attention than heretofore. Their major sources are in the outdoor air (containing contaminants such as pesticides) that may also infiltrate the building giving high level of concentration in the indoor environment. The trend nowadays, with the new building materials becoming cleaner, is that the VOC levels tend to decrease and the SVOC levels tend to increase, reflecting a substitution of VOC with SVOC to decrease exposure concentrations. The use of additives to increase the performance of building materials, as biocides and flame retardants, contribute also to the increase of SVOC emissions. However, the toxicity of the new compounds is unclear and health related criteria for the substitution is lacking (ECA Report 25, 2006).

Release of low-volatility chemical substances from construction materials and products in buildings has been reported, e.g. dibutylpthalate from wall paint (Risholm-Sundman, 1981), TXIB from vinyl floor covering (Rosell, 1990), PCB from paint on ceiling tiles (Todd, 1987) and various hydrocarbons from sealants and rubber floor coverings (Wolkoff, 1990). These SVOCs seem to be largely adsorbed on airborne particles. SVOCs can condense on electronic equipment and cause it to malfunction. Extensive measurements have therefore been made in telephone exchanges and other installations (Weschler and Shields, 1987).

Deposition of SVOCs on dust may lead to significant exposure through inhalation of indoor air. Additive phosphor containing flame retardants (PFR) are ubiquitous substances that appear to be present in all types of indoor environments and identified sources include floor coverings and acoustic ceilings (Hartmann *et al.*, 2004, Marklund *et al.*, 2005). The increasing strictness in regulating the use of additive brominated flame retardants will probably cause a further increase of the use of PFR (WHO, 1997).When dust in residential buildings is heated - e.g. on radiators, refrigerator compressors and incandescent lamps - phthalates and other substances can be released into the air (Vedel and Nielsen, 1984).

4.3.1.3. Decay of emissions in building materials

When an emission has been caused by a chemical reaction in or between building materials, it has often been difficult to document precisely when the elevated rate of emission occurred. The progress of the chemical reactions naturally depends on the materials involved and, in many cases, also on if and when the structure was exposed to moisture (Gustafsson, 1996).

However, when the emission has not been caused by chemical reactions but can be regarded as straightforward evaporation, it will be highest for new (or newly applied) materials. Well-known examples are solvent-borne paint and varnish, from which the volatile substances have largely evaporated after a few hours. Water-borne paints take longer to dry out, and glycol ethers have been found in indoor air six months after the application of paint (Wolkoff, 1990).

Regarding the time course of the reduction of emissions from building materials is concerned, a study in Denmark concluded that for the majority of houses investigated, the indicative sum of volatile substances had halved over periods of 2 to 6 months (Molhave, 1985).

4.3.2. Emissions from HVAC systems

Outdoor and other pollution sources related to ventilation **-** Outdoor air used for ventilation may also be source of pollution containing particulate matter, particulates of biological origin (microorganisms, pollen, etc.) and various gases such as NO_x and O_3. Some O_3 is removed by the contact with building surfaces. In the naturally ventilated buildings all pollutants in the outdoor air enter indoors. In mechanically ventilated building it is possible to reduce concentrations of certain pollutants in outdoor air for ventilation air before it enters indoors, but usually not NO_x and O_3. Daily inhalation intakes of indoor O_3 (μg/day) are estimated to be between 25 and 60% of total daily O_3 intake. This is especially noteworthy in light of recent work indicating little, if any, threshold for ozone's impact on mortality.

The outdoor air intakes should be placed so that the air taken into the building is as clean as possible and in summer time as cool as possible and not polluted by any sources close to the building. Such potential outdoor sources include a garbage collection point, evaporative cooling systems and cooling towers (risk of *Legionella*), busy streets, loading decks, exhaust air openings, biomass burning stoves and boilers, etc. The arrangement of air intakes and discharge openings should also minimize the possibility of external recirculation between polluted exhaust air and clean air for ventilation.

Pollutants in air handling equipment and systems - Several studies have shown that the prevalence of SBS symptoms is often higher in air conditioned buildings than in buildings with natural ventilation (Mendell and Smith 1990; Seppänen and Fisk, 2002). This can be explained by the VOCs and other chemical pollutants that are emitted by HVAC components and ductworks. The emissions may originate from any component in the HVAC system.

The emission of VOCs may increase when the components and surfaces get dirty due to inadequate maintenance. Poor condition and maintenance of HVAC systems has been identified as a risk factor (Mendell *et al*., 2003, 2006). Current findings (Mendell *et al*., 2007) support earlier findings (Mendell *et al*., 2006) that moisture-related HVAC components such as cooling coils and humidification systems, when poorly maintained, may be sources of contaminants that cause adverse health effects in occupants, even if we cannot yet identify or measure the causal exposures.

The European audit project on IAQ (Bluyssen *et al*., 1996), the European Data Base Project on Air Pollution Sources (Clausen and Oliveira Fernandes, 1997) and the European Airless project (Bluyssen *et al*., 2001) have shown that the perceived quality of supply air is not always the best possible, and is often even worse than the perceived quality of outdoor air quality. The perceived air quality of the air supplied to the rooms, however, was usually not as bad as it was immediately after passing through a filter. This may be due to absorption in duct systems or chemical reactions in the air. A recent study (Wargocki *et al*., 2000b) has shown a slightly lower but still significant pollution load from building sources including the air handling systems (0.04 - 0.27 olf /m^2).

The emission of VOCs may increase when the components and surfaces get dirty due to inferior maintenance. This hypothesis is supported by several field studies which have reported the association between the indoor air problems and cleanliness of HVAC system.

One of the most important reasons for duct cleaning is preventive maintenance. Duct cleaning minimizes the possibilities of microbial growth that would be likely in dirty ducts should water leaks or high humidity conditions occur (Luoma *et al*. 1993; Batterman & Burge 1995; Fransson 1996). Another reason is the reduction of odorous compounds in the indoor air. Björkroth *et al*. (1998) showed in a laboratory setting using a trained sensory panel that an old dirty duct and a new not-cleaned duct emitted odour to the supply air whereas a new clean duct absorbed odour from the supply air. Odour generation of dirty ducts increased with air velocity, which also increased the sink effect of the new cleaned duct. Additionally, Björkroth and Asikainen (2000) found a strong correlation between perceived air pollution and the cumulative mass of oil residuals in old ventilation ducts.

Ventilation systems have several other components beside ducts which may act as a source of odours, and their effects on perceived air quality have been investigated in several studies (e.g. Pejtersen *et al*., 1989; Finke and Fitzner, 1993; Tuomainen *et al*., 2000; Alm 2001; Bitter and Fitzner, 2002). The main potential components increasing the sensory load are filters, humidifiers, heating and cooling coils and rotating heat exchangers (Bluyssen *et al*., 2003).

Severe problems are created also with condensation if the components are not properly maintained, drained and cleaned. Improperly maintained condensing cooling coils may be a major source of microbial pollution in buildings. For example a study in Southern California discovered that one third of the cooling coils in the large air handling units and two thirds in the small ones were contaminated in the United States (Byrd, 1996).

Ventilation and spread of contaminants – Ventilation, together with stack effects and wind, affects also the pressure differences over the building structures. Pressure difference is a driving force for the airflows which transport water vapour and gaseous or particulate contaminants.

One of the most important issues in respect of healthy buildings is to keep building structures dry and prevent the condensation of water in and on structures. Air and moisture convection through the building envelope may cause severe moisture loads for the structures. The effect of the pressure differences is utilized in certain spaces which are designed for overpressure in relation to outdoors or adjacent spaces. Clean rooms, rooms for sensitive electronic/data processing equipment and operating theatres in hospitals are examples for such spaces. In situations with no special requirements or emissions, ventilation systems are normally designed for neutral pressure conditions in the building. Pressure conditions should also be continuously monitored in spaces where heavy emission of impurities occurs. The air pressures in stairways, corridors and other passages should be designed so that they will not cause airflows from one room or apartment to another.

The relative pressures of the building, different spaces and the ventilation system should be designed so that spreading of odours and impurities in harmful amounts or concentrations is prevented. No significant changes to the pressure conditions should occur as a result of changes in weather conditions. The air tightness of the building envelope, floors and partition walls, which affect the pressure conditions, should be studied and defined at the design stage, taking account of both temperature and wind conditions. The pressure relationships should be confirmed in the commissioning of the building and periodically re-commissioned to ensure that deterioration of building components or shifting due to thermal, wind or seismic forces has not compromised the envelope tightness or other pressure-critical components.

Low ventilation may lead to high indoor humidity and moisture accumulation into building structures or materials. That may lead to increased dust mites, and particularly high humidity can increase the risk of microbial growth, and subsequently to microbial contamination and other emissions in buildings. In epidemiological studies, moisture damage and microbial growth in buildings have been associated with a number of health effects including respiratory symptoms and diseases and other symptoms (Bornehag *et al*., 2001; Nevalainen, 2002); although, the evidence of a direct link between higher air humidity levels and adverse health is quite limited. In many cases ventilation reduces the moisture contents indoors. The effect of ventilation is two fold. Ventilation can remove indoor generated moisture directly, and dilute the water content of the air to a lower level. However, when it is hot outdoors, the moisture content in the outdoor air is often higher than the indoor moisture content, because air conditioning and/or dehumidification systems are used to reduce indoor moisture levels. In these situations, ventilation is ineffective for indoor humidity control – in fact ventilation becomes a source of moisture and mechanical systems are needed to remove moisture from the incoming outdoor air or from recirculated air. In climatic conditions (summer in some coastal areas) the outdoor moisture contents may be high. In those conditions the ventilation is not effective.

4.3.3. Consumer products

A paper from Salthammer (Salthammer, 1999) shows that VOCs are emitted from a wide variety of household and consumer products with emission rates that are strongly dependent on the type of application and distributed over several orders of magnitude. A number of product classes are identified and information on ingredients and available data on emissions from individual products are presented. The product classes identified are newspaper and journals; electronic devices; insecticides; air fresheners/deodorisers; household cleaners; adhesives; polishes; personal hygiene and cosmetics and toys.

Nazaroff *et al*. (2004) identified the following mechanisms by which cleaning products can influence inhalation exposure:

- volatilisation of ingredients, e.g. formaldehyde from wood floor cleaning spray,
- production of airborne droplets, e.g. through aerosol or pump-spray delivery,
- suspension of powders, e.g. sodium tripolylphosphate from carpet cleaner,

- suspension of wear products, e.g. surfactants, disinfectants,
- inappropriate mixing, e.g. chloramines from mixing bleach and ammonia-based cleaners,
- chemical transformations, e.g. terpene reaction with O_3 to form radicals,
- altered surfaces, e.g. enhanced VOCs emissions from wet linoleum.

Jensen and Knusden (2006) undertook a health assessment of chemicals in the indoor environment released from various consumer products. The assessment was based on 60 reports published by the Danish Environmental Protection Agency on the study of chemicals in various consumer products, although not all considered release to the indoor air. Potential indoor concentrations of eight selected VOCs (phenol, formaldehyde, acetaldehyde, benzene, toluene, xylenes, styrene and limonene) were estimated in three model rooms: a hall/utility room, a kitchen/family room and a children's room. The products shown to release the prioritised chemicals are listed and include, for example for xylenes; computers, monitors, chargers, playing consoles, household ovens, decorative lamps, hair dryers, mobile phones, TV apparatus, recharged batteries, printed matter, incense, tents for children, beads, Christmas spray.

It was concluded that the highest concentrations in a home are likely to occur in the children's room as this room is normally smaller than most others and it contains many products which may release chemicals into the air. It is noted that products differ from each other by having different emission patterns.

Use of incense and spray products indoors were the most polluting of the studied products/activities and emitted considerable amounts of hazardous chemicals. Spruyt *et al.* (2006) investigated chemicals released from 20 air fresheners of different types - candles (white and scented), gel and spray - in an environmental chamber and investigated six products in real rooms. Jann *et al.* (2005) reported results of chamber tests of nearly 60 hardcopy devices (printers, copiers and multifunctional devices) to determine rates of emission of VOCs, O_3 and dust. Ozone emission rates were mostly near zero, but nine products gave between 2 and 9 mg h^{-1}. Dust emission was below 4 mg h^{-1}. A wide range of VOCs were emitted and 59 individual compounds were identified. Nonaka *et al.* (2005) investigated the performance of a test chamber method to determine the chemical emissions from a laser printer, including formaldehyde and VOCs.

There is an increasing concern about the use of consumer products in indoor environments, because of their content of terpenes that potential react with O_3 to produce harmful oxidation products, both gaseous and ultrafine particles. For example, use of consumer products has been associated with airway problems among preschool children and cleaning personnel (Wolkoff *et al.*, 2008).

As well as the direct impact on indoor air quality of emissions from indoor sources, consideration should be given to impacts resulting from exposure to the products of chemical reactions in the indoor air. Weschler (2003) reviewed the role of indoor chemistry in the formation of particles in indoor air. Reactions of O_3 and hydroxyl radicals with terpenes were once considered only an issue for outdoor air, with photochemistry playing an important role, but occurrence of such reactions indoors is now well recognised. As well as entering buildings from outdoors, O_3 can be released indoors from photocopiers, laser printers, electrostatic precipitators and ozone generators marketed as 'air purifiers'. Terpenes can be emitted during use of solvents, cleaners, degreasers, odorants in various products, air fresheners and from unsealed wood products. The ozone/terpene reaction products have a broad range of volatilities; those of low volatility adsorb to existing particles or may nucleate to form new particles. About half of the initial mass increase resulting from indoor terpene/ozone reactions is in the ultra-fine mode, and this fraction has high deposition in the human respiratory tract.

Results presented by Singer *et al*. (2006) provide information about emissions and concentrations of primary pollutants and the secondary pollutants of cleaning products and air fresheners. They conclude that the use of such products in the presence of elevated indoor O_3 is of concern because of the formation of secondary air pollutants that pose health risks. Limonene and other ozone-reactive terpenoids present in cleaning products can reach milligram per cubic meter levels in air and persist at levels of tens to hundreds of micrograms per cubic meter for many hours after cleaning. Air fresheners can produce steady-state levels of tens to hundreds of micrograms per cubic meter of ozone-reactive terpenoids. Some household cleaning agents contain formaldehyde solution as disinfectant.

Likewise contaminants in the air, consumer products are a source of some non-volatile and semi-volatile contaminants found in house dust. Chemicals in the dust can be ingested directly, particularly through hand to mouth contact by children and through contamination of foodstuffs. They can also be inhaled when re-suspended which can occur during human activities such as cleaning. Sources of chemicals in dust include material tracked in from outdoors, compounds deposited after entry of contaminated outdoor air and indoor sources. Contaminants from consumer products include nicotine from ETS and pesticides from products used in the home (Butte 1999, Butte 2003).

4.3.4. Occupant behaviour and maintenance

This section concerns the release of pollutants resulting from human activities and the associated use of consumer products. This encompasses a wide range of indoor sources involving release of inorganic gases, particles and organic compounds as a consequence of the activity. For some releases, such as from air fresheners, the release is a necessary part of the activity to achieve the intended effect whereas for others, such as the release of combustion fumes from a gas appliance, the purpose of the action (in this case generation of heat) is different from the emission.

While not discussed further here, it should be noted that humans and their associated activities, such as washing and cleaning as well as combustion of fuel, release water vapour into the indoor environment.

It is difficult to generalise about the relative importance of human activities as sources of indoor pollutants compared with other sources such as contaminants in outdoor air, emissions from building and furnishing materials, and infiltration of soil gas. The relative importance will depend on the particular pollutant and the characteristics of the building and the occupants. It can be expected that the concentration will have a time dependency that relates to the use of the product that is the indoor source.

Combustion sources - Combustion processes are an important source of the following air pollutants: carbon monoxide (CO), nitrogen dioxide (NO2), sulphur dioxide (SO2), particulates and associated inorganic and organic chemicals, organic vapours, e.g. formaldehyde, acetaldehyde, benzene.

Sources of these are present in both ambient and indoor environments. The concentrations present in the ambient air provide a baseline for the levels of pollutant found indoors as the outdoor air enters indoors by processes of infiltration and ventilation. However, the concentration indoors will be modified by processes of sorption to and re-emission from surfaces and chemical reaction depending on the chemical and physical properties of the pollutant and the internal surfaces. Also sources of these pollutants indoors will result in direct emissions to the indoor environment and resulting concentrations will depend upon rates of emission, dilution by internal space, reactions indoors and removal by air exchange with the outside.

The most common cause of elevated exposure to CO indoors is the smoking of tobacco. Faulty domestic cooking and heating appliances inadequately vented to outside air can cause high concentrations. Gas stoves, unflued gas stoves, unflued gas room heaters and exhaust from vehicles in attached garages are important sources. Burning of fuels for heating and cooking, as well as candles and incense, are sources of organic compounds such as formaldehyde, acetaldehyde and benzene. Cooking fumes generated by the heating of cooking oils contain potentially harmful chemicals such as aldehydes, ketones, hydrocarbons, fatty acids, alcohols, aromatic compounds and heterocyclic compounds. The surveys of indoor pollutants that look at associations between pollutant concentrations and possible sources can provide information about the relative importance of sources including combustion products. For example the IAQ survey of England found a significant correlation between the presence of a gas cooker with indoor NO_2 concentrations and integral garages with benzene concentrations in the occupied rooms of homes.

Some incense was revealed as important source of CO and benzene (Kotzias *et al*., 2005). Jetter *et al*. (2002) reported emission rates of 23 different types of incense such as incense rope, cones, sticks, rocks, powder etc. that are typically used indoors. The measured emission rates of CO ranged 144-531 mg/h. Lee and Wang (2004) reported similar results when studying emissions of incense burning in chamber (18 m^3) tests. They measured maximum carbon monoxide concentrations up to 44 mg/m^3 during burning and concluded that incense burning is an important indoor air pollution source in addition to CO also to fine particles and VOCs.

Nazaroff and Kleipeis (2003) reviewed the contribution of environmental tobacco smoke (ETS) to indoor air concentrations and human exposures to particles. ETS is a mixture of gases and particles generated by combustion of tobacco products including cigarettes, cigars and pipes. Once released, the particles and gases are subject to processes that alter their concentration, physical form and chemical composition. The particles are small liquid products mostly in the size range 0.02-2 µm. Studies have demonstrated that ETS is an important source of fine particles indoors. The chemical composition of the gases and particles is complex, with more than 4,000 components identified in mainstream smoke (Guerin *et al*., 1992). As well as the release of a wide range of VOCs and SVOCs during tobacco combustion, CO and oxides of nitrogen are important pollutants with regard to risks to human health. In the context of the Expolis study in Helsinki it was noted that the only significant indoor source of benzene was tobacco smoke.

Other - People themselves are a source of emissions of chemicals and gases, notably CO_2, but also a range of organic compounds referred to as body odours. The removal of such body odours is a prime objective of ventilation in order to achieve a satisfactory indoor environment.

The maintenance activities in a building are also other behaviour that could be a cause of problems. Mould and fungi problems could be avoided with a good maintenance by the owners of the buildings, for example.

Hubbard *et al*. (2005) refer to the many air purifiers available, including those marketed as electrostatic precipitators, negative ion generators that produce O_3. Several government agencies in the United States have warned against their use. This group undertook experiments to determine the effect of an air cleaner on indoor air O_3 levels and investigated the formation of particles in the air resulting from chemical reactions involving O_3 and terpenes.

Evidence from epidemiological studies and laboratory measurements supports the hypothesis that a contaminated HVAC-system may be source of pollutants, and increases exposure to pollutants that may increase the prevalence of sick building symptoms in office buildings. There is also substantial evidence that neglected maintenance is a major reason for these problems. Inferior maintenance appears to be a common problem both in North America and Europe.

A case of the energy and burden of disease cost assessment of IAQ illustrative and thought provoking one, kindly supplied by Hal Levin, Hal Levin & Associates, Santa Cruz, CA, USA, is particularly useful when balancing different ventilation, energy and IAQ policies (Annex A).

5. Policy Assessment

This chapter assesses the policies that influence IAQ, and more specifically those policies which target the sources of indoor air contamination as well as those targeting the means of controlling these sources.

After addressing the mains points of relevance of the reverse EnVIE chain health – exposure-sources, it is the time to address the issue of IAQ policies bearing in mind the role of the integration of all IAQ related policies and their specific interfaces in order to tackle the IAQ issue in a comprehensive and holistic way.

The primary focus is on European level policies, secondary on legally binding national policies, such as building codes, in European countries and tertiary on voluntary actions such as industry standards, e.g. product labelling schemes, professional good practices, etc. The report reviews and evaluates the existing policies, identifies some policy gaps, and makes attempts to define some needs for research which are deemed essential for filling these gaps with evidence based policies. The policies of interest are not limited to those intended for IAQ, but include also those which have other main objectives but have clear and significant IAQ implications, e.g. regulation of toxic chemicals in solvents.

The policy assessments shown here are organised primarily according to the indoor pollution source and control topics, as presented in Table 1, and secondarily as follows:

International & EU policies cover directives, codes, regulations and international agreements, which are either *de jure* binding at national level, or have by example and harmonisation *de facto* broadly dictated national regulations.

National policies in Europe cover those national laws, codes and regulations, which are not based in international/EU level models.

Professional and industry standards & practices cover first international and secondly national non-governmental conventions, which are widely used as guidance or directly referred to in contracts and professional conduct.

Policy gaps and new policy needs identify and list the gaps that emerge in the assessment of the existing indoor air exposure and health consequences on one hand and the existing regulations and practices on the other. The intention is also to suggest policies to fill the most important gaps. An obvious and difficult example of such policy gaps is the need to protect children from ETS in the home. We might or might not be able to formulate a credible policy to fill this gap.

- all the policy proposals are evaluated for their potential of reducing population and individual exposures and risks at European level,
- all policy proposals are also evaluated for feasibility,
- feasibility requirements are highest for the policies with the lowest risk reduction potential, and *vice versa,*
- in the final assessment, only the policies with the best combinations of risk reduction potential and feasibility are recommended.

Research needs for evidence-based policy development follow on from the previous assessment, which may also point out fundamental gaps in knowledge that effectively prevent the formulation of necessary but non-existing (evidence based) policies.

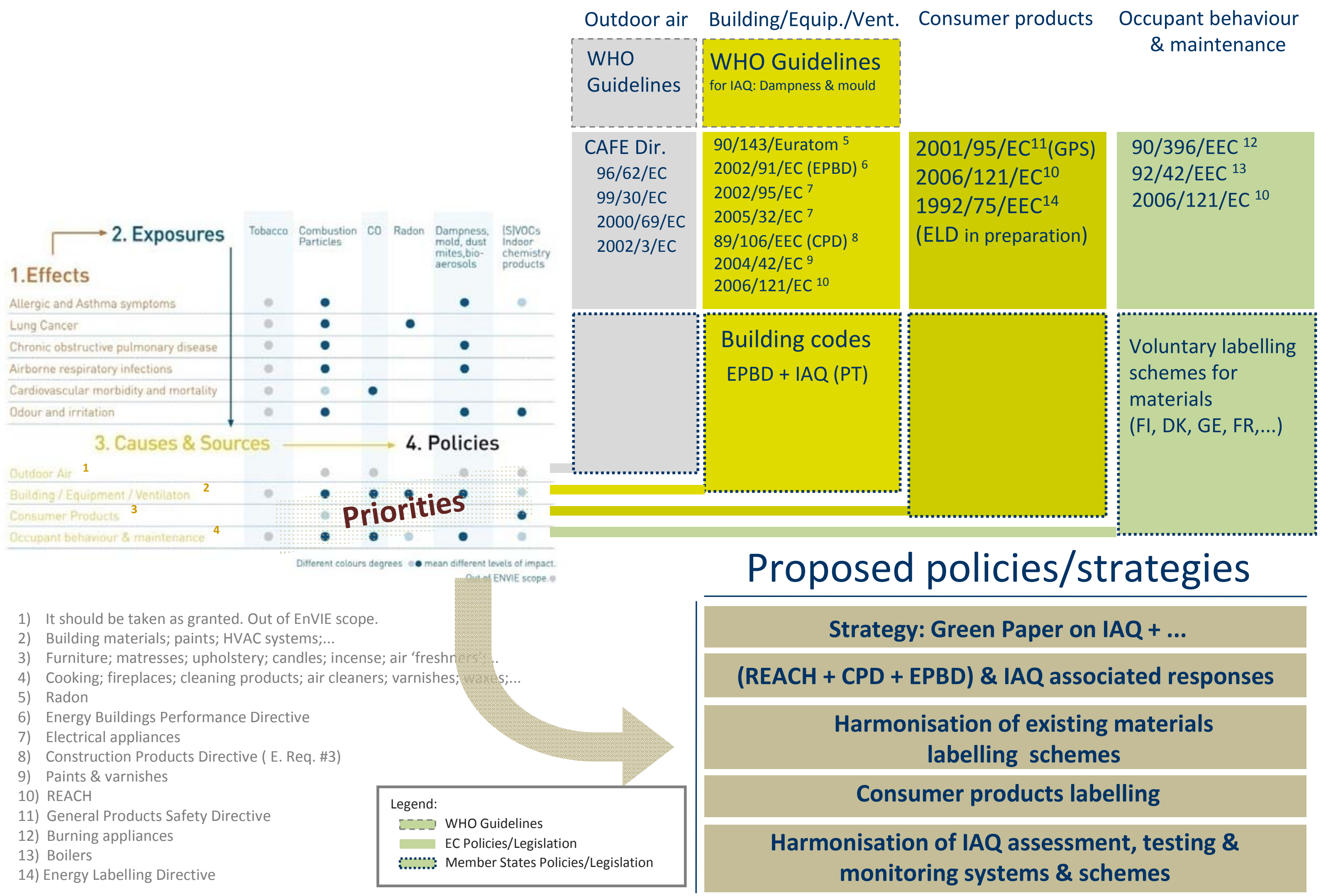
Policies may present many different levels of enforcement: at one extreme ***standards and decrees*** describe how something must be done or what is forbidden. These are legally binding policy instruments, but standards may also be industrial conventions and procedures which are binding when they are referred to in contracts. Consequently, standards and decrees must meet the requirements of technical, social and economical feasibility and compatibility with the overall legal framework within the entire area (e.g. EU), where they are to be applied.

Guidelines and recommended practices are also documented in detail, but because they are not binding, except when so specifically agreed case by case, the above mentioned feasibility and compatibility requirements do not apply; e.g. WHO Air Quality Guidelines (WHO, 2006b), and WHO Guidelines for Indoor Air Quality (currently under development) can be based on exposure and health considerations alone, and be applied voluntarily as guidance for the selection of materials, technologies and calculation of the necessary ventilation rates for a new building.

Warning labels describe the dangers that may be associated with improper use of a product and may also give instructions for proper use, including personal protection. Basically they provide only information, but for many products and equipment warning labels may be mandatory, with their format and content defined by a legal decree. Other decrees or agreements may mandate obedience to this information. For product manufacturers and retailers the warning labels are often useful for restricting the liability in the case of improper use. Sometimes these liability restrictions lead to excessive use of warning labels and consequently to fading credibility of these and also other warning labels amongst users. Maximising the use of warning labels, therefore, does not necessarily maximise their safety benefits.

Use labels are softer and less formal than warning labels. They also describe the contents and characteristics of the product, its proper use and precautions, but can, compared to warning labels, be based more on common sense and on reasonable – but not always realistic - assumptions about the knowledge level of the users.

Neither of these types of label should be confused with other labelling schemes stating the product’s “greenness”, ethics or domestic origin, all of which represent different dimensions and criteria. It is therefore important that the criteria and documentation of the warning and use labelling schemes are publicly accessible, and clearly described in a way which is understandable to both professionals and the general public selecting, using or exposed to the products.



This diagram is by no means exhaustive. It aims to illustrate the wide spectrum of policy tools (directives, guidelines,…), policy making levels (WHO, EU, member states, ..) and source groups (outdoor air, building, consumer products,…). It also underlines the must strategic axes for policy making in the future.

Figure 3. Existing and proposed policies/legislation

5.1. EU Policies

This section presents five EU-policies which are broadly applicable across the management of IAQ, the case of a wide international platform being put in place by WHO for ETS with an active EU response including a Green Paper and a reference to the EU's climate and energy in buildings in a broad approach that IAQ policies should consider.

5.1.1. Regulation (EC) no 1907/2006 concerning Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and Establishing a European Chemicals Agency

General: The purpose of the 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.

Products and articles: REACH follows a substance based approach, so the obligations do not directly apply to preparations and articles. Suppliers of articles shall inform their customers about SVHC in concentrations above 0.1% by weight.

For each substance manufactured or imported in quantities of ≥1 tonne/year, there is a general obligation for manufacturers and importers to submit a registration to the European Chemical Agency (ECHA). This also applies to substances manufactured or imported as part of a preparation.

Downstream users formulating preparations are required to classify and label the preparation and prepare Safety Data Sheets. In some cases also exposure scenarios needs to be made.

REACH requires all substances that are intended to be released from articles during normal and reasonably foreseeable conditions of use to be registered according to normal rules, it they are produced or imported ≥1 tonne/year per producer or importer. REACH does not apply to cosmetics.

Occupants: REACH requires manufactures and importers to communicate how their substances or preparations can be used safely. The format follows old Material Safety Data Sheets. Sometimes Safety Data Sheet has to be annexed with exposure scenarios specifying the conditions under which the substance can be used safely.

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

General: This directive covers all consumer products. Special attention is given to products that are used by children and elderly. The directive requires that products that are available in the market are safe. This includes both composition and packaging. Also, the 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 safe when it, and its use, do not cause a threat to health in normal use. The safety requirement covers the whole economically reasonable working life. A product is not considered as unsafe just because there are safer products available, or that it can be made safer.

The producer should give the consumer all the information needed to evaluate the risks associated with the product and its use. Warning signs do not free the producer from their responsibility for product safety. The producer should follow up the safety of the product after it is released to the consumer market (post-market surveillance).

Building: The assembly, use, maintenance and eradication instructions should be made in such a way that they will not (or a lack of them will not) cause risk to consumers. Attention should also be paid to package markings.

The GPS directive covers do-it-yourself products and other construction products available in the consumer market.

Electrical equipment: The GPS directive supplements the coverage of the Council Directive 73/23/EEC on the Harmonization of the Laws of Member States Relating to Electrical Equipment Designed for use Within Certain Voltage Limits (LVD). The GPSD applies to electrical equipment for example on identification of the products, follow up of product safety, requirements to producers to inform authorities about unsafe products and requirements for producers to co-operate with authorities.

Household products: The GPS directive supplements the coverage of the Council Directive 76/768/EEC on the Approximation of the Laws of the Member States Relating to Cosmetic Products (Cosmetics Directive). The CPSD supplements, for example, the general requirement for the safety of cosmetics and the follow up of product safety.

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

General: This directive covers very broadly the finished building, 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 these: it applies to all constructions that are fixed to the ground. Construction products are defined as materials that are permanently part of the construction work.

Ambient environment: Construction products should not release pollutants or waste to the environment resulting risk to human beings, animals, plants or ecosystem. The requirement is concerned with the protection of people and with the prevention of any impact on the immediate environment by pollution of the air, the soil and the water.

Building: "The construction work must be designed in such a way that it will not be threat to hygiene or health of the occupants or neighbours". The requirements concerning air quality in the indoor environment are concerned with the elimination and control of wide range pollutants (and gamma radiation) in indoor environment. Different types of sources have been taken into account - also different control methods.

Materials & technologies: Different construction materials have different requirements concerning their mechanical properties: moisture, water suction properties and durability against biological attack. The design and execution of construction work should take into account thermal environment, lighting, air quality, dampness and noise. The construction work must provide a healthy indoor environment for occupants and building users. The requirements are concerned with the elimination of pollutants in the indoor environment.

The directive requires a construction to be designed and built in such a way, that it will not be a threat to hygiene, health or environment by giving off toxic gases, presenting dangerous particles to the air, or by emitting dangerous radiation.

HVAC: Air-conditioning and ventilation is regulated by specification to ventilation rates and average and peak concentrations of pollutants. The main concern of hot water storage and supply regulation is the hazard of Legionnaire's disease. Regulated combustion equipment includes all equipment used for heating and cooking, air-inlets, fail-safe devices and other controls, flues and chimneys. The directive also takes into account, for example, the electrical and fire safety issues and energy efficiency.

Dampness: The CPD requires design and construction to be done in such a way that dampness will not be a threat to hygiene, health or the environment. Relative humidity should not be too low or high and the indirect effects of dampness (mould growth, etc.) should be taken into account.

Life cycle & building operation: The construction should satisfy requirements for an economically reasonable working life, when subjected to normal maintenance. Normal use should not cause serious risk in service or in operation. Normal use includes also actions of children, disabled and elderly people.

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

General: 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, then is an opportunity to tackle the problem of IAQ. Portugal is the only Member State to include IAQ assessment in the procedure of assessing energy performance according to the Directive.

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

Based on this directive, specific regulations are prepared for 30 pre-selected product categories, many of them affecting IAQ as potential sources: air conditioning appliances, electric motors, pumps, fans, boilers and water heaters (gas/oil/electric), personal computers, imaging equipment, televisions, battery chargers and external power supplies, office and public street lighting, commercial refrigeration and freezers, standby and off-mode losses of EuPs, solid fuel combustion installations, laundry dryers, vacuum cleaners, complex set-top boxes, domestic lighting, local room heating equipment, central heating equipment using warm air to distribute heat other than CHP, domestic and commercial ovens, domestic and commercial hobs and grills, professional washing machines, non-tertiary coffee machines, stand by losses of networks, domestic uninterrupted power supplies.

5.1.5. Directive proposal of the European Parliament and of the Council on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products (ELD)

The aim of the recast *Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances and repealing Directive 79/530/EEC*, hereafter referred to as the "Energy Labelling Directive" or "ELD", 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 (means of transport are excluded). 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.

The resulting Energy Labelling Directive, which also includes provisions relating to public procurement and incentives, will be an essential building block for an integrated sustainable environmental product policy, promoting and stimulating the demand for better products and helping consumers to make better choices. The recast of the Energy Labelling Directive was announced as a priority of the Energy Efficiency Action Plan and of the Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan. The SCP/SIP concluded that the Energy Labelling Directive should be amended to indicate, on the one hand, use phase energy consumption/savings and, on the other hand, other relevant and significant environmental parameters of the product.

5.1.6 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

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,

both of which are directly relevant for IAQ policies.

The WHO FCTC had, by the end of 2006, been signed by 168 and ratified by 141 Parties, including 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 in the 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 should be taken.

No change from the status quo: This would mean continuing the current work on ETS via different community programmes and relying on member's states implementation of FCTC. In addition, work on IAQ including ETS will continue as a follow up to Action 12 of the EHAP (Environment and Health Action Plan). Resources will come from Life^{+} 2007-2010, the 7th Framework Programme and the Public Health Programme. 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. Sectorial 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, with reporting and periodical review 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. A simpler shortcut to legally-binding EU level ETS policies could be achieved through 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; their impact would be strongest on workplaces - including restaurants and bars - in countries where workplace smoking is not already banned.

In 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 yet even been suggested.

5.1.7. EU's climate and energy package

This package includes a broad range of EU legislation, programmes, R&D support, etc. (see http://ec.europa.eu/energy/index_en.htm & http://ec.europa.eu/climateaction/) most having indirect and many also direct implications for buildings. As buildings consume ca. 40 % of the total primary energy, and the zoning and location of residential, commercial, occupational and recreational buildings relative to each other very much influence the quantity and mode of transport, urban development and building construction can be expected to be major targets for the EU’s climate and energy policies.

Looking at the impacts of climate change on the energy needs of buildings is fairly simple. Climate warming decreases the heating and increases the cooling needs. The climate change impacts on rainfall range from increasing to decreasing, and thus its impacts on moisture in the buildings are more variable.

Interconnections within the urban structure make an overall energy optimisation of the whole conurbation more complex than the sum of the energy efficiencies of individual buildings or transportation vehicles, private or public. It is generally believed – and this is supported by data from inter-city comparisons - that a compact city is more energy efficient than a dispersed one. Compared to a city dispersed over a large area a compact city can rely to a greater extent on rail, bicycle and foot transport, and its buildings can be economically and efficiently heated by hot water pipelines from heat and power cogenerating stations. On the other side of the coin, the remaining motor traffic, emissions and noise are condensed into a smaller area, closer to homes, schools and workplaces; also generating stations are located close to city centres, the urban heat island effect is stronger and summertime cooling needs greater and more difficult to meet by shading by trees, convective air flows and night-time cooling via open windows than in a more dispersed urban area. A well designed compact city is more energy efficient that a well designed dispersed city, but for healthy and comfortable IAQ and night-time silence for good sleep for its inhabitants, its buildings need mechanical ventilation, air filtration and refrigerative cooling, all of which consume energy and could be more or less avoided in a more dispersed urban structure.

Consequently, the most energy efficient buildings, and the most energy efficient urban structures, are not necessarily compatible with each other.

It is possible, however, to combine the benefits of both in a smaller town, small enough that proximity can be combined within a 'garden city of low energy eco-buildings', but big enough that heat and power co-generation is still a viable option.

The impacts of the EUs climate and energy package are too broad for IAQ policy assessment alone, because they involve the whole urban structure, and therefore this issue is not covered further in the current report. Yet, it is fundamentally important to keep in mind the interlinks between energy, climate and IAQ policies when making any final decisions on any of these policies independently. It is also important to realise that an optimal solution for the development of one community might not be a suitable model for another community of a different size and in a different climate zone.

Examples of other EU, WHO and National policies, as well as industrial standards and professional guidelines and practices are presented in Annex B and referred to in the text as appropriate.

5.2 Indoor Air Quality Policy Assessment

Indoor Air Quality policies stand on five pillars:

Ambient Environment - the air outside and the soil beneath,

Building - materials, water systems, equipment

Ventilation - local extract, air exchange, cleaning,

Consumer products – furnishings and electrical appliances, cleaning and household products,

Occupants - maintenance, product use, smoking.

The rest of this chapter provides details on these five pillars, and identifies some gaps and makes attempts to define some needs for research which are deemed essential for filling these gaps with evidence based policies.

Dissemination of information concerning the risks related to inadequate IAQ, the indicators of the different IAQ problems and their prevention and mitigation for general public and professionals forms the core of all efforts to ensure healthy and pleasant IAQ. Such information should be tailored to each recipient's level of knowledge and language and be available when needed. At the general level this requires, amongst other things, well maintained, fact-laden and easy-to-navigate internet websites. At the building level, comprehensive standard format and up-to-date documentation is required and this should be found in the possession of an assigned individual responsible for the building.

5.2.1 Ambient Environment: Outdoor Air and Soil Radon

IAQ should be prioritised in all policies on urban development, zoning, energy supply systems, buildings, and household products. Buildings consume a large fraction of all consumed energy, heat and power, and are thereby responsible for a similar fraction of all ambient air pollution which is generated by energy production. AAQ (Ambient Air Quality) forms the basis for indoor IAQ and therefore each building should be equipped with an energy supply that minimises ambient air pollution. Similarly, the levels of soil radon should be considered in land use and zoning and should be reflected locally in the building permissions and requirements.

"Build tight and ventilate right" policies have been developed to ensure that air exchange and distribution within the building is sufficient and controlled to meet the needs for fresh air, contaminant filtration and dilution, and environmental thermal control. In addition, in particular when building on radon rich or contaminated soils, it is also necessary to construct and maintain an airtight floor (slab) against the ground and/or well ventilated and under-pressurised space under the building.

Building codes and engineering guidelines exist for the design of building envelopes, for the estimation of outdoor air exchange needs and/or outdoor and recirculation air filtration needs to reach indoor air quality targets with given indoor source rates and ambient air contaminant levels. Tight building envelopes are essential for meeting the increasing demand of energy efficiency. This increases the risk of too low ventilation rates and consequently increased contaminant concentrations and moisture damage. To avoid these problems (which emerged, for example, after the first energy crisis), it is critical to develop or adjust ventilation guidelines and control methods regarding adequate ventilation, and at the same time to re-evaluate mandated ventilation rates.

Ventilation does not only extract or dilute indoor air pollutants and replace it with fresh air, it also brings outdoor air pollutants indoors. The requirements for air cleaning in the ventilation system should therefore be a prerequisite for obtaining a building permit in polluted urban and industrial areas or along major traffic arteries. Location of the air intake ducts at an elevated level and as far as possible from traffic also helps bring clean fresh air to the building. This principle is to a certain extent written into some national building codes and European standards but it deserves more than its current attention.

To further optimise the use of energy and IAQ, however, operation of the ventilation system should be better controlled according to the outdoor air temperature, humidity and pollution level. Control technologies, optimisation algorithms and practises for this need further development.

The building envelope and air cleaning can provide significant protection against outdoor air pollutants. Hänninen *et al*. (2004) demonstrated that in Helsinki, the $PM_{2.5}$ exposure of people who reside and work in buildings built after 1990, which meet the more recent building codes and ventilation standards, is about a quarter less than the exposure of the people who live and work in the older buildings.

Particulate matter can be effectively removed from the air with state-of-the-art fibre or electrostatic filters in balanced mechanical ventilation systems. Cleaning of gaseous pollutants from air is more complicated and less advanced. In high pollution areas and/or to protect highly sensitive occupants, however, cleaning of gaseous air pollutants may already have feasible applications.

Aside from outdoor air pollution, another issue that relates to the penetration of pollutants from outside into the building concerns the entry of radon (a noble gas and product of the radioactive decay of uranium in soil) from soil into the building. The driving forces for radon entry are sub-slab soil permeability and its radon concentration, foundation of the building directly on the ground without a vented airspace, air tightness of the slab or ground floor, and pressure difference from the ground to the building interior. Indoor radon causes up to half of the total radiation dose of the population in many European countries, and as a cause of lung cancer it is arguably second only to tobacco smoking. There are, therefore, regulations specifically concerning construction on high radon soils, to reduce the radon levels in the entire new or refurbished building stock, and to build provisions for later installation of active radon removal equipment (radon wells, sub-slab ductwork and vacuum pumps).

Current policies in Europe (Table B.1)

Outdoor air pollution levels in Europe are regulated by the Clean Air for Europe Directive (CAFE, Directive) 2008/50/EC (SO_2, NO_2, NO_x, PM, Pb, benzene, CO, O_3) and its daughter directive, 2004/107/EC (As, Cd, Hg, Ni, PAH), and guided by the WHO Air Quality Guidelines, Global Update 2005 (WHO, 2006a). For fine particulate matter, however, the WHO guideline values are much tighter (7 $\mu g/m^3$ as annual average and 25 $\mu g/m^3$ as highest 24 h average concentration for PM2.5) than the respective EC Limit value (25 $\mu g/m^3$ as annual average).

Radon levels are regulated by Directive 90/143/Euratom, and also by 96/29/Euratom (EU Basic safety standard for radiation protection). DG TREN is presently revising Directive 96/29/Euratom, aiming to introduce requirements on radon in dwellings.

Policy gaps and new policy needs

IAQ objectives should form a part of all policies dealing with sustainable cities, energy efficiency in cities and in buildings, and IAQ should specifically be considered in the energy performance evaluation procedure for buildings (EPBD).

Modern ventilation technology has been shown to be able to significantly reduce exposure to and health effects from, ambient air pollutants - fine PM and ozone in particular. This potential should be exploited by specific requirements for ventilation systems, air cleaning and building envelopes for all new and renovated buildings in all European areas where air pollution exceeds threshold values for these air pollutants, i.e. 7 $\mu g/m^3$ as annual average and 25 $\mu g/m^3$ as highest 24 h average concentration for $PM_{2.5}$ and 70 $\mu g/m^3$ as highest 8 h concentration for ozone. A great majority of the European [urban] populations live in communities where these reference levels are exceeded.

New policies are also needed to restrict zoning of residences, schools, offices, and other occupied buildings on exceptionally high radon ground and to specify mandatory indoor radon control and monitoring requirements for other high radon areas.

Most of the total population radon exposure and associated risk, however, is accumulated in regions and buildings that meet current indoor radon guidelines. Exposure should, therefore, be recognised and controlled in all, and not just the high radon buildings/locations. Radon safe building design and construction practices should be further developed and applied as the state of the art technology for the whole new building stock.

Research needs for evidence based policy development

The central urban areas which are most accessible by public transport, walking and cycling, and commonly exhibit the lowest per m^2 heating energy needs, usually suffer from the highest outdoor air pollution levels. Spreading the residences, shopping malls and offices out and around to suburban areas has been the urban planning trend for decades. This increases the transportation and energy needs, greenhouse gas and air pollution emissions per inhabitant, yet brings also cleaner ambient air for the people. Dilution has, for the past decades, increased more than pollution. Cleaner urban air and greenhouse gases abatement, thus, appear incompatible.

The solution might be a combination of motor traffic free zones, separation of motor traffic from pedestrians and bicyclists, and sealed low energy buildings with balanced ventilation and indoor air cleaning.

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.

Research is also needed to establish the relationship between improved control of indoor sources, ventilation rates and air cleaning to develop systems that can be effectively solely controlled based on relationship between AAQ and IAQ.

5.2.2 Building/Water Systems/Fixed Equipment

Most buildings are operated and all buildings occupied by people who are not building construction, equipment or maintenance professionals, and who should be able to safely work and live over 90% of their life in the buildings. At a general level fail-safe designs - meaning that failures would not lead to imminent danger and would immediately be observed by the occupants -should therefore be applied for all critical installations (combustion, heating, ventilation, electrical systems, water and sewage, etc.). Self diagnostics of the systems and IAQ should, therefore, be developed and used.

5.2.2.1 [Emissions from] building materials

Many building materials release gaseous, vapour phase or particulate contaminants into indoor air. Both natural and man-made materials exhibit such releases. Examples include terpenes and formaldehyde from fresh wood and monomers and phthalate plasticisers from man-made polymers. Some releases are caused by inherent decay of the material, such as formaldehyde from chemically unstable urea-formaldehyde resins and vapour phase irritants from the slow oxidation of aging linoleum, while some result from moisture induced reactions, such as ammonia release from the degradation of wetted casein containing fillers. Releases are not necessarily inherent for a certain material, such as PVC tiles or latex paints; rather it is the quality of the specific product brand and batch - e.g. its monomer residue level or physical durability - that may critically determine the exposure of the occupants. The emissions from a material may not be due to the material itself, but instead to chemicals used to treat it, for example to reduce fire hazard (e.g. PBDE in furniture, carpets and appliances) or to prevent mould growth - i.e. for purposeful beneficial purposes in their own right. Releases from some building materials may decay in days or weeks, such as the smell of fresh wood or new carpet, while others may persist as long as the material is present. There are materials which exhibit inherently low emissions, such as stone, glass and stainless steel in the extreme, but these cannot be used for everything.

Some releases may be toxic, allergenic, and odorous or irritating, others are - so far as is known at present - harmless and innocuous at the levels to which we are presently exposed.

The huge qualitative and quantitative differences in the releases and their health effects (if any) set remarkable challenges for the regulators and industry concerning how to measure, test and report the releases, how to judge the data, and how to select and best use the materials considering both long and short term risk and benefits.

Current policies in Europe (Table B.2)

The releases and respective risks of building materials and products are regulated at a general level by Directive 2006/121/EC (REACH), and specifically by the Construction Products Directive 89/106/EEC (CPD), Essential Requirement #3 (Hygiene, health and the environment) . In addition, there is a number of European Concerted Action on Indoor Air

Quality and its Impact on Man (ECA) consensus reports concerning releases from building materials (Reports 2 and 7), guidelines for measuring the emissions (Reports 8 and 14) and for the evaluation of building products (Report 18).
Material emissions are also covered in some national building codes and measurement standards as well as professional and industry standards such as the Classification of Indoor Climate produced by FiSIAQ (2001). Many countries and/or markets are using voluntary schemes to control emissions from building materials. Report 24 Harmonisation of indoor material emissions labelling systems in the EU, Inventory of existing schemes (2005) from ECA present with detail, comparing and discussing, the different labelling schemes: ECA report no. 18. (A concept for a global scheme for the evaluation of VOC emissions from building materials, established by a European working group), AgBB scheme (Germany), CESAT - Evaluation of environmental and health-based properties of building products (France), M1- Emission classification of Building Materials (Finland), Indoor Climate Label (ICL-Denmark), LQAI scheme (Portugal), Natureplus (Germany and Europe), The Blue Angel (Germany), Ecolabel scheme (Austria), GUT for carpets (Germany and Europe), Emicode system by GEV for adhesives and related material (Germany and Europe), and schemes applied in Belgium and UK and The Scandinavian Trade standards.

Policy gaps and new policy needs

Considering the very widespread health and comfort implications of building materials and the huge economical interests involved, there is a long overdue need for the agreement of a European harmonised protocol for building material emissions measurement, assessment and reporting to ensure:

- healthiness and high quality of the used building materials,
- information to design, build and renovate for high and predictable IAQ,
- trust of the builders and occupants, and
- efficient internal market within the EU.

Good starting points for such agreements are provided, for example, by ECA Report 18 and the FiSIAQ classification system, which covers materials, building practices and building commissioning and good prospects are offered from initial contacts among some member states (Denmark, Finland and Germany) to consider the harmonization of their current voluntary labelling schemes.

Research Needs for evidence-based policy development

Low emitting materials reduce the necessary ventilation rate and thus help reduce energy needs, but only down to the baseline ventilation rate required for human bio-effluents (incl. moisture and CO_2). The relationship between materials emissions and ventilation requirements should, therefore, be evaluated simultaneously when developing the criteria for low emitting materials.

Research is needed on the characterisation of pollution sources in buildings and technologies to control the sources and their effects on health and well-being and on source apportionment of the pollutants in indoor environment.

The knowledge of the dynamics of the air with the surface indoors is a key element towards the fine tuning of the ventilation needs. Nowadays, with all computer models capacities, the gooseneck resides clearly on the quantification of the role of the adsorption/desorption phenomena for the different coupling chemical substance/surface material.

5.2.2.2. Water systems, dampness and mould

Water and sewage systems (also rainwater drain pipes and sometimes condensed water from cooling elements) become IAQ issues when leakages occur, and in particular, when the water leakage in parts of the building structure remains hidden for long periods of time. Building surfaces and also hidden structures may also be repeatedly and continuously wetted by condensation due to combinations of cold surfaces and high humidity due to uneven or discontinued thermal insulation levels; by insufficient or non-existent ventilation in the kitchen or bathroom, and by seepage of ground water through porous materials due to inappropriate building site, poor site draining and improper construction.

Relatively small quantities of leaked or condensed water may keep large structures wetted, and structures that are exposed to water and air may start growing fungi, mould, algae and eventually higher life forms which will deteriorate the integrity of the structure – i.e. cause water damage - and subsequently emit potentially harmful spores and toxins into the indoor air. Buildings provide all the necessary ingredients for biological proliferation – surfaces to grow on, air to extract CO_2 from, and a constant and favourable temperature – the only necessity that a building may deny for such growth is water. Consequently, with water added, biological proliferation is inevitable.

Microbes grow also in the water systems, and one species in particular, *Legionella,* which grows in hot water systems up to 55 ºC, when the microbiological competition fades, is a life threatening pathogen when it is aerosolised (e.g. in showers or cooling towers) and inhaled.

Damp buildings have been known to pose a health hazard for centuries - before anyone knew about microbes and the sensitization and inflammation mechanisms. A combination of (i) the practice of hiding water and sewage piping in the building structure, (ii) making flat roofs fashionable in wet and cold climate zones, (iii) reduced ventilation rates, and (iv) building renovation by sealing of old building structures under new vapour barriers and insulation materials in response to the energy crises of the '70's and '80's, brought damp buildings of the past into the IAQ focal point in the '90's.

Current policies in Europe (Tables B.5 and B.6)

International policies relating to the moisture problems in buildings consist of guidelines and guidance documents by WHO (2007, under work in 2008), ISIAQ (1996) and ECA report No. 12 (1994) on how to assess, remediate and prevent the problems – but without technical details or regulatory power.

National policies, in contrast, are written into the building codes, are quite technical dealing with thermal insulation levels for energy/comfort purposes but also for the preservation of fabrics and refer to environment and health issues only occasionally. Also national policies are clearly aimed at preventing water leaks, condensation and persistent moisture in buildings. No post occupational proper assessment and its consequences have been duly considered.

Policy gaps and new policy needs

The insulation levels for comfort/energy reasons should be assured avoiding discontinuities causing thermal bridges or non uniformities in indoor surface temperatures.

Building walls, ceilings and attics should be designed to resist predictable quantities of condensed or leaked moisture and to dry by convective/natural air circulation. This requires that the construction is not tightly packed, but has provision for air entry and exit and sufficient space for convective air flow in between.

Ventilation systems – including kitchen, laundry and bathroom extract fans - should be controlled according to indoor/outdoor temperature and moisture.

Water and sewage pipes for new buildings and buildings undergoing piping renovation should be so installed that any leaks are either safely drained or immediately noticed.

Hot water systems should maintain a temperature above 55ºC to prevent *Legionella* growth and dispersal.

The building owner/occupant/manager should obtain a layout plan of the water (including heating) and sewage system and components in the building tailored to his/her level of knowledge and language:
-this should include trouble-shooting guidance, specify indicators for risky conditions, contain an inspection schedule and forms to fill in the performed tasks,
- it should be updated according to any modifications made to the system, and passed forward to any new owner/manager.

Dishwashers and laundry machines that are not located in bathrooms, etc. should be equipped with automatic water shutoff and alarm systems for any water leaks.

Bathrooms and laundry washing and drying spaces should be built with watertight sloped floors, floor drains and exhaust ventilation that does not recirculate the air back into other rooms.

Building envelopes and windows should be properly insulated, avoiding cold bridges to prevent condensation.

Research needs for evidence based policy development

It will be important to know the susceptibility for the potential grow of fungi on construction products. Several factors influence the risk of microbial growth among which some are related to the indoor environment (hair speed, relative humidity and temperature near surfaces) and others to product characteristics (nature of the surface, structure of the material). Studies on this contribution will be important.

5.2.2.3. Fixed household equipment/appliances (including heating and combustion)

Indoor combustion devices, in particular gas stoves that are not equipped with hoods and extract fans, and gas fired water heaters which are not flued outdoors, are major sources of NO_2 when they function properly, and combustion generated particles and CO when they do not. Combustion particles and NO_2 are harmful for health in the longer term, but CO may cause and often does cause severe intoxication and death after relatively short exposures. New appliances are usually safe when operated properly and in conjunction with appropriate ventilation. Risks are caused mostly by the millions of appliances in use which age, deteriorate, and often are used daily for decades without any professional maintenance or inspection.

Harmful emissions are, however, also caused by electrical heaters and radiators - in particular those with heating elements that are directly exposed to indoor air. When these heaters are not used they accumulate dust, and when they are switched on at the beginning of the heating season, pyrolysis of the dust can generate irritating organic compounds and potentially high concentrations of ultrafine particles in the indoor air.

Current policies in Europe (Table B.3)

Indoor fuel-burning appliances are regulated under Directive 90/396/EEC, and central heating boilers under Directive 92/42/EEC. The alternative to combustion-based or electrical heating is district heating via hot water pipelines, where available, because district heating offers a multitude of both environmental and economical benefits, it is promoted by COM 2004/8/EC and Directive 2005/32/EC on ecodesign requirements for energy using products.

Because of the very significant public health, environmental and economical impacts of the heating and cooking equipment, such equipment is extensively regulated in national building codes, and usually require some officially recognised testing and approval before installation plus regular maintenance and inspections by authorised personnel through their service life.

Policy gaps and new policy needs

IAQ should be a pre-requisite of European energy saving measures in buildings. Under the current requirements energy saving measures may, in practice, result in deteriorate IAQ.

All fuel-burning heating devices in spaces occupied by people should be fixed and flued outdoors. Open flame heating devices should not be used or made available to the public. Kitchen stoves should be equipped with mandatory fume hoods, gas stoves and gas-fired hot water heaters, also with automated mechanical extract fans. Smoke and CO detectors should be mandatory in all indoor spaces where any fixed combustion equipment is located.

The building owner and/or manager should be provided with operating manuals for all heating and combustion equipment tailored to his/her expected level of knowledge and language.

- this should include trouble shooting guidance, specify indicators for non-optimal operation, and contain a mandatory inspection and maintenance schedule and forms to fill in the performed tasks,
- it should be updated according to any modifications made to the system, and passed forward to any new owner/manager.

Policies should be developed to encourage maximal participation in high efficiency and low emission district heating systems, wherever available, and conversely, to discourage the use of solid fuel fired individual boilers, fire places and furnaces, particularly in urban and suburban areas.

Research needs for evidence based policy development

There is still room to design more efficient gas burning appliances, better sized for given purposes, and more environmental friendly. The same applies to stoves and fire places using better adapted burning products. Definitely, the energy performance of the building stock leading to lower needs of “commercial energy” for heating puts new challenges for small powers and heating devices and systems. That transformation shall encompass better environmental performances, too.

5.2.3 Ventilation [general and local extract] and air conditioning systems

Ventilation has many impacts on IAQ and human responses. In general, ventilation decreases the concentration of indoor generated pollutants and exposure to them, but may also carry outdoor air pollutants indoors. A properly designed ventilation system extracts the pollutants from indoor point sources and prevents them from spreading indoors. Most indoor sources, however, are dispersed throughout the building and therefore not dealt with by local extracts. Basic human presence and activities in residences and offices creates a minimum air exchange requirement for the dilution and removal of bio-effluents and moisture, even when no other indoor sources are presents. Cooling during sunny days and the warm season may require much higher ventilation rates, which can sometimes and in some places be met by opening windows and doors. Due to ambient air pollution, however, this cannot be the general solution in many urban areas. Increasing the ventilation rates from 10 to 17 and 25 L/s per person has often been found to benefit health, wellbeing and work performance, and much of the additional heating and cooling energy loss from the increased ventilation can be recovered in heat exchangers. A modern ventilation system needs to balance the apparently contrasting requirements of indoor and outdoor pollution control, temperature and humidity control with energy conservation, without sacrificing healthy and comfortable IAQ in the residences or causing economical losses due to reduced performance or increased absenteeism in the workplaces.

Ventilation is the biggest single energy user in buildings. About 10% of all primary energy is used for ventilation. Due to increasing demand for GHG reduction there is an increasing pressure to decrease the energy use of buildings and an evident danger that ventilation rates will again be reduced, as they were in the '70's, without proper consideration of IAQ and protection against the build-up of dampness in the building structure and surfaces.

Current policies in Europe (Table B.4)

The importance of ventilation is recognized, but no international consensus exists on required ventilation rates. A summary and general guidelines relating to moisture, dampness and ventilation is under preparation but will remain at a very general level (WHO 2007). Most ventilation guidelines have been developed from engineering practice (EN 13779) or energy issues (EN 15251) without sufficient support from health and performance research. European Standard EN 13779 (2007) sets performance requirements for ventilation and room-conditioning systems in non-residential buildings, and EN 15251 (2007) sets indoor environmental input parameters in relation to energy performance of buildings. CEN CR 1752 (1996) sets design criteria for ventilation in relation to indoor environments.

National building codes, HVAC codes and standards, maintenance and inspection schemes, all consider and affect IAQ. They lack coordination, however, partly due to genuine differences in the climatic conditions and regional building and housing practices, but partly due to lacking scientific background.

There are also a number of professional standards and guides by VDI (6022 Blatt 1 (2006) and 2 (2007)), REHVA (Guidebook 8 and 9 (2007)) and ASHRAE (62.2. 2007) which are applied beyond national borders.

Policy gaps and new policy needs

Ventilation codes have not yet been unified across Europe, and the different national codes and regulations bring additional costs and difficulties for product development and ventilation control.

Good IAQ should be a prime consideration for all European energy conservation measures in buildings.

New and renovated buildings should be equipped with a fail-safe ventilation system, in which no malfunction that is not obvious to the occupant should endanger his/her safety or health. Particular focus is needed on the renovation of existing building so that adequate ventilation rates are guaranteed for all parts of the building even when the building envelope is sealed to reduce air leakage.

The building owner and/or manager should be provided with information on how to update and maintain proper ventilation.

Regular inspections of ventilation systems and their performance should be considered in the context of the EPBD implementation, and experiences gained from the systems used in other countries (e.g. Japan, Sweden) utilized.

European labelling/classification/authorisation system should be developed and agreed for ventilation and air conditioning equipment, products and installation procedures.

Research needs for evidence based policy development

The following research issues are evident:

- the relationship of the ventilation with the dispersion of pathogenic microbes within the building; the dynamics of generation of pollutant indoors and the control of emissions from surfaces, in particular in cases of dampness and moulds,

- ventilation requirements for buildings with very low emitting building materials and minimal other sources,

- principles of residential ventilation – should it be based on over all ventilation rate of the residence or ventilation of the individual rooms?,

5.2.4 Consumer Products used in Buildings

5.2.4.1 Furnishings, interior surface materials and electrical appliances

These products differ from building materials in the sense that they can be cleaned and replaced relatively easily, and dermal (rather than inhalation) exposures of the occupants may become significant, even the most significant exposure route.

The characteristics of and emissions from these materials are very similar to those of building materials (see 5.2.2.1), yet the main points are repeated here. Products made from both natural and man-made materials may pollute indoor air. Some releases are caused by inherent decay of the product (e.g. some latex paints). Releases are not necessarily inherent to a certain chemical composition, but may depend on the technical quality of a specific brand and batch. The emissions may not originate from the material itself, but by chemicals used to treat it, for example to resist dirt or fire hazard. Some releases may decay in days or weeks, others may persist as long as the material is present.

Some releases may be toxic, allergenic, odorous or irritating, but most - for far as we know - will be harmless. The qualitative and quantitative differences in the releases and their health effects, if any, set remarkable challenges for the regulators and industry concerning how to measure, test and report the releases, how to judge the data, and how to select and use the materials considering both long and short term risk and benefits.

Furniture, wallpapers, carpets and other indoor textiles may act as both primary sources and reservoirs for VOCs and dust.

Most electrical home & office equipment, such as computers, printers, TV-sets, music instruments, and microwave ovens are built into plastic frames, generate heat and collect dust in their non-accessible interiors. Consequently they may emit pyrolysis products of both construction materials and dust (giving the smell of old product in use). These emissions reduce IAQ, may be harmful to health and should be prevented, minimised or exhausted from the room. Pyrolysis of the accumulated dust can also create a fire hazard (regulated elsewhere).

With proper selection of materials, these problems can be kept to a minimum. Aside from some rare and grave safety problems and health risks, the marketplace is probably the best place and means to improve product quality, also in terms of their impact on IAQ. For the marketplace to function, however, the consumer needs reliable, comparable and relevant information, which mostly is not available.

Current policies in Europe (Table B.7)

The REACH directive (2006/121/EC) covers the safety of materials used for these products and equipment, GPSD (2001/95/EC) concerns the safety of these products, directive 2004/42/EC covers paints and varnishes, and directives 2002/95/EC and 2005/32/EC cover electrical appliances. ECA Report No. 6 provides guidelines for sampling VOCs in indoor air and Report No. 8 for evaluating product emissions in the laboratory.

In addition, national regulations exist concerning the chemicals in and measurement standards for, the emissions/releases from furnishings, carpets, interior surface materials and paints, and may provide various labelling schemes which should be carefully evaluated before interpretation for IAQ.

National regulations and standards exist also for the energy efficiency, safety and use of the ever increasing electrical equipment. Such regulations mention IAQ only rarely.

Policy gaps and new policy needs

Agreement on a European harmonised protocol for the measurement, assessment and reporting of the emissions from furniture, interior textiles, paints and varnishes used in buildings is essential to ensure:

- healthiness and high quality of the products used,
- information necessary for the management of a high and predictable IAQ,
- trust of the occupants, and
- an efficient internal market within the EU.

A European harmonised protocol for the measurement, assessment and reporting of the emissions from electrical home equipment - also after they have been used for a long time - is essential to ensure:

- safety, healthiness and high quality of the products,
- information necessary for the management of a high and predictable IAQ, and
- an efficient internal market within the EU.

Paints are not considered a building material, and in consequence are not covered by CPD, being the object of control the VOC content (in can) and not the emissions to indoor air (directive 2004/42/CEE). One controversy aspect in paints versus construction products is that the definition of VOCs is not the same for both groups, which increase the difficulty of comparison.

Research needs for evidence based policy development

Further research is needed to evaluate the emissions from and risks of new and used/aged electrical equipment and to develop techniques for their prevention.

Another area in which more data are required is on the assessment of the emissions of chemicals from consumer products.

5.2.4.2 Cleaning and other household products

Exposure to cleaning agents and other household chemicals/products differs from exposure to releases from building materials (5.2.2.1) or the previously covered consumer products (5.2.4.1) by being usually of higher concentration and shorter duration, by the exposure being predominantly of the user (dominated by dermal route) rather than the other occupants (dominated by inhalation route), and by being easily removed or replaced by other products.

Information about product composition is presented in a more or less standardised form and provides a reasonable first order indication of the user's exposure. Instructions for safe use are usually at hand – on the package – when the product is being used. Many quite different products compete for the same market, and the users can and do compare product information labels and use their own experiences to make the purchasing decisions.

Current policies in Europe (Table B.8)

At European level also these products are covered by the REACH (2006/121/EC) and GPSD (2001/95/EC) directives.

The multitude of national regulations is in broad agreement on many of the most important safety and health issues, but they are not harmonised. These regulations induce bans and restrictions for certain chemicals, product labelling requirements and use restrictions.

Industrial guidelines apply for professional use of cleaning and polishing agents.

Policy gaps and new policy needs

Agreement on a European harmonised protocol for the measurement, assessment and reporting of emissions from the use of cleaning and other household chemicals and products used in buildings is essential to ensure

- healthiness and high quality of the products used,
- information to manage a high and predictable IAQ,
- trust of the occupants, and
- an efficient internal market within the EU

Research needs for evidence based policy development

Guidelines and procedures to measure emissions from consumer products should be developed including criteria for low emitting products and a labelling system to control emissions from consumer products.

Define standard methods for testing emissions from consumer products similar to those developed for building materials and furnishings within the European standards organisation (CEN) to provide comparable data on the release of chemicals and gases during the use of consumer products.

5.2.5 Occupant Behaviour

5.2.5.1 Maintenance, ventilation practices

In reality, most of the current building stock in the developed world still relies on natural ventilation - i.e. the activity of the occupants, outdoor air circulation, pressure balance and ambient temperature. Also natural ventilation can be effective for the optimised management of IAQ, energy and costs, but this requires a proper location and design of the building and knowledgeable and active occupants, who pay attention and react to the signals and needs with proper measures and action. The occupants are then the intelligent - more or less - feedback and control system. This, no doubt, works quite efficiently and to the satisfaction of the occupants in millions of small residential buildings all around the world.

Most of the buildings are operated without any maintenance schedules or manuals. Facing the increasing levels of technical equipment - heating, ventilation, air conditioning, radon well depressurising, water piping and circulating, automated fire extinguishing, sewage draining, electrical and data wiring, lighting etc. - in the building and its dependence on proper functioning of these equipment, regular maintenance schedules and detailed manuals need become the norm for most of these functions, not only for gas appliances and elevators as required in most countries already today. Further developments in intelligent feedback system would promise significant energy and cost reductions without sacrificing IAQ, but they will function properly only as long as they are strictly and professionally maintained.

To maintain good IAQ the ventilation systems - like any indoor air contact surfaces - need to be cleaned regularly. Angell and Daisey (1997), Engdahl (1998), Dorgan et al. (1999), Bluyssen et al (2003) and other studies have clearly demonstrated the strong association of IAQ to HVAC system maintenance and cleaning.

Current policies in Europe (Table B.9)

Although the design criteria and technical requirements of the HVAC systems are regulated at national level all across Europe, maintenance and cleaning of these systems has been given much less regulatory attention. Many industrial standards and professional guidelines have, however, been written and applied. ECA Report No. 11. provides general guidelines for ventilation requirements in buildings. VDI 6022 (2006-7) and ASHRAE 62.2 (2007) define hygienic standards for ventilation system components. ISIAQ (1966) published guidance for cooling coil cleaning, and REHVA (2007) for general cleanliness of the ventilation system.

European standards EN 15239:2007 and EN 15240:2007 for energy inspections of buildings, and EPBD (2002/91/EC) requirements for the inspection of air conditioning systems which is often integrated to ventilation systems, both bypass the indoor environment and IAQ.

Policy gaps and new policy needs

New and renovated buildings according to their dimension and complexity and of their systems should be provided with a comprehensive maintenance and operation manual and have designated and sufficiently qualified personnel for operation. They should receive proper training - an example of training is presented in VDI 6022.

EPBD specifies that all major buildings should have an energy certificate. Similarly, a respective IAQ certificate should be developed and linked to the energy certificate.

In radon prone areas guidance should be provided for building location and design and for existing buildings for radon monitoring.

Research needs for evidence based policy development

There is a need to promote the development of robust tools for sustainable buildings where low energy demand, energy efficiency, life cycle analysis, environmental assessment and proper performance (comfort, good indoor air quality) and management are assured from the design phase and the commissioning period. That will require:

- comprehensive criteria and tools to assess the holistic performance of buildings,
- integrated tools assessing the compromise between good IAQ and low energy level and soft control and management strategies.

5.2.5.2 Smoking (cooking hobbies, pets)

In residences where smoking takes place, it is almost always the single dominating source for indoor air pollution (PM_{10}, $PM_{2.5}$, ultrafine particles, CO, benzene, formaldehyde, total PAH, etc). Even when averaged over the whole building stock tobacco smoke is the biggest source of indoor air pollution in Europe. At the same time smoking is the biggest avoidable cause of death. Smoking prevalence is steadily decreasing, smoking habits are changing faster. Only 20..40 years ago tobacco smoke was present in most homes, and almost all workplaces, public buildings, offices, restaurants, public transportation vehicles, in some countries even in theatres. Today, smoking is increasingly allowed only outdoors – not everywhere – and in private residences. Some countries are more tolerant to ETS than others but basically all are on the same track towards smoke free Europe (as stated in the EC Green Paper (COM(2007)27) tracking each other by a few years at most. In many European countries a non smoker can presently go about his/her daily business for months without being exposed to tobacco smoke. One consequence of this favourable development is that in general the tolerance towards any smoke has been strongly reduced.

While non-smoking adults have been effectively detached from ETS at work, in restaurants, shopping malls and public buildings, protection of small children in their homes has advanced less. A decreasing proportion of the decreasing number of smoking parents still smoke inside their home and in front of their children, but those remaining represent the low end of the social ladder, where the children are exposed not only to tobacco smoke but also to many other risk factors. The fact that the civil society can provide the least protection to its most vulnerable children is an intriguing challenge.

Current policies in Europe (Table B.10)

In addition to the WHO's global and EC's European policies, described in the beginning of this report, smoking is currently banned in the workplaces, public buildings and public transportation in most EU countries and in restaurants, bars and pubs in a rapidly increasing number of EU countries. It can be foreseen that smoking outside of private residences, most outdoor areas and some designated smoking rooms in airports etc. will be forbidden in almost all EU countries within 5-10 years – even without any new EU policies.

Policy gaps and new policy needs

Encourage all EU countries to ban smoking in all indoor spaces under public jurisdiction. Raise public awareness on the hazards of tobacco smoke, and discourage smoking in the homes.

Consider and encourage smoking bans in public housing, apartment buildings and condominiums, because also non-smokers outside of the households of smokers may be exposed, leasing a smoke infested apartment to the next tenant is increasingly difficult and, thus, the property values are deteriorated.

Consider further possibilities to protect the unborn, babies and children from tobacco smoke exposure in the homes.

Research needs for evidence based policy development

Study the impact of tobacco smoke on the value and ease of selling or renting a property to (i) inform property owners about the premium above the normal rent that they should charge from indoor smokers, and (ii) to inform residents about the reduction of the value of their own home if they smoke or allow smoking inside it.

Studies to define a marker of vapour phase of ETS will be important, in order to facilitate control measures to be implanted to confirm success of banning policies.

5.3 New policies needs – a synopsis

Table 2 presents a summary of the identified policies needs discussed in the previous section.

Table 2 Generalised table of the new policies needs to improve indoor air quality in buildings

Focus area	Policy or action	Type of action		
		Legislative actions	**Standards and guidelines**	**Information**
General policies	Disseminate information concerning IAQ and related risks and their prevention for general public and professionals.	To be mentioned in all legislative actions dealing with the built environment.		Use professional organisation and citizens organisations
	Develop European harmonised IAQ monitoring protocols and techniques to ensure comparability across Europe for the needs of surveys as well as compliance assessments	Recast EPBD related actions	CEN standards	Technical guidance documents for survey design, sampling and analyses
	Develop health surveys to verify the efficacy of the preventive measures. Define indoor exposure guidelines, in particular for dwellings and schools			
Building construction	Integrate IAQ in policies on urban development, regarding energy supply systems, and zoning. Because ambient air quality (AAQ) forms the basis for IAQ use energy supply that minimises ambient air pollution and plan and design for low energy buildings.	Sustainable urban planning		Guidelines of principles to administrators, planners and architects
	Develop and apply European harmonised protocols for IAQ testing, reporting and labelling for building materials, equipment and products.	REACH and CPD related actions	CEN standards	
	Develop European moisture control guidelines for building design, use and maintenance, to prevent persistent dampness and hidden and visible mould growth	CPD related actions European guidelines National building codes	CEN standards Design guidelines	
	Apply radon safe design and construction criteria for buildings in radon risk areas.	European guidelines National building codes	CEN standards	Design guidelines to professionals
Ventilation	Develop European health based ventilation guidelines to control exposure to pollutants and moisture from indoor and outdoor sources	European guidelines National building codes	CEN standards	Design guidelines to professionals
	Mandate regular inspection and maintenance for all ventilation and air conditioning systems (integrate with energy performance inspections)	Recast of EPBD related actions European guidelines National building codes	CEN standards	Guidelines or professionals
	Ban all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandate CO detectors and regular maintenance/inspection for all combustion devices.	European directive	CEN standards Design guidelines	Design guidelines to professionals
Consumer products	Develop and apply European harmonised protocols for IAQ testing, for consumer products	GPSD related actions	CEN standards	
Occupant behaviour and Operation and maintenance	Provide systematic documentation and operating, inspection and maintenance manuals for major buildings and installations which may deteriorate IAQ or cause health risks		CEN standard	Guidelines or professionals
	Integrate IAQ knowledge, criteria nad values in all urban planning and building sustainable approach and performance assessment.			
	Develop policy and methods to integrate IAQ into the energy performance evaluation and audits of buildings	Recast EPBD	CEN standard	Guidelines or professionals
	Ban smoking in all indoor spaces under public jurisdiction	European directive		
	Develop policies to protecting children from ETS at home	European policy		Information campaign
	Develop information for pressure and action to encourage smoking bans in public housing and apartment buildings.			Information campaign

6. Recommendations

6.1. Health impact assessment of the policy alternatives

Although many IAQ policies depend on and/or overlap with others, the public health benefits that could be achieved by each policy are here each assessed individually. This assessment does not consider the costs or political feasibility of the policies, and it is assumed that each policy is fully implemented throughout the building stock.

The assessment follows the EnVIE concept from starting with the shortlist of health impacts: SBS, sensory irritation, asthma & respiratory allergy, infectious diseases, lung cancer, cardiovascular disease, COPD, acute intoxication;

then the EnVIE shortlist of exposures: VOCs, combustion products, bio-aerosols, pathogens, radon, carbon monoxide;

and finally the EnVIE shortlist of sources: AAQ (implications for building envelope, ventilation and air cleaning), radon (implications for building envelope, ventilation and air cleaning), building materials, fixed heating and combustion equipment/appliances, ventilation and air conditioning systems, water systems, dampness and mould, furnishings, interior surface materials and electrical appliances, cleaning and other household products and smoking (cooking hobbies, pets).

The overall health risk [sum of the listed health risks] reduction potential of each policy is then evaluated according to its potential for reducing each of the exposures from each of the listed sources. Because smoking, when present, is such an important source of indoor air pollutant and, health risk, separate analyses were done including and excluding ETS.

6.1.1. Public health impacts of the contaminants in indoor air

As the first step loss of healthy life [expectancy], expressed as disability adjusted life years (DALY see Prüss-Üstün *et al*. 2003 for description of the methodology), for each country in Europe was assessed for each health impact due to indoor exposures originating from each of the listed sources – 24 assessments in all.

The reference level of all these estimations is *ideal IAQ*, not *good IAQ*, i.e. zero risk from zero exposure, no indoor emissions and no transmission of outdoor air pollutants or radon to the indoor environments. Consequently, we report on the health impacts, causal agents and sources of *non-ideal IAQ* rather than *poor IAQ*. The reason is that zero is a clear and unambiguous reference level, albeit not a realistic one. The alternative reference level, borderline between poor and good IAQ, in contrast, is far from solid, being neither commonly agreed nor easily defined. Indoor Air Quality Guidelines, which aim at giving some qualified answers to the question of good vs. poor IAQ have been developed in the INDEX Report (Kotzias *et al*., 2005), are currently being updated in a DG SANCO funded and JRC coordinated revision of the INDEX and also are the focus of an ongoing WHO programme (WHO, 2006a). This should be kept in mind when interpreting the data. On the other hand, the presented results can be easily interpreted into more realistic estimations. As an example, reducing radon entry from soil to indoor air by 25% instead of 100%would similarly reduce the lung cancer risk attributable to Radon by 25% of the presented estimates.

To avoid any confusion, we use in the following policy assessments the terms *non-ideal* or *ideal IAQ* and not *good* or *poor IAQ.*

Each estimate was calculated as a product of

(i) underlying national burden of disease (BoD) for each health impact (e.g. asthma) in each country, see *Death and DALY estimates for 2002 by cause for WHO Member States* at WHO website: www.who.int/healthinfo/global_burden_disease/estimates_country/en/index.html,

(ii) population attributable fractions of the disease (e.g. asthma) caused/aggravated by the indoor air contaminants in the EnVIE shortlist of exposures, which originate from indoor and outdoor environments (0 - 1.0),

(iii) proportion of the indoor air contaminants in the EnVIE shortlist of exposures originating from each of the EnVIE shortlist of sources in the (0 – 1.0).

For each country this analysis produces a list of 24 DALY estimates for the BoD attributable to the EnVIE diseases linked to the EnVIE exposures and the respective sources. The list is reduced from the theoretical 336 (7 diseases x 6 exposures x 8 sources) to the more manageable 24 because most diseases are caused by only a few or only one exposure from few or single sources, and by summing up for each source and disease the DALYs from multiple exposures (see table 3, one DALY estimate for each line).

Table 3. Structure of the 24 National BoD estimations for IAQ caused DALYs for the EnVIE shortlisted Diseases, Exposures and Sources.

Disease	Exposure	Source of indoor exposure
SBS, sensory irritation	Combustion products, VOCs, bio-aerosols	AAQ (implications for building envelope, ventilation and air cleaning) Building materials Fixed heating and combustion equipment/appliances Ventilation and air conditioning systems Water systems, dampness and mould Furnishings, interior materials, electric appliances Cleaning and other household products
Asthma (& allergy)	Combustion products, VOCs, bio-aerosols	AAQ (implications for building envelope, ventilation and air cleaning) Building materials Fixed heating and combustion equipment/appliances Ventilation and air conditioning systems Water systems, dampness and mould Furnishings, interior materials, electric appliances Cleaning and other household products
Resp. infections	Pathogens	Ventilation and air conditioning systems Water systems, dampness and mould
Lung cancer	Radon, combustion products	Radon (implications for building envelope and ventilation) AAQ (implications for building envelope, ventilation and air cleaning) Fixed heating and combustion equipment/appliances
Cardiovascular diseases	Combustion products	AAQ (implications for building envelope, ventilation and air cleaning) Fixed heating and combustion equipment/appliances
COPD	Combustion products	AAQ (implications for building envelope, ventilation and air cleaning) Fixed heating and combustion equipment/appliances
Acute toxication	CO	Fixed heating and combustion equipment/appliances

BoD – Burden of Disease AAQ – Ambient Air Quality

For each country the relative contributions of each exposure to the DALYs from each disease is estimated using the indoor/outdoor PM, radon and VOC concentrations from the EnVIE WP-2 Report on Exposure. Except for Radon and PM of outdoor origin, these data are sparse and rarely nationally representative. The fractions of lung cancer, CV diseases and COPD attributable to indoor air are based on the work of the EnVIE WP-1 Report on Health.

The assessment depends critically on the assumption that within the realistic range of exposures, the risk attributable to each contaminant increases linearly with and in proportion to the concentration of that contaminant. This assumption is in accordance to the accepted models for lung cancer risk from radon and combustion particles, it is supported by ambient air epidemiology for CV-mortality risks from (combustion) particles, and it can be considered to be acceptable for estimating the risks of infectious diseases (pathogens), and possibly also the initiation of asthma and respiratory allergies which are essentially stochastic. The risks of asthma and respiratory allergy symptoms are very host and medication dependent with individual step function dose-responses, i.e. no credible population level dose/response function can be given.

The risk of acute intoxication by carbon monoxide is clearly deterministic, and the national estimations are based on very sparse and heterogeneous national CO poisoning statistics. We believe – together with most experts on CO intoxications – that the overall estimation is an underestimation -the data do not support any comparisons between the countries, but we suggest that it provides a European level estimation at the low end of the uncertainty range, which is still useful. Finally, no dose-response function has been proposed for SBS.

Fractions ii and **iii** were estimated by the EnVIE steering group in a two day meeting (2-3 September.2008) held at the Helsinki University of Technology in Otaniemi, Espoo, Finland. They are based on the EnVIE WP-1, WP-2 and WP-3 Reports on Health, Exposure, and Indoor Spaces and Sources, and the WHO Report on the burden of disease estimation in DALYs (WHO, 2002). The current estimation focuses on the whole of the EU, with country estimates for those countries from which sufficient exposure data were considered to be available and a joint estimate for the remaining countries assuming EU average inputs, but using national inputs when available. Useful country-specific estimates were found for most of the **fraction ii** [proportion of disease caused by indoor exposure]**,** but for **fraction iii** [proportion of indoor exposure from source] country-specific estimates were available only for *pathogen exposure* from *water systems, dampness and mould*, using relative scaling between the countries (taken from WHO EnHIS Fact sheet for Indicator *Percentage of children living in homes with dampness problems - RPG3_Hous_Ex2)*, For European level assessment the estimates are believed to be robust and correct within an order of magnitude, but due to many heterogeneous and missing national input data, differences between the countries are mostly underestimated, quantitative comparisons between the countries are not justified and even qualitative comparisons should be made cautiously.

Attribution of the health impacts of non-ideal IAQ to diseases and symptoms

Table 4 presents the per-country estimates of DALYs in each year due to non-ideal IAQ attributed to different diseases and symptoms. The values reflect both the sizes of the populations in each country and the contributions of non-ideal IAQ to the diseases and DALYs of each population. According to the modelling exercise more than two million healthy life years are lost due to non-ideal indoor air quality. Remembering that the reference has been set to zero contamination levels, realistically something in the order of one half of the attributed DALYs might be avoidable.

The contributions of different diseases/symptoms to the IAQ DALYs for different diseases vary significantly, and although some of this variation is due to data heterogeneity, it is interesting to take a closer look. According to the assessment results the average IAQ DALYs attributable to cardiovascular disease is 30% ranging from 14% to 54% for the 15 countries with country specific-estimates, the value for asthma is 29 % (16 to 47%), SBS 24% (16 to 31%), lung cancer 6% (2 to 10%), CO intoxication 5% (2 to 16%), COPD 3% (1 to 6%), and respiratory infections 2% (1 to 3%). A high relative proportion of one disease in a country does not necessarily indicate its absolute importance as a disease induced by poor IAQ. It may also be due to particularly low DALY contributions of the other IAQ induced diseases in that country.

Figure 4 points to the fact that the leading cause of IAQ DALY is *cardiovascular diseases*. In the absence of tobacco smoke a lion's share of these DALYs is caused by combustion particles, due in particular to outdoor air pollution entering indoors. *Asthma and respiratory allergies* come a close second, and are increasing all over Europe. The reasons for this increase are still mostly unclear. Clearly the reasons are not genetic, so we need to analyse the role of the environment, including the changing diet, decreasing microbial exposure, and increasing exposures to new materials and products, etc. particularly in the early childhood.

According to our estimate, on average about half of asthma and respiratory allergies are caused by indoor air exposures, and about half of these from exposures of indoor *origin*. At any rate, most of the changes which could explain the increase in asthma have occurred in the indoor environment. *Sick building syndrome* comes in third position, but it is also the most unspecific block of symptoms with the largest uncertainties. Arguably all SBS DALYs can be attributed to indoor environments, but the prevalence of SBS as well as the severity valuation of the symptoms carries both large uncertainties and inconsistencies between countries. Its DALY significance is more likely over- than underestimated, but its economical significance is, nevertheless, very large due to its impact on work productivity and absenteeism. The high contribution of indoor air to *lung cancer* is primarily due to radon and secondarily to combustion generated particles from both indoor and outdoor sources. The more than 100000 DALYs due to *CO poisoning* are certainly an underestimation CO exposure shortens individual life more than any other IAQ related factor and the CO-dependent DALYs are among the most cheaply and easily preventable.

Tobacco smoke, which remains outside of this evaluation, contributes significantly to all of the above diseases except CO poisoning (although tobacco is also a source of indoor air CO).

Table 4. Contribution of non-ideal IAQ to symptom and disease burden in the European countries, DALYs [1)] per year (thousands). ETS not included.

kDALY/year per country, diseases and symptom avoidable by ideal IAQ in Europe	Asthma	Cardiovascular diseases	COPD	Lung (& trachea & bronchus) cancer	Sick building syndrome, sensory irritation	Respiratory infectious diseases	Acute CO toxication
Belgium	12	10	2	3	12	1	2
Czech Republic	15	22	1,5	6	11	1	3
Denmark	5	5	1,4	1,3	6	0,3	3
Finland	7	3	0,2	1,3	6	0,6	0,9
France	96	55	8	19	67	6	5
Germany	90	88	9	18	86	8	22
Greece	7	19	0,9	3	12	1,1	3
Ireland	7	5	0,7	1,2	5	0,4	1,2
Italy	42	92	8	17	63	4	16
Netherlands	28	18	3	3	17	2	1,1
Poland	45	136	3	15	40	3	10
Portugal	21	16	2	2	11	2	1,1
Slovakia	5	12	0,3	2	6	0,6	1,5
Sweden	9	7	0,7	2	10	0,6	1,1
United Kingdom	138	56	9	7	64	7	9
Remaining EU-countries [2)]	132	131	14	24	104	10	21
TOTAL	**661**	**674**	**64**	**125**	**517**	**48**	**101**

[1)] DALY - Disability-Adjusted Life Year

[2)] Austria, Bulgaria, Cyprus, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Romania, Slovenia, Spain

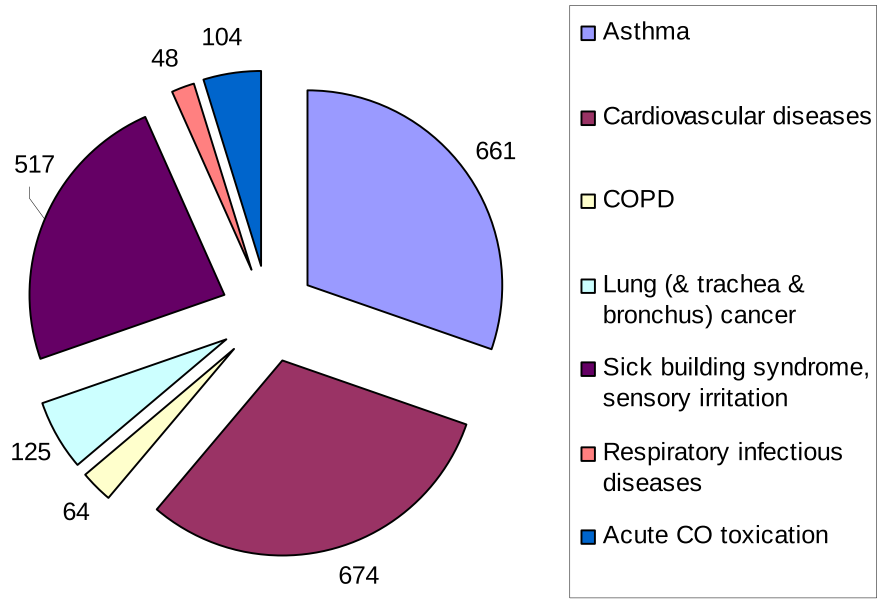


Figure 4. Contribution of non-ideal IAQ to symptom and disease burden in Europe, DALYs per year (thousands). ETS is not included.

Attribution of the health impacts of non-ideal IAQ to exposures

Table 5 presents the per-country estimates of DALYs in each year due to non-ideal IAQ attributed to different indoor air contaminant exposures. The values reflect both the sizes of the populations in each country and the contributions of different indoor exposures to the diseases and DALYs of each population.

Combustion products, mostly from outdoor air, but also from indoor combustion sources clearly dominate the total DALYs, and this dominance becomes even more obvious, when CO is added to the combustion products. Combustion products (causing CV-disease, lung cancer and CO poisoning) are followed in importance by bio-aerosols (causing asthma, other respiratory diseases and symptoms and SBS) and VOCs (causing SBS and aggravating asthma). According to the assessment results the average IAQ DALYs attributable to combustion products is 41 % ranging from 19% to 64% between the 15 country-specific estimates, the figure for bio-aerosols is 31% (15 to 48%), VOCs 14% (8 to 20%), carbon monoxide 5% (1 to 15%), radon 4% (1 to 8%) and pathogens 4% (3 to 6%).

Figure 5 presents the overall situation very clearly. Combustion generated particles and gases, originating from both indoor and outdoor air are responsible for half of all burden of disease that can be attributed to indoor air exposures. This is further highlighted by the fact that CO is a combustion product, and that tobacco smoke (not included in this analysis), which is the most important indoor air pollutant, is totally comprised of combustion products,). In the developing world the contribution of combustion products is even larger, both relatively and absolutely, and a larger proportion of the exposure originates from indoor sources (World Health Report. WHO, 2002).

The very important role of combustion generated particles and gases does not in any way reduce the significant public health impacts of bio-aerosols and VOCs, which are both responsible for over 300000 DALYs per year in Europe. The three remaining exposures, carbon monoxide (acute poisoning) - when assessed separately from the other combustion products, pathogens (respiratory infections) and radon (lung cancer) are all responsible for about 100000 DALYs per year. Of these CO and Radon exhibit more skewed risk distributions than any other, with long term radon exposure levels ranging over three orders of magnitude and short term CO levels being acutely lethal to some people, while most others are exposed to less that 1/10 of the level of any concern.

Attribution of the health impacts of non-ideal IAQ to sources

Table 6 presents the per-country estimates of DALYs in each year due to non-ideal IAQ attributed to different indoor air contaminant sources. The values reflect both the sizes of the populations in each country and the contributions of different sources of indoor exposures to the diseases and DALYs of each population.

In the absence of tobacco smoke, about half of the total estimated burden of disease from indoor air pollution appears be related to the outdoor air (Figure 6). This estimate does not downplay the importance of the other sources, it merely highlights the fact that between half and 90% of our exposure to ambient air pollution occurs - and damages our health - indoors in spite of the fact that it is often erroneously referred to as 'outdoor air exposure'.

According to the assessment results the average IAQ DALYs attributable to outdoor air quality – or more precisely to indoor air pollution originating from outdoor air - is 52% ranging from 44 to 57% between the 15 country-specific estimates, for water systems, dampness and mould it is 17% (9 to 25%), heating and combustion equipment 14% (9 to 23%), furnishings, interior surfacing materials and electric appliances 6% (4 to 8%), building site (mostly radon from soil) 5% (1 to 8%), cleaning and other household products 3% (2 to 5%), ventilation and air conditioning systems 2% (1 to 3%) and building materials 1 to 2%. It should be noted that the dermal and near field inhalation exposures and possible respective health effects of the users of the cleaning and household products are not included in this assessment.

Table 5. Contribution of indoor air exposures to symptom and disease burden in the European countries, DALYs [1)] per year (thousands). ETS is not included.

kDALY/year per country and exposure avoidable by ideal IAQ in Europe	Combustion products	Bio-aerosols	Volatile Organic Compounds	Radon	Pathogens	CO
Belgium	16	14	7	2	2	2
Czech Republic	28	15	8	5	2	3
Denmark	8	7	2	1	0,6	3
Finland	4	9	3	1,2	1,1	0,9
France	90	99	42	13	12	5
Germany	128	105	45	13	16	22
Greece	26	7	8	2	2	3
Ireland	7	7	3	1	0,9	1,2
Italy	126	37	47	12	7	16
Netherlands	31	31	6	1,3	3	1,1
Poland	164	45	22	7	7	10
Portugal	21	21	8	2	3	1,1
Slovakia	15	5	3	1,5	1,2	1,5
Sweden	11	10	6	2	1,2	1,1
United Kingdom	88	139	44	4	14	9
Remaining EU-countries [2)]	186	137	65	16	21	21
TOTAL	**950**	**688**	**321**	**84**	**95**	**101**

[1)] DALY - Disability-Adjusted Life Year

[2)] Austria, Bulgaria, Cyprus, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Romania, Slovenia, Spain

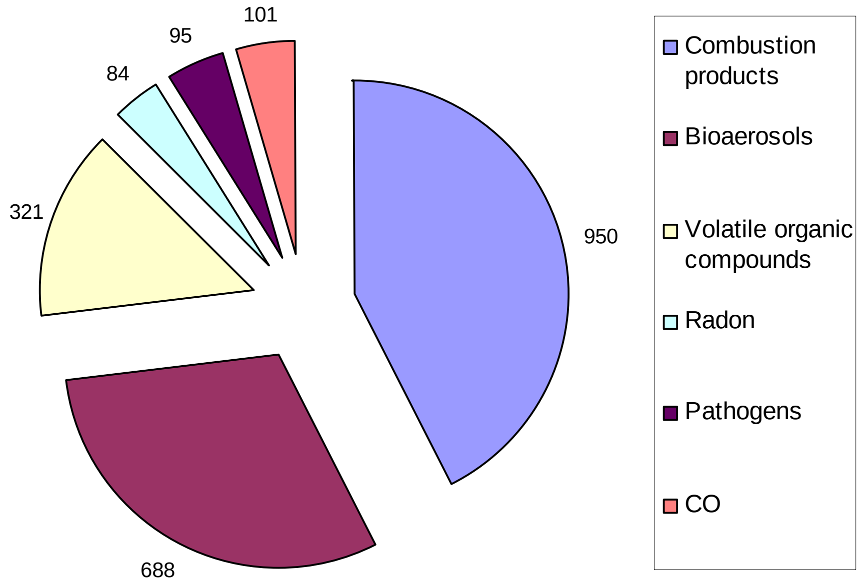


Figure 5. Contribution of indoor air exposures to symptom and disease burden in Europe, DALYs per year [thousands]. ETS is not included.

Table 6. Contribution of the sources of indoor air pollution to symptom and disease burden in the European countries, DALYs [1)] per year (thousands). ETS is not included.

kDALY/year per country and source avoidable by ideal IAQ in Europe	Ambient air quality	Water systems, dampness and mould	Heating and combustion equipment/ appliances	Building site (radon from soil)	Furnishing, decoration materials and electric appliances	Ventilation and conditioning systems	Cleaning and other household products	Building materials
Belgium	21	7	5	2	3	1,1	2	0,7
Czech Republic	31	8	8	5	3	1,2	2	0,7
Denmark	10	3	5	1	0,8	0,5	0,4	0,2
Finland	8	5	2	1,2	1,2	0,6	0,7	0,3
France	127	50	23	13	17	7	10	4
Germany	161	55	48	13	18	7	10	4
Greece	25	5	8	2	3	0,8	2	0,7
Ireland	10	3	3	1	1,4	0,5	0,8	0,3
Italy	125	20	41	12	19	4	11	4
Netherlands	40	16	7	1,3	3	2	1,5	0,6
Poland	153	24	43	7	9	4	5	2
Portugal	29	11	5	2	3	2	2	0,6
Slovakia	15	3	4	1,5	1,4	0,5	0,8	0,3
Sweden	15	5	3	2	3	0,8	1,4	0,6
United Kingdom	147	68	27	4	18	10	10	4
Remaining EU-countries [2)]	226	72	58	16	27	10	15	6
TOTAL	**1143**	**355**	**291**	**84**	**131**	**52**	**73**	**29**

[1)] DALY - Disability-Adjusted Life Year

[2)] Austria, Bulgaria, Cyprus, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Romania, Slovenia, Spain

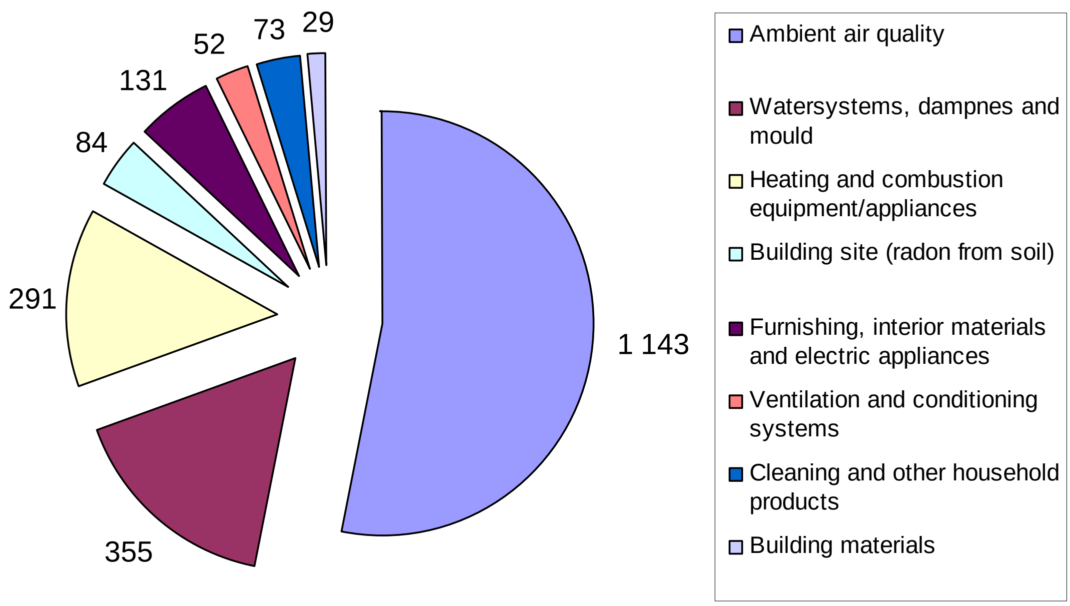


Figure 6. Contribution of the sources of indoor air pollution to symptom and disease burden in Europe, DALYs per year (thousands). ETS is not included.

The contribution of *ambient outdoor air* to indoor air pollution and the respective DALYs is more than half. This should be expected, because 75% or even more of the huge burden of disease attributed to outdoor air pollution in Europe is caused by indoor exposure – simply, because outdoor pollutants penetrate indoors, where the people spend some 90%or more of their time. Besides, a large fraction of the bio-aerosol exposures indoors, which both cause and aggravate asthma and respiratory allergies, originates from outdoors and is transmitted into indoor air by ventilation. The IAQ DALYs for the indoor sources of air pollution divide into three groups with similar contributions: *heating and combustion equipment* (including gas stoves); *water systems, dampness* (leaks and condensation) *and mould*; and *the combination of all other sources ranging from furnishings, interior surface materials and electric appliances to building materials*.

Summary

When judging these estimations or drawing conclusions from them it is important to keep in mind that they are based on sparse, partly missing and heterogeneous input data, they use simple linear models and the reference baseline values are set at zero emissions, concentrations and risks. Ambient air quality is monitored using standardised sampling, analysis and quality assurance techniques, monitoring sites are selected according to common guidelines to enable the estimation of population exposures and the impacts of sources such as traffic, industrial areas, power plants etc. Indoor air monitoring data, in contrast, have been collected by non-harmonised techniques in varied national campaigns and individual studies - most of which have not even attempted to be representative at national or even local level. These studies and data are described in more detail in the EnVIE WP-2 Report on Indoor Air Exposures in Europe.

The contributions of the different diseases, exposures and sources to the indoor air induced burden of disease vary greatly within Europe. Ambient air pollution, soil radon, fuel use for, cooking and heating, ventilation systems and building materials and technologies all vary between the different regions of Europe. These variabilities are even larger between buildings within the same regions. Risks which are marginal at the European level may well be critical for some population subgroups and/or in some buildings and locations.

While the current report assesses the average IAQ impacts on public health the impacts over several hundred million homes, schools, offices, and other indoor spaces in the whole of Europe, it misses the fact that poor, even hazardous IAQ is encountered in millions of buildings that are difficult to identify and, therefore, rarely professionally monitored, assessed and remedied. An inevitable consequence of this condition is that while programmes, such as mandatory regular inspection of fixed combustion installations are helpful, a vast majority of IAQ problems will only be identified, assessed and remedied by the occupants. Although some indoor environment problems are detectable by our senses and remedied by obvious and immediate actions – opening the window or adjusting the thermostat, for example – many others (CO, Radon and [hidden] mould as prime examples) are not. These facts set important boundary conditions for IAQ policies as well as requirements for information availability and format.

6.1.2. Public health gains from IAQ policies

The second step was the assessment of the public health gains, i.e. DALY reductions, which could be achieved by the selection of different general and specific indoor air quality policies listed in paragraph, 6.1. This Europe wide assessment was made by assigning each policy an impact coefficient (0 – 1.0) describing how much (0 - 100%) it could on average, when fully implemented through the entire building stock, reduce the exposure to each indoor air pollutant from each source, (see Table 7). These factors are based on the joint expertise and judgement of the EnVIE Steering Group as expressed during a two day meeting on 2.-3 September.2008 at the Technical University in Otaniemi, Espoo, Finland. Some of them have small uncertainty – e.g. the benefit from radon-safe construction practices (radon exposure reduction = 0.6) or CO detectors (CO-exposure 0.5), while some others would depend strongly on how they would be interpreted and implemented in practice (e.g. integration of IAQ into the EPBD procedure for buildings). All impact coefficients for SBS, with the possible exception of ventilation, have large uncertainties because SBS itself consists of a non-specific set of symptoms.

The same policy impact coefficients are applied for all European countries. An example of the caveats of this approach is the policy to *Provide kitchens, bath- and laundry rooms with controlled extract ventilation, bath- and laundry rooms also with waterproofed surfaces.* In some countries this policy has already been mandated for decades for all new and renovated kitchens and bathrooms, while in others no such policy exists. Also the sources and exposures are different: in many countries gas stoves and hot water heaters are common, in others practically non-existent. On the other hand, the selected policy impacts coefficients are relative, i.e. a high [European] coefficient applied to a small [national] risk (DALYs) leads to a small [national] DALY impact, thus not showing unrealistic gains for problems that have already been solved. Yet, due to this procedure, differences between the countries are more likely to be under- than overestimated. Again, we emphasize the importance of avoiding quantitative comparisons between the countries, stressing the needs to focus instead on the overall levels and variations.

Only one of the assessed policies is assumed to impact only one disease, exposure, source and risk – that is keeping domestic hot water temperature above 55ºC to prevent proliferation of *Legionella* bacteria. All other policies are assumed to impact multiple risks, sources, exposures and even diseases. The assessment of a single policy sums up all of them into one predicted health gain, expressed in DALY per year and country or Europe.

The results of the policy assessments are not necessary additive, i.e. the combined impact from all policies would not necessarily equal the sum of the impacts from each policy.

For comparison the policies are divided into three groups:

<u>Policies concerning energy efficiency, building materials, products and maintenance.</u>

- integration of IAQ into the EPBD procedure for buildings
- development and application of European harmonised protocols for IAQ testing, reporting and labelling for building materials, equipment and products (common IAQ monitoring procedures) (REACH, GPSD)
- providing for each building systematic documentation and operating, inspection and maintenance manuals for all installations and assigning a sufficiently qualified person with control of all documentation and responsibility for all building tasks

Table 7. Structure of the BoD 1) and policy impact estimations for the EnVIE shortlist of diseases, exposures and sources and the used impact coefficients of the different policies

1) BoD - Burden of Disease

				General policies			Outdoor environment		Fixed heating & combustion installations						
Disease	Exposure	Source of indoor exposure	DALYs	Integrate IAQ into the EPBD procedure for buildings	Develop and apply European harmonised protocols for IAQ testing, reporting and labelling for building materials, equipment and products (common IAQ monitoring procedures…) (REACH, GPSD)	Assign for each building a sufficiently qualified and trained person with control of all building documentation and responsibility for all building related tasks	Mandate radon safe construction for all new buildings	Apply tight building envelopes, balanced ventilation and air cleaning for all new/renovated buildings when ambient air quality is below WHO AQG	Ban all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandate CO detectors regular maintenance/inspection for all combustion devices (integrate with EPBD procedures)	Develop health based ventilation guidelines to control exposure to pollutants from indoor and outdoor sources, indoor moisture and ensure comfortable indoor temperature.	Mandate regular inspection and maintenance for all ventilation and air conditioning systems (integrate to EPBD)	Develop moisture control guidelines for building design and maintenance, to prevent persistent dampness and hidden and visible mould growth.	Keep domestic hot water [tap water] temperatures above 55 °C	Provide kitchens, bath- and laundry rooms with controlled extract ventilation, bath- and laundry rooms also with waterproofed surfaces	Avoid spaces, structures and materials which would not dry by convective airflows
SBS, sensory irritation	Combustion products, VOCs, bio-aerosols	AAQ (implications for building envelope, ventilation and air cleaning)		0,5		0,2		0,3		0,3	0,1				
		Building materials		0,3	0,8					0,5					
		Fixed heating and combustion equipment/appliances		0,8	0,5	0,3			0,5	0,3					
		Ventilation and air conditioning systems		0,8		0,5				0,8	0,7				0,1
		Water systems, dampness and mould	Current DALYs attributable to source, …	0,1		0,3	0,1			0,4		0,8		0,3	0,2
		Furnishings, interior materials, electric appliances		0,3	0,8					0,3					
		Cleaning and other household products			0,5	0,3				0,2					
Asthma (& allergy)	Combustion products, VOCs, bio-aerosols	AAQ (implications for building envelope, ventilation and air cleaning)		0,5		0,2		0,9		0,3	0,1				
		Building materials		0,3	0,8					0,5					
		Fixed heating and combustion equipment/appliances		0,8	0,5	0,3			0,5	0,3					
		Ventilation and air conditioning systems		0,8		0,5				0,8	0,7				0,1
		Water systems, dampness and mould		0,1		0,3	0,1			0,4		0,8		0,6	0,5
		Furnishings, interior materials, electric appliances	…agent, indoor exposure and disease	0,3	0,8					0,3					
		Cleaning and other household products			0,5	0,3				0,2					
Resp. infections	Pathogens	Ventilation and air conditioning systems		0,3		0,3		0,8		0,8	0,5				
		Water systems, dampness and mould		0,1		0,3	0,1					0,2	0,8	0,1	0,1
Lung cancer	Radon, combustion products	Radon (implications for building envelope and ventilation)		0,1		0,1	0,6	0,3			0,1				
		AAQ (implications for building envelope, ventilation and air cleaning)		0,5		0,2		0,8		0,3	0,2				
		Fixed heating and combustion equipment/appliances		0,8	0,5	0,3			0,5	0,3					
CV-diseases	Combustion products	AAQ (implications for building envelope, ventilation and air cleaning)		0,5		0,2		0,8		0,3	0,2				
		Fixed heating and combustion equipment/appliances		0,8	0,5	0,3			0,5	0,3					
COPD	Combustion products	AAQ (implications for building envelope, ventilation and air cleaning)		0,5		0,2		0,8		0,3	0,2				
		Fixed heating and combustion equipment/appliances		0,8	0,5	0,3			0,5	0,3					
Acute toxication	CO	Fixed heating and combustion equipment/appliances		0,8	0,5	0,4			0,5	0,2	0,1				

Policies concerning the impacts of outdoor environment

- Mandating radon-safe construction for all new buildings
- Applying tight building envelopes, balanced ventilation and air cleaning for all new/renovated buildings when ambient air quality is below WHO

Policies concerning specific building constructions and equipment

- Banning of all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandating CO detectors regular maintenance/inspection for all combustion devices (integrate with EPBD procedures);
- Development of health based ventilation guidelines to control exposure to pollutants from indoor and outdoor sources, including indoor moisture, and ensure comfortable indoor temperature;
- Mandating regular inspection and maintenance of all ventilation and air conditioning systems. (integrate to EPBD);
- Developing moisture control guidelines for building design and maintenance, to prevent persistent dampness and hidden and visible mould growth, and Keeping domestic hot water [tap water] temperatures above 55ºC;
- Providing kitchens, bath- and laundry rooms with controlled extract ventilation, bath- and laundry rooms also with waterproofed surfaces;
- Avoiding spaces, structures and materials that would not dry by convective airflows.

Policies concerning energy efficiency, building materials, products and maintenance

The potential public health benefits of these rather general policies are huge, ranging from 300000 to nearly one million DALYs, per year - in other words, better health for millions of Europeans.

As one might expect, these policies appear quite high on the priority list. Uncertainties in their evaluations are also considerable, concerning not only how effective they might be in reducing specific risks but also how they would be implemented. Integrating the provisions and requirements for good IAQ as conditions for the certification required by the Energy Performance of Buildings Directive could both improve indoor air quality and prevent its deteriorations as a result of strict and blinkered energy conservation measures – as happened for example in the late 1970's and early 1980's. Potentially the health benefits of this policy could be high but so also are the uncertainties, particularly if this policy did not mandate specific technical measures.

The health benefits of the European harmonised protocols for testing, reporting and labelling building materials, equipment and products would probably be the least uncertain. Experiences from labelling schemes - as introduced in Finland (FiSIAQ, 2001), for example demonstrate that as soon as reliable, comparable and understandable information about materials, products, technologies and practices becomes available, it profoundly benefits the best alternatives in the market.

The health benefits of comprehensive standardised documentation, training and clear responsibilities for the building, its installations and equipment and its inspection and maintenance could also be high. Such policies would help the prevention and early detection of damages to the buildings and of any health deterioration to the occupants and, thus, bring concrete economic benefits – for example in insurance costs. It should be in the interests of Insurance Industry to advance these policies, e.g. by providing reduced premiums for buildings that meet certain documentation, responsibilities, inspection and maintenance standards.

Table 8. Estimated potential public health benefits achievable in European countries by general IAQ policies concerning energy efficiency, building materials, products and maintenance. DALYs [1)] per year (thousands). ETS policies are not included.

Policies concerning building materials, products and maintenance: kDALYs/year per country and policy avoidable by ideal (maximum capacity for each policy) IAQ in Europe	**Integrate IAQ into the EPBD procedure for buildings**	**Develop and apply European harmonised protocols for IAQ testing, reporting and labelling for building materials, equipment and products (common IAQ monitoring procedures…)**	**For each building: provide systematic documentation and operating, inspection and maintenance manuals for all installations and assign a sufficiently qualified person with control of all documentation and responsibility for all building tasks**
Belgium	17	6	9
Czech Republic	26	8	13
Denmark	10	4	5
Finland	7	2	4
France	102	33	56
Germany	140	47	73
Greece	22	8	10
Ireland	8	3	4
Italy	111	45	52
Netherlands	31	7	17
Poland	123	33	56
Portugal	22	6	12
Slovakia	12	4	6
Sweden	12	5	7
United Kingdom	118	36	67
Remaining EU-Countries [2)]	189	62	98
TOTAL	**951**	**309**	**490**

[1)] DALY - Disability-Adjusted Life Year

[2)] Austria, Bulgaria, Cyprus, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Romania, Slovenia, Spain

Policies concerning the impacts of outdoor environment

Protecting the quality of ambient air and preventing soil contamination are worthy objectives of their own right. The primary method of preventing the health impacts of outdoor air pollution is – and should always be - to reduce the anthropogenic air pollution emissions, heat and power generation, traffic, industry, etc. A considerable fraction of the health impacts of outdoor air, however, is due to pollen, fungal spores and other biological particles. On one hand, these are, of course, of natural origin, but on the other they may result from planted vegetation and/or inadequate weed control in urban areas.

The IAQ policies covered here, do not aim to prevent outdoor ambient air pollution, but rather to lessen the public health impacts of indoor air pollution. Because outdoor air is the source of fresh indoor air and because modern people spend over 90 % of their time indoors, exposure to and the health effects of outdoor air contaminants, both natural and man made, occur mostly indoors. The most influential building/indoor policies would seal the building envelope, improve ventilation and air cleaning and ensure regular inspections and maintenance of the ventilation system. The surprisingly strong emergence of ventilation issues is due to the fact that balanced ventilation with integrated air cleaning can significantly reduce the exposures to ambient air pollutants, - particulate matter, pollen, mould spores and ozone in particular. Such reductions have considerable and demonstrated benefits to exposure reduction (e.g. Hänninen *et al*., 2005) and improvement in public health (e.g. Janssen *et al*., 2002). On the other hand ventilation technology is also the most universal means of controlling indoor air pollution from indoor sources. It should be noted, however, that a contaminated, malfunctioning and improperly maintained ventilation system can bring major health risks of its own and significantly contribute to the risks of SBS, allergies and asthma. Full implementation of these building envelope and ventilation technology policies through most of the entire building stock would also be a very expensive undertaking ranging over several decades, it's only feasible application is through the construction of new buildings and renovation of existing ones. However, this is already an ongoing process: new policies are not needed to initiate a change, but rather to give the ongoing development increased motivation, more ambitious objectives and more detailed technical guidance. The overall potential of this policy is very high -namely a significant reduction in the total mortality currently caused by ambient air pollution in Europe (WHO CAFÉ Report), independently of and in addition to the health benefits of outdoor air pollution mitigation.

Table 9. Estimated potential public health benefits achievable in European countries by IAQ policies concerning radon safe construction, tight building envelopes, balanced ventilation and air cleaning. DALYs [1)] per year [thousands]

Policies concerning the impacts of outdoor environment: kDALYs/year per country and policy avoidable by ideal (maximum capacity for each policy) IAQ in Europe	**Mandate radon safe construction for all new buildings**	**Apply tight building envelopes, balanced ventilation and air cleaning for all new and renovated buildings when ambient air quality is below WHO AQG**
Belgium	2	16
Czech Republic	4	25
Denmark	1	8
Finland	1,2	6
France	13	100
Germany	13	122
Greece	2	19
Ireland	1	8
Italy	9	98
Netherlands	2	31
Poland	7	123
Portugal	2	23
Slovakia	1,2	12
Sweden	2	11
United Kingdom	9	116
Remaining EU-countries *	17	176
TOTAL	**86**	**892**

[1)] DALY - Disability-Adjusted Life Year

[2)] Austria, Bulgaria, Cyprus, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Romania, Slovenia, Spain

Radon is known to cause one particular disease, lung cancer. About 10% of all lung cancer in Europe, is caused by indoor exposure (the outdoor air radon levels are very low). The presence of radon is not sensed, and the risk is, therefore, not easy to comprehend, in particular when common knowledge associates lung cancer with tobacco smoking. In principle the risk is fully preventable, in practice the prevention is a slow process, which depends on the radon awareness and preventive measures in new building construction and – sometimes – in the renovation of existing buildings. Radon risks have been known for decades, research, policy development and implementation have been ongoing since 1980's, and yet the average radon levels in the building stock have only quite recently ceased to increase and began to decrease.

Radon policies that focus only on buildings with excessive radon levels reduce the excessive lung cancer risks of only high risk individuals, those that impact the entire building stock can significantly reduce the *overall* lung cancer caused by radon.

Policies concerning specific building constructions and equipment

These policies are further divided into three subcategories, concerning:

- fixed heating and combustion installations,
- ventilation and air conditioning,
- water systems and moisture management.

The largest health benefits, again, are linked to the ventilation systems. It should be noted, however, that these potential benefits, and also the policies when implemented, overlap widely with each other and the building envelope, ventilation and air cleaning benefits discussed in the previous paragraph. The combined benefit potential of all three ventilation related policies is not their sum but about the same as the highest benefit of a single policy.

Building dampness and water damage prevention policies appear at a 'medium' level on the list, although much of the moisture prevention benefits are already covered in the ventilation policies. With the exception of the minimum hot water temperature policy, these policies and their benefits also overlap. The combined benefit, however, can be expected to be clearly higher than any of the single policy estimates. Damp buildings have been known for centuries to be unhealthy, and if it would have been possible to carry out as powerful epidemiological studies on the health impacts of moisture damages as have been done on combustion particles, environmental tobacco smoke and radon, these policies would probably appear higher in the assessment. Prevention of water leaks, seepage and condensation in a building is, however, also highly and unquestionably beneficial for the preservation of its structural integrity and value, as well as avoidance of expensive renovations.

Indoor exposure to combustion generated particles and gases – from both indoor and outdoor sources – produce over 40% of all indoor air health risks (Figure 5) and it is therefore obvious that policies focusing on combustion and heating devices can bring significant public health benefits. Combustion of fuels for the heating of buildings is also a major source of ambient air pollution, and therefore contributes – with great variation across urban and rural Europe – to outdoor air pollution and its health effects. The policy benefits assessed here only consider the direct benefits of the reduced exposures and risks in the buildings where combustion equipment is located.

Table 10. Estimated potential public health benefits achievable in European countries by IAQW policies concerning the heating and combustion, ventilation and air conditioning, water and wastewater systems and moisture management. DALYs [1] per year (thousands).

Policies concerning specific building constructions and equipment: kDALYs/year per country and policy avoidable by ideal (maximum capacity for each policy) IAQ in Europe	**Fixed heating & combustion installations**	**Ventilation & air conditioning**		**Water systems, moisture management**			
	Ban all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandate CO detectors, regular maintenance/inspection for all combustion devices (integrate with EPBD procedures)	Develop health based ventilation guidelines to control exposure to pollutants from indoor and outdoor sources, indoor moisture and ensure comfortable indoor temperature.	Mandate regular inspection and maintenance for all ventilation and air conditioning systems (integrate to EPBD)	Develop moisture control guidelines for building design and maintenance, to prevent persistent dampness and hidden and visible mould growth.	Keep domestic hot water [tap water] temperatures above 55 °C	Provide kitchens, bath- and laundry rooms with controlled extract ventilation, bath- and laundry rooms also with waterproofed surfaces	Avoid spaces, structures and materials which would not dry by convective airflows
Belgium	3	13	4	5	0,7	3	3
Czech Republic	4	17	7	6	0,7	4	3
Denmark	3	6	2	3	0,2	2	1,3
Finland	0,8	6	2	3	0,4	2	2
France	11	78	25	37	5	25	21
Germany	24	96	33	39	6	26	21
Greece	4	14	5	3	0,8	2	2
Ireland	1,3	6	2	3	0,3	2	1,5
Italy	21	70	27	14	3	9	8
Netherlands	4	23	8	11	1,2	8	7
Poland	22	75	32	17	2	12	10
Portugal	3	17	6	8	1,2	5	5
Slovakia	2	8	3	2	0,4	1,3	1,1
Sweden	2	9	3	4	0,4	3	2
United Kingdom	13	95	29	51	4	36	30
Remaining EU-countries [2]	29	132	46	52	7	35	29
TOTAL	**145**	**665**	**233**	**259**	**34**	**173**	**147**

[1] DALY - Disability-Adjusted Life Year

[2] Austria, Bulgaria, Cyprus, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Romania, Slovenia, Spain

Summary

Altogether the total loss of healthy life years, or more correctly, DALYs, due to indoor air contamination also engulfs most of the DALYs due to ambient outdoor air contamination, both natural (pollen, mould) and man made (PM, NO_2 and O_3). Without considering the impacts of environmental tobacco smoke indoors, the total contributions to human exposures and risks of air contaminants from outdoor sources (to a large extent from heat and power generation for buildings) is similar and to those from indoor sources. ETS increases the health risks of air contaminants from indoor sources to a clearly higher level than the health risks of air contaminants from outdoor sources.

When judging the estimations of the potential benefits of different IAQ policies for Europe or drawing conclusions from them it is important to consider that not only are some policies more influential than others, but also that the listed policy alternatives are not mutually independent: they range from very general to quite specific. Some policies require other to be operating and they also overlap to a greater or lesser extent with each other. The cost and invasiveness of the policies range from those associated with posting **No Smoking** signs to those linked with the regulation of the design, construction, management and renovation of the entire building stock. Similarly, certain policies can be implemented in a short time – e.g. '*Mandate CO detectors for all spaces with combustion devices'* – while others may require decades for their full impact to be felt – e.g. '*Apply tight building envelopes, balanced ventilation and air cleaning*. These facts need to be kept in mind when prioritising the individual policies or policy packages according to potential public health benefits. A cheap and non-invasive policy, e.g. setting the hot water thermostat to 55ºC, may bring only marginal benefits, yet provide excellent benefit/cost ratio, and help avoid very high individual risks. The highest requirements feasibility should be set on policies that provide the lowest health benefits and vice-versa.

Finally, it would be logical to police those indoor air contaminants that exhibit dose [or concentration] dependent individual and public health effects mainly via indoor air quality based approaches, and to police those that induce host dependent symptoms and discomfort for which dose/response cannot be established, mainly via product labelling and customer/occupant information.

6.2. Framework for a EU Green Paper on IAQ

The most important question that emerged from this IAQ policy assessment is: Is there a need for preparing a EU Green Paper on IAQ? If so, what should be its objective and which IAQ issues should it enclose? And, finally, how could a technically and economically feasible policy be formulated and implemented to bring with it maximum public health benefit and individual risk reduction with minimum unwanted interferences.

In the following we will try to answer the first two questions.

Yes, there is a need for an EU Green Paper on IAQ. The preparation of the Green Paper should be carefully coordinated with other legislative tools of policies related to IAQ (that is REACH, GPSD, CPD and EPBD). It should in general give sufficient priority of the IAQ issues in all urban development, building materials, technologies, equipment and household products related policies to ensure that IAQ is rather improved than deteriorated in implementing respective policies. Specifically it should associate IAQ into the energy efficiency procedures of EPDB.

The ultimate objective of the EU Green Paper on IAQ should be healthy IAQ. Other objectives would follow from this according to the EnVIE concept, i.e. to health damaging indoor exposures and further to the sources where the indoor exposures originate from, and/or to technologies which can cut the pathway from sources to exposures. The Green Paper should formulate criteria and framework for regulating both the sources and the exposure mitigating technologies, and for the management of the buildings to ensure healthy IAQ. On the other hand, it may not be advisable to include into the Green Paper on IAQ issues that have no implications on construction technology, building materials or equipment or which are progressively being dealt with elsewhere (e.g. smoking).

The Green Paper on IAQ should:

- enable an objective dialogue among all relevant stakeholders (including industries, NGOs, medical doctors, building owners, consumer associations, architects, general public), the European Parliament and the European Commission;
- propose strategies and priorities to enhance the existing policies;
- clarify, harmonize, streamline and coordinate the action of the various actors dealing with IAQ matters;
- promote the hollistic view needed for the management of the built environment in tune with new values such those ultimately associated with the concept of sustainability.

The EU Green Paper on IAQ should prepare the ground for effectively dealing with and putting in place the following issues:

Documentation requirements and responsibility assignment

Provide systematic documentation and operating, inspection and maintenance manuals for buildings 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.

Design criteria for new buildings and renovations

Building structures and materials: Apply tight building envelopes. Avoid spaces, structures and materials which would not dry by convective airflows. Mandate radon safe construction for all new buildings.

Heating: Ban all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandate CO detectors for all spaces with combustion devices (integrate with EPBD procedures).

Ventilation: Apply balanced ventilation and air cleaning for all new/renovated buildings when ambient air quality is below WHO AQG (integrate with EPBD).

Water systems, moisture management: Provide kitchens, bath- and laundry rooms with controlled extract ventilation, bath- and laundry rooms also with waterproofed surfaces.

Inspection and maintenance of existing buildings

Foresee regular maintenance and inspection for all combustion devices, for all ventilation and air conditioning systems, and for all water and drainage systems.

Effective implementation of the framework of actions to be proposed by a EU Green Paper on IAQ requires the following harmonised protocols and guidelines, which should be prepared as **Technical Guidance Documents**:

- European harmonised protocols for IAQ testing, reporting and labelling for building materials, equipment and products.
- European harmonised criteria and procedures for IAQ monitoring and reporting for the residential and occupational building stock.
- European health based ventilation guidelines to control exposure to pollutants from indoor and outdoor sources, indoor moisture and ensure healthy indoor temperature

European moisture control guidelines for building design and maintenance, to prevent persistent dampness and hidden and visible mould growth

7. Future Research

More evidence-based information about health indoor determinants and the efficacy to the measures to prevent/counteract adverse health determinants are needed. Studies should be performed on the relationship between IAQ and healthy, on the efficacy of the remedial actions in reducing the health effects, in particular about the effects of emissions from materials, including mould and dampness; cooling and heating equipments; and ventilation conditions (including outdoor air and air treatment systems).

Similarly, more research is required to determine the effects and costs of preventive and remedial measures.

The European Union should assign research funds to address these issues. 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 exposure in the indoor environments, especially in home and schools. Epidemiological studies should be performed on the relationship 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 products which emit indoor air pollutants 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. Assessment of exposure patterns (short and long term in different environments) to indoor air pollutants, and identification of the most relevant exposure indicators.
3. Definition of indoor exposure guidelines, in particular for dwellings and schools.
4. Characterisation of pollution sources in buildings and technologies to control the sources and their effects on health and well-being. Source apportionment of the pollutants in indoor environment. Assessment of the emissions of chemicals from consumer products. Harmonization of all monitoring and assessment methods and labelling systems.
5. Research on ventilation rates and energy use in different types of existing buildings and effects on indoor air quality and climate, health and well-being. Research is needed to establish the relationship between improved control of indoor sources, ventilation rates and air cleaning to develop systems that can be effectively controlled based on outdoor and indoor air quality. The relationship between materials emissions and ventilation requirements should be evaluated simultaneously when developing the criteria for low emitting materials. The relationship of the ventilation systems and rates with the dispersion of pathogenic microbes within the building should be evaluated.
6. The research on the dynamics of the air with the surfaces indoors is a key element towards the fine tuning of the ventilation needs. Nowadays, with all computing models capacities, the gooseneck resides clearly on the quantification of the role of the adsorption/desorption phenomena for the different coupling chemical substance/surface material.
7. Research is needed on the susceptibility for the potential grow of fungi on construction products. Several factors influence the risk of microbial growth among which some are related to the indoor environment (air velocity, relative humidity and temperature near surfaces) and, others to product characteristics (nature of the surface and structure of the material). Studies on this contribution will be important.

8. Research and new technology to clean the indoor air and the outdoor air used for ventilation. Development of low energy technologies for ventilation for better air quality, e.g. via improvement of air distribution efficiency, and air quality based intelligent control of ventilation and air cleaning,
9. 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.
10. There is a need to promote the development of robust tools for sustainable buildings where low energy demand, energy efficiency, life cycle analysis, environmental assessment and proper performance goals(comfort, good indoor air quality) and management are assured since the design phase and the commissioning period. That will require:
    - comprehensive criteria and tools to assess the holistic performance of buildings,
    - integrated tools assessing the compromise between good IAQ and low energy level and soft control and management strategies.

Despite gaps in the body of knowledge, there must be no delay in taking action to improve the indoor environment in Europe. The actions proposed by this project are based on scientific evidence and the evidence that by counteracting adverse health determinants, health is improved.

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Annex A

A case of the energy and burden of disease cost assessment of IAQ

The case is a generalised, illustrative and thought provoking one, and kindly supplied by Hal Levin, Hal Levin & Associates, Santa Cruz, CA, USA. It is particularly useful when balancing different ventilation, energy and IAQ policies.

The magnitude of the burden (both economic costs and diminished well-being) caused by symptoms and discomfort related to indoor air pollution is not well-known. The economic costs include both losses experienced by the individual, costs induced in the local network or organization of which this individual is a part (e.g., renovation of buildings or sick leave), and costs inflicted on society (e.g. in the form of medical therapy or early retirements). Added to this are indirect costs e.g., related to guideline setting and their enforcement and control.

The following is a constructed example illustrating the costs of poor IAQ in a typical office building. The building is assumed to be a suburban 14-story office building, each floor of 500 m^2, built in 1980. The estimated value of the building is US$ 15 000 000. The ventilation system has a heating and cooling system for a temperate climate. The energy consumption is US$ 15/m^2 or US$ 105 000 each year. There are 30 employees per floor, i.e., 420 employees. The average annual salary is US$ 35.000 corresponding to a total annual salary of US$ 14 700 000. Total annual turn-over of business in the building is US$ 50 000 000. An HVAC company suggests investing US$ 1 400 000 in the HVAC system (about US$ 200/m^2) to improve the system within the existing HVAC guidelines, and estimates that the owner will save 50% of the energy cost, corresponding to a full return on investment in 30 years. The process also includes replacement of ozone-depleting coolants with new environmentally acceptable liquids. This renovation is done.

One year after renovation the expected energy savings are found (now US$ 53 000 a year), but multiple complaints about poor IAQ, relating to the thermal and acoustic environment and odours, are reported among 90% of the occupants. The number of lost working days due to sick leave increases from 7 to 12%. The turn-over of staff increases from 10% to 15% annually, and reduced work productivity from 100% to 97% is reported but the associations to IAQ of these last two are uncertain. After four years, an IAQ investigation is made by external consultants. Their conclusions are that the first renovation achieved significant energy savings, but to a large extent by reducing the amount of outdoor air (and, therefore, the cost of conditioning more outdoor air). The IAQ problems are associated with the reduced outdoor air fraction -- the operational decisions made by the building operators, and not about system efficiency or performance *per se*. Conditioning outdoor air is roughly half of the ventilation system operating costs; running fans is the other half – in gross terms. There are also filtration costs that will decrease if outdoor air flow is reduced. Their recommendations are that changes should be made in the building and its HVAC system. Total price: US$ 400 000 (incl. US$ 50 000 salary). The changes result in increased operational costs to US$ 75 000. Symptoms and sick leave decrease to levels lower than those observed before the initial renovation. The energy savings are environmentally friendly and support the corporate goals.

Conclusions are that the initial renovation resulted in energy savings corresponding to US$ 53 000 a year, but these savings resulted in lost productivity due to sick leave corresponding to 5% of US$ 14 700 000 which equals US$ 735 000 a year. The annual balance is US$ 100 000 versus US$ 750 000. The more uncertain or potential loss due to decreased productivity is 3% of US$ 50 000 000 (US$ 1 500 000 a year). It takes 1 month to train a new employee corresponding to US$ 3 000. Therefore 21 new employees correspond to a cost of US$ 63 000 a year.

The lessons learned here are:

1. IAQ problems are often related to ventilation systems,
2. existing minimum ventilation guidelines may not always be adequate,
3. energy savings may be small compared to economic losses due to the impacts of poor IAQ on employee health and work performance.

Annex B - European, National and Professional Policies with IAQ Implications

Table B.1. Current policies related to ambient environment (outdoor air and soil radon)

Outdoor air		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
International Guidelines WHO Air Quality Guidelines, Global Update 2005 ***EU Directives*** Directive 96/62/EC (CAFE) Directive 99/30/EC (limit values for PM10, NO_2, NOx, SO_2, Pb) Directive 2000/69/EC (limit values for C_6H_6, CO) Directive 2002/3/EC (relating to O_3) Directive 2004/107/EC (relating to As, Cd, Hg, Ni, PAHs) Directive 2008/50/EC (SO_2, NO_2, Nox, PM, Pb, C_6H_6, CO, O_3)	***MS Legislation*** Building codes & ventilation codes National regulations and standards	***International and National*** HVAC engineering standards and practices
	Soil radon	
EU Directives Directive 90/143/Euratom (radon) Directive 96/29/Euratom (EU basic safety standard for radiation protection) ***EU Reports*** ECA Report No. 1 Radon in indoor air (EUR 11917 EN, 1988) ECA Report No. 15 Radon in indoor air (EUR 16123 EN, 1995)		

Table B.2. Current policies related to emissions from building materials

[Emissions from] building materials		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
International Guidelines WHO IAQ Guidelines (under development) ***EU Directives and Standards*** Directive 89/106/EEC (CPD, Construction Products Directive) CEN/TC 351 (Technical Committee, Construction Products: Assessment of Release of Dangerous Substances) CEN 1996. Technical report CR 1752. Ventilation for buildings: Design criteria for indoor environment. European Committee for Standardisation. Brussels Directive 2002/91/EC (EPBD, Energy Performance of Buildings Directive) Directive 2006/121/EC (REACH) EN 13779 (2007). European Standard. Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems EN 15251 (2007). European Standard. Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics	***MS Legislation*** National building codes Materials and products emission measurement standards and labelling schemes ***Voluntary systems*** AgBB scheme (Germany) CESAT - Evaluation of environmental and health-based properties of building products (France) M1- Emission classification of Building Materials (Finland) Indoor Climate Label (ICL-Denmark) LQAI scheme (Portugal) Natureplus (Germany and Europe) Blue Angel (Germany) Ecolabel scheme (Austria) GUT for carpets (Germany and Europe) Emicode system by GEV for adhesives and related material (Germany and Europe)	***International and National*** Classification of Indoor Climate 2000, FiSIAQ Publication 5 E. Target Values, Design Guidance and Product requirements Classification of Indoor Climate 2008, FiSIAQ (will be published 2008)

Table B.2. Current policies related to emissions from building materials (continuation)

[Emissions from] building materials		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
EU Reports SCHER Report ECA Report No. 2. Formaldehyde emissions from wood based materials: guideline for the determination of steady state concentrations in test chambers (EUR 12196 EN, 1989) ECA Report No. 6. Strategy for sampling chemical substances in indoor air (EUR 12617 EN, 1989) ECA Report No. 7. Indoor air pollution by formaldehyde in European countries (EUR 13216 EN, 1990) ECA Report No. 8. Guideline for the characterisation of volatile organic compounds emitted from indoor materials and products using small test chambers (EUR 13593 EN, 1991) ECA Report No. 13. Determination of VOCs emitted from indoor materials and products. Interlaboratory comparison of small chamber measurements (EUR 15054 EN, 1993) ECA Report No. 14 Sampling strategies for volatile organic compounds (VOCs) in indoor air (EUR 16051 EN, 1994) ECA Report No. 16. Determination of VOCs emitted from indoor materials and products: Second interlaboratory comparison of small chamber measurements (EUR 16284 EN, 1995)	***Voluntary systems*** Other schemes applied in Belgium and UK and The Scandinavian Trade standards	

Table B.2. Current policies related to emissions from building materials (continuation)

[Emissions from] building materials		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
EU Reports ECA Report No. 18. Evaluation of VOCs from building products: solid flooring materials (EUR 17675 EN, 1997) ECA Report No. 19. Total Volatile Organic Compounds (TVOC) in indoor air quality investigations (EUR 17675 EN, 1997) ECA Report No. 21. European interlaboratory comparison on VOCs emitted from building materials and products (EUR 18698 EN, 1999) ECA Report No. 24. Harmonisation of indoor material emissions labelling systems in the EU, Inventory of existing Schemes (EUR 21891 EN, 2005)		

Table B.3. Current policies related to fixed household equipment/appliances

Fixed household equipment/appliances (including heating and combustion)		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
International Guidelines WHO IAQ Guidelines (under development) ***EU Directives*** Directive 90/396/EEC (burning appliances) Directive 92/42/EEC (boilers) Directive 2004/8/EC (promotion of cogeneration based on a useful heat demand in the internal energy market requests considerable increase in co-generation) Directive 2005/32/EC (ecodesign requirements for energy-using products) ***EU Reports*** ECA Report No. 3. Indoor pollution by NO_2 in European countries (EUR 12219 EN, 1989)	***MS Legislation*** Building codes and standards, maintenance and inspection schemes, and gas appliances approval, maintenance and inspection schemes, etc. covering the issues which may affect IAQ	

Table B.4. Current policies related to ventilation (general and local extract) and air conditioning systems

Ventilation [general and local extract] and air-conditioning systems		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
International Guidelines WHO IAQ Guidelines (under development) ***Standards*** CEN 1996. Technical report CR 1752. Ventilation for buildings: design criteria for indoor environment. European Committee for Standardisation. Brussels BS EN 1886: 1998. Ventilation for buildings. air handling units. Mechanical performance. British-Adopted European Standard / 15-Nov-1998 / 16 pages. ISBN: 0580298221 EN 13779 (2007). European Standard. Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems EN15251 (2007). European Standard. Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics DIN EN 15780: 2008. Lüftung von Gebäuden - Luftleitungen - Sauberkeit von Lüftungsanlagen, Deutsche Fassung prEN 15780: 2008	***MS Legislation*** Building codes, HVAC codes and standards, maintenance and inspection schemes, etc. covering the issues which may affect IAQ Most of European countries have building codes and guidelines for ventilation rates, design and construction of ventilation systems ASHRAE Standard 52.2-1999 – Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size BS 5440-2:2000 Installation and maintenance of flues and ventilation for gas appliances of rated input not exceeding 70 kW net (1st, 2nd and 3rd family gases). Specification for installation and maintenance of ventilation for gas appliances. ISBN 0 580 33098 2 BS 5720:1979. Code of practice for mechanical ventilation and air conditioning in buildings. British Standards Institution / 31-Oct-1979 / 80 pages. ISBN: 0580107183	***International and National*** VDI 6022 Blatt 1 Hygienic requirements for ventilating and air-conditioning systems and air-handling units, 2006-4 VDI 6022 Baltt 2 Hygienic requirements for ventilation and air-conditioning systems - Measurements procedures and examinations in hygiene check-ups and hygiene inspections. 2007-7 ASHRAE 62.2. (2007) ANSI/ASHRAE standard 62.2-2007. Ventilation and acceptable indoor air quality in low-rise residential buildings. American Society of Heating Refrigerating and Air Conditioning Engineers. Atlanta REHVA 2007a.Cleanliness of ventilation systems. Federation of European Heating and Air-conditioning Associations (REHVA), Guidebook No 8. www.rehva.eu REHVA 2007b. Hygiene requirement for ventilation and air-conditioning. Federation of European Heating and Air-conditioning Associations (REHVA), Guidebook No 9. www.rehva.eu CIBSE Handbook of Domestic Ventilation CIBSE AM13: Mixed Mode Ventilation

Table B.4. Current policies related to ventilation (general and local extract) and air conditioning systems (continuation)

Ventilation [general and local extract] and air-conditioning systems		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
Standards DIN EN 13141-7, August 2008. Lüftung von Gebäuden - Leistungsprüfungen von Bauteilen/Produkten für die Lüftung von Wohnungen - Teil 7: Leistungsprüfung von mechanischen Zuluft- und Ablufteinheiten (einschließlich Wärmerückgewinnung) für Lüftungsanlagen in Einfamilienhäusern; Deutsche Fassung prEN 13141-7:2008. 2008, 41 S ***EU Reports*** ECA Report No. 11. Guidelines for ventilation requirements in buildings (EUR 14449 EN, 1992) Report No. 23. Ventilation, good indoor air quality and rational use of energy (EUR 20741 EN, 2003)		***International and National*** CIBSE AM10: Natural Ventilation CIBSE Guides A and B2 CIBSE Minimising pollution at air intakes. CIBSE Technical Memorandum TM21:1999 Lüftung in Wohnbauten. Gültig ab: 01.06.2008; Ersatz für: SIA 2023:2004Hrsg.: SIA Schweizerischer Ingenieur- und Architektenverein Zürich 2008, 56 S VDI 3804. Raumlufttechnik für Bürogebäude (VDI-Lüftungsregeln). Ausgabe: 2008Vorgesehen als Ersatz für: VDI 3804 VDI 3817. Technische Gebäudeausrüstung in Baudenkmalen und denkmalwerten Gebäuden. Ausgabe: 2008 VDI 6035. Raumlufttechnik - Dezentrale Lüftungsgeräte - Fassadenlüftungsgeräte (VDI-Lüftungsregeln). Ausgabe: 2008Nachdruck in: VDI-Handbuch Technische Gebäudeausrüstung Band 2 VDI 2087 Berichtigung. Luftleitungssysteme - Bemessungsgrundlagen - Berichtigung zur Richtlinie VDI 2087:2006-12. Ausgabe: 2008Änderung von: VDI 2087 (2006-12). 2008, 2 S

Table B.4. Current policies related to ventilation (general and local extract) and air conditioning systems (continuation)

Ventilation [general and local extract] and air-conditioning systems		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
		International and National ÖNORM EN 13779, 01. Januar 2008. Lüftung von Nichtwohngebäuden - Allgemeine Grundlagen und Anforderungen für Lüftungs- und Klimaanlagen und Raumkühlsysteme 2008, 73 S

Table B.5. Current policies related to water systems

Water systems		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
Standards ISO 11731 (1998). Water quality–detection and enumeration of *Legionella* ISO 11731-2 (2004). Water quality–detection and enumeration of *Legionella*-part 2:direct membrane filtration method for waters with low bacterial counts	***MS Legislation*** UK Building regulations; Approved document G - Hygiene (1992 edition) Bundesgesundheitsamt, Mitteilung des Bundesgesundheitsamtes über den Nachweis von Legionellen in erwärmtem Trinkwasser, Bundesgesundhbl. 36 (1993), p. 162.	***International and National*** CIBSE BAG19/00: 2000. Guide to Legionellosis-operation and maintenance CIBSE BAG20/00: 2000. Guide to Legionellosis-risk assessment CIBSE Technical Memorandum TM13: 2002. Minimizing the risk of Legionnaires' Disease CIBSE GVG: 2004. Guide G: Public health engineering Health and Safety Executive (www.hse.gov.uk/biosafety/diseases/legionnaires.htm) Legionnaires' disease: a guide for employers Legionnaires' Disease: Essential information for providers of residential accommodation Local authority guidance on Legionnaires' disease Evaluation of HSC's ACOP and guidance Legionnaires disease: the control of *Legionella* bacteria in water systems" (L8) 'Legionnaires' Disease HPA & HSE Guidance: Management of Spa Pools: Controlling the risk of Infection' HSE *Legionella* Information

Table B.5. Current policies related to water systems (continuation)

Water systems		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
		International and National Legionnaire's disease at chemical sites Department of Veteran Affairs Veteran Health Administration Washington DC 20420 VHA Directive 2008-10 February 11-2008. Prevention of Legionella Disease Drinking water systems (including domestic hot and cold water systems) Deutsche Vereinigung des Gas-und Wasserfaches e.V. W 551 DIN 19643-1: 1997. Deutsches Institut für Normung (1997a) Treatment and disinfection of water used in bathing facilities, Part 1: General requirements. Berlin, Beuth Verlag VDI 6022-3. Cooling towers VDI 6022 all parts. Air-conditioning

Table B.6. Current policies related to dampness and mould

Dampness and mould		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
International Guidelines WHO IAQ Guidelines (under development) Flannigan and Morey (1996) present the general principles for moisture and mold safe construction and operation of buildings IEA (1991). Report Annex 14: Condensation and Energy: reviews the relations between mould, surface condensation, climate, building design and occupancy factors and presents a comprehensive overview of the design guidelines in cool, humid climates IEA (1991). Report Annex 14: Condensation and energy, Vol 1, "Source Book" IEA (1991). Report Annex 14: Condensation and energy, Vol 2, "Guidelines and Practices IEA (1991) Report Annex 14: Condensation and energy, Vol 3, "Catalogue of Material properties" IEA (1991) Report Annex 14: Condensation and energy, Vol 4, "Case studies "	***MS Legislation*** Building codes that regulate moisture safety issues: water insulation, seepage, leak and condensation prevention in the construction and renovation of buildings Building codes and guidelines for moisture safety issues in construction including both moisture safe structural solutions and moisture control in the construction process. Partly the differences in technical guidelines can be explained by the differences in climate and construction practice, but the diversity of the guidelines also reflects the lack of scientific background on mould and dampness and consequent health outcomes DIN 4108-3:2001-07 (2001). Thermal protection and energy economy in buildings .Part 3: Protection against moisture subject to climate conditions. Requirements and directions for design and construction DIN 4108-4:2001-07 (2001). Thermal insulation and energy economy in buildings .Part 4: Hygrothermal design values	***International and National*** Flannigan, B., and P.R. Morey (1996). Control of moisture problems affecting biological indoor air quality. ISIAQ Guideline TFI-1996. Ottawa: International Society of Indoor Air Quality and Climate CIBSE EHDV: 2005. Handbook of Domestic Ventilation Richtlinie VDI 4300 Blatt 10: Messen von Innenraumluftverunreinigungen - Messstrategien bei der Untersuchung von Schimmelpilzen im Innenraum ASHRAE Standard 160P (2004). Design Criteria for Moisture Control in Buildings, Working Draft, Nov. 2004, p. 5

Table B.6. Current policies related to dampness and mould (continuation)

Dampness and mould		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
Standards EN ISO 13788 (2001). Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods prEN 15026 (2006). Hygrothermal performance of building components and building elements - Assessment of moisture transfer in building components by numerical simulation EN ISO 10211-1 (1995). Thermal bridges in building construction - Heat flows and surface temperatures - Part 1: General calculation methods ***EU Reports*** ECA Report No. 12. Biological particles in indoor air (EUR 14988 EN, 1994)		

Table B.7. Current policies related to furnishings, decoration materials and electrical (computing & entertainment)

Furnishings, decoration materials and electrical (computing & entertainment)		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
EU Directives Directive 2001/95/EC (GPS) Directive 2002/95/EC and 2005/32/EC (electrical appliances) Directive 2004/42/EC (paints and varnishes) Directive 2006/121/EC (REACH) ***EU Reports*** ECA Report No. 6. Strategy for sampling chemical substances in indoor air (EUR 12617 EN, 1989) ECA Report No. 8. Guideline for the characterisation of volatile organic compounds emitted from indoor materials and products using small test chambers (EUR 13593 EN, 1991)	***MS Legislation*** National regulations concerning the chemicals in and measurement standards for the emissions/releases from furnishings, loose carpets, interior decorations, paints, labelling schemes, etc. National electrical product safety regulations, standards & practices	

Table B.8. Current policies related to cleaning and household products

Cleaning and other household products		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
EU Directive Directive 2006/121/EC (REACH) Directive 2001/95/EC (GPS)	***MS Legislation*** National household product safety regulations & standards National regulations concerning the chemicals in and measurement standards for the emissions/releases from consumer products and articles, labelling schemes, etc. concerning in particular cleaning and finishing chemicals intended for interior use	***International and National*** Professional cleaning and cleaning product standards and practices

Table B.9. Current policies related to maintenance, ventilation practices

Maintenance, ventilation practices		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
EU Reports ECA Report No. 11. Guidelines for ventilation requirements in buildings (EUR 14449 EN, 1992)	***MS Legislation*** Regulations, standards and practices concerning the commissioning of the buildings, and the operating, maintenance and inspection manuals and schedules for the building equipment National regulations and guidance – if any – concerning proper maintenance including cleaning of the building, instructions and guidance for the use of mechanical as well as natural ventilation, regulations and instructions concerning equipment and materials which should be avoided indoors (such as unvented paraffin heaters, impregnated wood, industrial solvents, etc.), etc.	***International and National*** Classification of Indoor Climate 2000, FiSIAQ Publication 5 E: Target Values, Design Guidance and Product requirements Classification of Indoor Climate 2008, FiSIAQ (will be published 2008) VDI 6022 Blatt 1 Hygienic requirements for ventilating and air-conditioning systems and air-handling units, 2006-4. VDI 6022 Baltt 2 Hygienic requirements for ventilation and air-conditioning systems - Measurements procedures and examinations in hygiene check-ups and hygiene inspections. 2007-7. ASHRAE 62.2. (2007) ANSI/ASHRAE standard 62.2-2007. Ventilation and acceptable indoor air quality in low-rise residential buildings. American Society of Heating Refrigerating and Air Conditioning Engineers. Atlanta REHVA 2007a.Cleanliness of ventilation systems. Federation of European Heating and Air-conditioning Associations (REHVA), Guidebook No 8. www.rehva.eu REHVA 2007b. Hygiene requirement for ventilation and air-conditioning. Federation of European Heating and Air-conditioning Associations (REHVA), Guidebook No 9. www.rehva.eu CIBSE TM44: 2007. Inspection of Air Conditioning Systems

Table B.10. Current policies related to smoking, cooking (hobbies, pets)

Smoking, cooking (hobbies, pets?)		
INTERNATIONAL & EU	**MEMBER STATES**	**PROFESSIONALS**
International Guidelines Warsaw Declaration for a tobacco free Europe WHO: European Strategy for tobacco control These need to be spelled out with a sentence or so for each	***MS Legislation*** National indoor smoking restrictions, guidance for the use of kitchen hood, vent and fan, guidance (product labelling) for the use of hobby materials indoors	

Dissemination and use

8. Dissemination material

8.1. Logo

8.2. Website

The website address is: http://www.envie-iaq.eu. The WP0 was in charge of the implementation and management of the EnVIE website, which serves as the core for an information and connection platform. It provided both public and more restricted working areas open only to partners. In particular, it shows regularly updated information about the status of the project. The website also kept all the coordination action partners fully informed on the project status, planning, administrative, financial, management and scientific general issues.

Thus, the following EnVIE general information was available on the project website:

- Contact and participants information;
- Project information;
- Conferences;
- Workshops;
- Reports, annexes and proceedings;
- Links to other relevant initiatives.

The following documents were available on the project web site in an electronic format:

- The project archives (contractual, administrative, scientific documents);
- Meeting minutes;
- Scientific progress and final reports;
- Conference Proceedings;
- Conference presentations;
- Workshop presentations.

Indoor Air EnVIE - Windows Internet Explorer
http://www.envie-iaq.eu/index.html
Indoor Air EnVIE
6th Framework Programme 2002-2006
> HOME
> What is it?
> What's new
> Contact
> Participants
> Workpackages
> Documents
> Conferences
> EnVIE flow chart
> Members Only
> Links
> Welcome!
EnVIE is a European Co-ordination Action interfacing science and policy making in the field of indoor air quality. EnVIE is collecting and interpreting scientific knowledge from on-going research, in particular from EU funded projects and Joint Reserch Center activities, to elaborate policy relevant recommendations based on a better understanding of the health impacts of indoor air quality.
This project is funded by the European Commission 6th Framework Programme of Research (http://cordis.europa.eu/fp6), Scientific Support to Policy.
EC contribution 824 977 €.
EnVIE project restarted from 1 March 2007 under IDMEC (University of Porto – Portugal) coordination and will last until 31 October 2008.
Thank you for visiting us
Eduardo de Oliveira Fernandes
IDMEC
© Copyright IDMEC - DD 2007 - About Software
start
Internet
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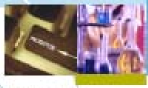
8.3. Brochure

To promote dissemination an EnVIE brochure was edited between Conferences (August 2007). The brochure was issued together with a poster. The brochure serves as a prestigious calling card for presentation of the project to influential readers – European policy-makers, national and local authorities, potential partners, investors, industrial end-users, technology licensees, media representatives. The content of the brochure and the poster was reviewed by the PSC and approved by the Commission prior to their dissemination.

EnVIE is a European Co-ordination Action interfacing science and policy making in the field of indoor air quality. EnVIE collects and interprets scientific knowledge from on-going research, in particular from EU funded projects and Joint Research Center activities, to elaborate policy relevant recommendations based on a better understanding of the health impacts of indoor air quality.



Context and Aim

Health and Environment are major issues for Europe. European air quality policies have devoted most of their efforts to control the urban outdoor air concentrations. Since European citizens commonly spend up to 90% of their time in indoor environments, there is a clear need for Europe to better address the potential interactions between indoor air quality and human health. Indoor air pollution from different sources causes and aggravates illnesses and increases mortality, resulting in a major economic and social impact. It is now recognised that new policies should be focussed on indoor air exposures to identify, control and eliminate indoor sources of air pollution and to reduce exposure to air pollution from indoors.

Knowing the relative contributions of indoor environments to exposure and health effects is essential for effective risk management and resources allocation.

The aim of the EnVIE Project is to evaluate the public health impact of poor indoor air quality in Europe and to inform policy makers about evidence-based preventive policies.

The EnVIE project will identify the most widespread and significant indoor causes and sources for those health impacts, and evaluate the existing and optional building and specially housing related policies for controlling them. It will address in particular how indoor air quality might contribute to the observed rise in asthma and respiratory allergy, together with other acute and chronic health impacts.

EnVIE Approach

In the frame of the EnVIE project the following diseases have been prioritised as being caused or aggravated by poor indoor air quality:

- Allergic and Asthma symptoms,
- Lung Cancer,
- Chronic obstructive pulmonary disease,
- Airborne respiratory infections,
- Cardiovascular morbidity and mortality,
- Odour and irritation

New evidences concerning cardiovascular effects and adverse effects on fetal development will also be part of the project.

Envie
Indoor air

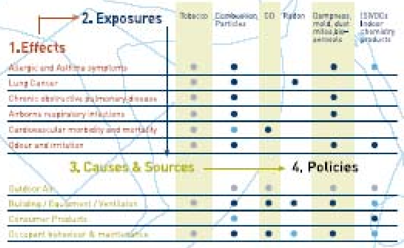
Many previous indoor air quality and policy assessments have taken specific contaminants or indoor sources as the starting points. The logic behind has been flow from sources via environment to exposure, dose assessment and the consequent health outcome.

The EnVIE approach follows an opposite logic, starting from the most pronounced indoor air related health outcomes (which have often also other sources and causes), then identifying the most widespread indoor air exposures which are likely to cause these health outcomes, and the most common sources which dominate the indoor air exposures – see Figure 1.

The 1st objective of this approach is to focus from the start on those indoor air quality issues of the highest Europe-wide health relevance. Having defined a shortlist of such indoor health-exposure-source chains, the project will evaluate the policy alternatives for minimising the unwanted health consequences in terms of achievable public health benefits, invasiveness, as well as political, legal, technological, economical and social feasibility.

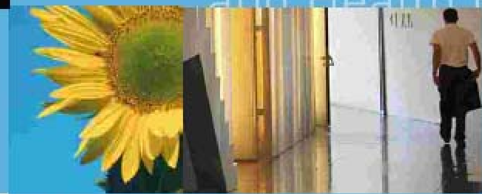
The 2nd objective is to identify and describe a set of beneficial and feasible indoor air quality policy alternatives for Europe. Europe wide applicability brings, aside of the health benefits, also the economical benefits of enhanced competition in a broader marketplace.

Figure 1.
Flowchart of the EnVIE approach

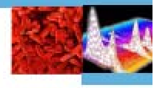


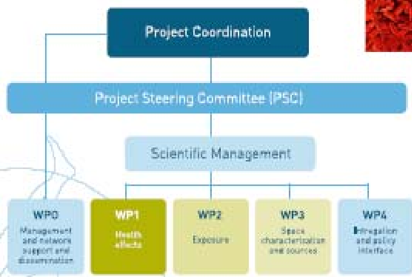
Different colours degrees ●● mean different levels of impact.
Out of ENVIE scope.

Indoor Air Quality and Health Effects



Sctruture, Actions and Deliverables





The 1st Conference of the ENVIE project was held in Helsinki in June 12th–14th 2007.
Proceedings of the 1st Conference will be available after August 31, 2007.

The 2nd Conference of the ENVIE will be in Copenhagen in August 2008, and will focus on source control policies, achievable exposures and health impacts, as well as on the requirements and consequences of the considered alternatives.

The final report of the ENVIE project will be ready in October 2008.

8.4. Poster


2004-2008
Indoor Air
EnVIE
Co-ordination Action on
Indoor Air Quality
and Health Effects
EnVIE is a European Co-ordination Action interfacing science and policy making in the field of indoor air quality. EnVIE collects and interprets scientific knowledge from on-going research, in particular from EU funded projects and Joint Research Center activities, to elaborate policy relevant recommendations based on a better understanding of the health impacts of indoor air quality.
The EnVIE approach scheme is:
1.Effects
2. Exposures
Tobacco
Combustion Particles
CO
Radon
Dampness, mold, dust mites bio-aerosols
Allergic and Asthma symptoms
Lung Cancer
Chronic obstructive pulmonary disease
Airborne respiratory infections
Cardiovascular morbidity and mortality
Odour and irritation
3. Causes & Sources
4. Policies
Outdoor Air
Building / Equipment / Ventilation
Consumer Products
Occupant behaviour & maintenance
Contacts
IDMEC
KTL
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IDMEC
KTL
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9. Events

9.1. Conferences

The first EnVIE Conference on “Indoor Air Quality and Health for EU Policy” was organised as a satellite event to Clima 2007 WellBeing Indoors, on 12-13 June in Helsinki. The first public announcement was done in Clima 2007 website (http://www.clima2007.org/portal/envie_conference/). The first Conference focused on the selected health effects, and their respective indoor exposures and sources, linking on one hand information compiled in the EnVIE project to information from other investigations and reviews, and on the other hand, the experts in public health, exposure and building design, construction and management that attended the Conference. The target audience for this Conference and its report was scientists and experts. The number of participants was about 60. The Conference programme is presented next. The Proceedings of the 1st Conference were edited, and were made available on the website.

Tuesday 12 June (conference room 25-26)	
08.30-09.00	Registration
09.00-09.10	Welcome by ENVIE project coordinator - E. de Oliveira Fernandes
09.10-10.15	**Session 1A: Overview of related European projects on Indoor Air Quality and Health** *Chair: A. Bartonova* *Rapporteur: M. Endrody* *Speakers:* IAQ activities in WHO - *M. Braubach* IAQ activities in ERS - *I. Annesi-Maesano* IAQ activities in JRC - *D. Kotzias* EC actions on IAQ - *S. Kephalopoulos*
10.15-10.45	**Session 1B: Introduction of EnVIE concept and overview of EnVIE project** *Chair: A. Bartonova* *Rapporteur: P. Harrison* *Speakers: M. Jantunen and P. Carrer*
10.45-11.00	Coffee break
11.00-12.30	**Session 2: Health topic - SBS, irritation, odours** *Chair: P. Carrer* *Rapporteur: D. Crump* *Speaker: L. Mølhave* Panel presentations and discussion Key exposure agent: VOCs - *H. Prejzner* Key sources: Building materials, consumer products - *H. Gustafsson*
12.30-13.45	Lunch
13.45-15.15	**Session 3: Health topic - Asthma and allergy** *Chair: M. Endrody* *Rapporteur: A. Bartonova* *Speaker: J. Sundell* Panel presentations and discussion Key exposure agent: Bio-aerosols - *A. Nevalainen* Key source: Moisture - *U. Haverinen-Shaugnessy*
15.15–15.30	Coffee break
15.30-17.00	**Session 4: Health topic - Infectious diseases** *Chair: M. Branis* *Rapporteur: S. Kephalopoulos* *Speaker: I. Holcatova* Panel presentations and discussion Key exposure agent: Pathogens - *B. Fisk, I. Holcatova* Key sources:Water systems - *V. Leal, E. de Oliveira Fernandes*

Wednesday 13 June (conference room 25-26)	
8.30-10.45	**Session 5: Health topic - Cancer, acute cardiovascular effects and COPD** *Chair: D. Kotzias* *Rapporteur: L. Mølhave* *Speakers: F. Forastiere, G. Viegi, I Annesi-Maesano* Panel presentations Key exposure agent: Combustion products - *M. Jantunen* Key sources: Outdoor air, indoor combustion processes - *D. Crump* **In Focus: CO and acute intoxication** - *P. Carrer* **In Focus: Radon and lung cancer** - *J. McLaughlin* Panel discussion
10.45-11.00	Coffee break
11.00-11.30	**Session 6: Indoor Air policy perspectives** *Chair: E. de Oliveira Fernandes* *Rapporteur: J. Molina* *Speaker: P. Harrison*
11.30-12.00	**Introduction and invitation to the EnVIE Workshop** - *E. de Oliveira Fernandes*

To be attended only by EnVIE partners

Tuesday 12 June (conference room 25-26)	
17.00-18.30	**EnVIE project overview** – *E. de Oliveira Fernandes*
Wednesday 13 June - ENVIE workshop	
13.30-14.30	**Plenary session: Rapporteurs' session reports** (conference room 25-26) *Chair: M. Jantunen* *Speakers:* Chair/ Rapporteur session 1A and B Chair/ Rapporteur session 2 Chair/ Rapporteur session 3 Chair/ Rapporteur session 4 Chair/ Rapporteur session 5 Chair/ Rapporteur session 6
14.30-16.00	**Three (3) Parallel Workshops** (WP 1, 2 and 3) (conference rooms 22, 23, 24)
16.00-17.00	**Plenary session: Reporting from the workshops, Wrap-up** (conf.room 25-26) *Chair: E. de Oliveira Fernandes* *Speakers:* WP1 leader WP2 leader WP3 leader

The 2nd Conference under the title 'Policies for millions of indoor environments' took place in Brussels in September 16-17, 2008, with 115 participants. The Conference started with the enunciation of the Preliminary Proposal on Policies by the Scientific Coordinator of EnVIE and had a sequence of sessions allowing representatives from different bodies and sensitivities to express their views. The presentations of the 2nd Conference were made available on the website.

EnVIE Conference

Policies for millions of indoor environments

Brussels – Belgium, 16 - 17 September 2008

Organised by the Co-ordination Action on Indoor Air Quality and Health Effects supported by Sixth Framework Programme of Research of the European Union

6th Framework Programme 2002-2006

Conference motto

Successful policies to ensure safe indoor environments for 400 million Europeans must involve not only building designers and regulators but also building construction and maintenance professionals, building managers, educators and professional associations. Following good practice is essential for success. Furthermore, in residential buildings the majority of indoor air problems can only be detected, assessed and remedies initiated by the occupants. Therefore, buildings should be 'fail-safe' in the sense that no failure in building systems or equipment should create a danger which is not obvious to a lay person.

Steering Committee

E. Oliveira Fernandes – Instituto de Engenharia Mecânica, Portugal
M. Jantunen – National Public Health Institute, Finland
P. Carrer – Universitá Degli Studi di Milano, Italy
O. Seppänen – Helsinki University of Technology, Finland

Webpage: http://www.envie-iaq.eu

1st Day, September 16

Time	Topic
09.30-10.00	Registration
10.00-11.30	**Opening Session – EnVIE Outcome for EU Policies** *Chairs: E. Oliveira Fernandes* *P. Harrison* Welcome. … *E. de Oliveira Fernandes* EnVIE Outcome. Proposals for EU Policies on IAQ & Health. …*Matti Jantunen* *Comments by:* DG Research…*Tuomo Karjalainen* DG Health & Consumers…*Giulio Gallo* DG Enterprise & Industry…*Manfred Fuchs* DG Environment… *Alessandro Bertello* DG Energy & Transport…*Pirjo-Liisa Koskimäki* DG Joint Research Centre…*Dimitrios Kotzias*
11.30-12.00	Coffee break
12.00-13.15	**International and European actors views** *Chairs: G. Gallo* *A. Bartonova* *Speakers:* The WHO work on indoor environments ...*Matthias Braubach* US-EPA ...*Laura Kolb* VITO ...*Rudi Torfs*
13.15-14.00	Lunch
14.00-15.30	**EnVIE Results: context and fundaments** *Chairs: T. Karjalainen* *Ivana Holcatova* *Speakers:* WP1 (Health effects) ...*Paolo Carrer* WP2 (Exposure) ...*Matti Jantunen* WP3 (Characterisation of spaces and sources) ...*E. de Oliveira Fernandes* *Discussion*
15.30-16.00	Coffee break
16.00-18.00	**Comments from stakeholders** *Chairs: J. Sundell* *G. Ventura* *Speakers:* EFA ...*Susanna Palkonen* Eurima ...*Aymon de Reydellet* Standardisation related to Indoor Environmental Quality ...*Bjarne Olesen* Industry policies: sustainable contributions to healthy indoor air ...*Loredana Ghinea* BEUC ... *Sylvia Maurer* Health & Environment Alliance ...*Christian Farrar-Hockley* Information and communication ...*Tom van Teunenbroek* *Discussion*

2nd Day, September 17

Time	Topic
9.00-11.00	**Experiences on IAQ policies and actions** *Chairs: D. Crump* *Ph. Bluyssen* *Speakers:* Ireland (Radon) …*James McLaughlin* The French experience: from research (RSEIN, National Observatory on IAQ) to IAQ policies (Grenelle de l'environnement) …*Corinne Mandin* A German view on tools and measures to improve IAQ ... *Christine Däumling* Finland (Material labelling & IAQ Guidelines) ...*Jorma Säteri* Recent advancements on harmonization of European labelling schemes ...*Stelios Kephalopoulos* *Discussion*
11.00-11.30	Coffee break
11.30-13.00	**Policies for better IAQ** *Chairs: L. Molhave* *H. Gustafsson* *Speakers:* Harmonisation of standards for testing emissions into Indoor Air … *Jean-François Vicard* Ways to improve technical building services for better indoor air quality ...*Olli Seppanen* Moisture control ...*Aino Nevalainen* Consumer products ... *Dimosthenis Sarigiannis* *Discussion*
13.00-14.00	Lunch
14.00-15.30	**Policies regarding 'built environment'** *Chairs: G. Viegi* *M. Branis* *Speakers:* Housing conditions and health in Europe – a LARES snapshot …*Matthias Braubach* Energy building codes and IAQ concerns: status, opportunities and threats …*Peter Wouters* IAQ & Sustainable Buildings …*E. de Oliveira Fernandes* *Discussion*
15.30-16.00	**Closing Session** *Chairs: E. Oliveira Fernandes* *B. Seifert* *Speaker:* *Matti Jantunen*

Conference Venue

Crowne Plaza Brussels City Centre – 'Le Palace'

Rue Gineste 3
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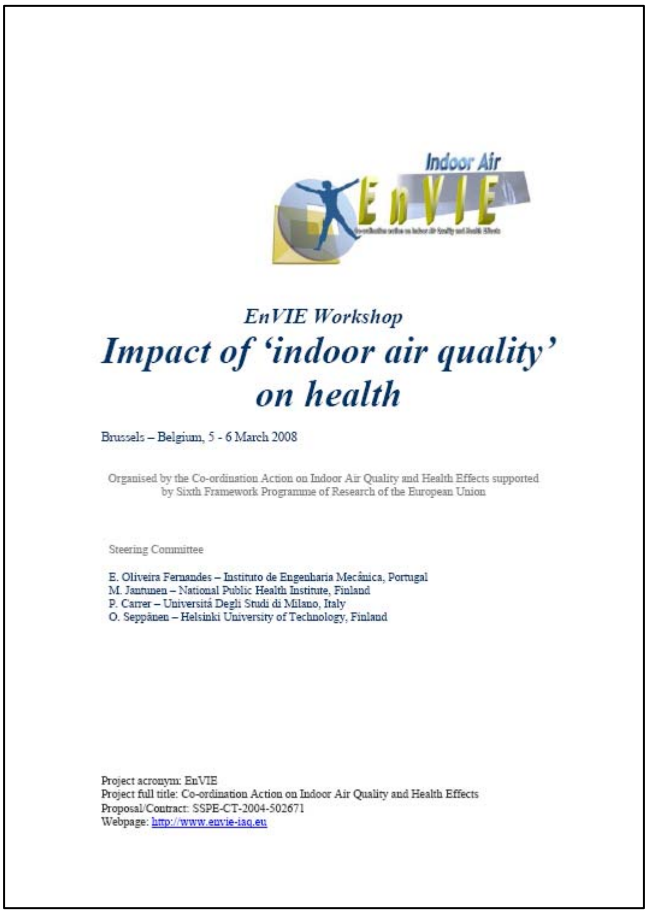
9.2. Workshops

Four Workshops were organized, two open and two restricted.

The first EnVIE, restricted, workshop (Baseline Workshop) took place in the premises of CSTB in Paris on June 14-15, 2004. In the two days workshop the state of the art of the key components of EnVIE (indoor relevant health issues, indoor exposures, indoor spaces, sources & ventilation, and policies) was reviewed, and the future work to focus was discussed.

A second EnVIE Workshop first open took place in Lisbon on June 5, 2006, inserted in the programme of "Healthy Buildings 2006" Conference, organised by partner 1, IDMEC. The Workshop was organised after the first attempt to re-start the project.

A restrict workshop was organised in Helsinki, focused on each work package immediately following the 1st EnVIE Conference.



EnVIE Workshop

Impact of 'indoor air quality' on health

Brussels – Belgium, 5 - 6 March 2008

Organised by the Co-ordination Action on Indoor Air Quality and Health Effects supported by Sixth Framework Programme of Research of the European Union

Steering Committee

E. Oliveira Fernandes – Instituto de Engenharia Mecânica, Portugal
M. Jantunen – National Public Health Institute, Finland
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O. Seppänen – Helsinki University of Technology, Finland

Project acronym: EnVIE
Project full title: Co-ordination Action on Indoor Air Quality and Health Effects
Proposal/Contract: SSPE-CT-2004-502671
Webpage: http://www.envie-iaq.eu

The fourth workshop was held in Brussels in March 5-6, 2008 with an attendance of 45 persons including all together representatives of 14 EU funded projects with some links to IAQ and 8 institutions with traditional records on IAQ issues. The aims of this workshop, among others, was to collect the most updated information, identified in the context of the EU-funded research projects, on the evidence of the impact of IAQ on health.

An overview of the activities is presented in Table 11.

Table 11. Overview table

Planned/ actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
June 14/15, 2004, Paris	1st Workshop	Research, Higher education (scientists and experts)	European Union	30	3 / all
June 5, 2006, Lisbon	2ndWorkshop	Research, Higher education (scientists and experts)	International	150	1 /All
September 2004/ June 2007	1st Conference	Research, Higher education (scientists, EC and EU experts)	International	60-80	1, 4, 5, 7/ All
November 2004/ August 2007	1st Conference Proceedings	Research, Higher education, Industry	European Union		1, 4, 5, 7/ All
September 2004/ June 2007	Workshop by WP topic	Research, Higher education scientists, EC and EU experts)	International	60-80	1, 4, 5, 7/ All
September 2006/ September 2008	2nd Conference	Research, Higher education, Industry (public health authorities, building (planned, new and in use) inspectors and regulators, building construction and materials industries, and building owners and managers)	International	115	1, 4, 5, 7/ All
November 2006/ October 2008	2nd Conference Proceedings	Research, Higher education, Industry	European Union		1, 4, 5, 7/ All
September 2006/ March 2008	Workshop by WP topic	Research, Higher education, Industry	International	50	1, 4, 5, 7/ All
April 2004	Project web-site- 1st version	Research, Higher education	European Union		3
June 2007	Project web-site- 2nd version	Research, Higher education	European Union		1
August 2007	Brochure	Research, Higher education, Industry	European Union		1

10. Other Dissemination Activities

Corresponding to the need of a comprehensive approach to tackle IAQ, and recognizing the importance of gathering the contributions of other policies and tools related to IAQ, EnVIE felt the need to propose, as a major step forward, a Green Paper on IAQ. The set of recommendations on its wide coverage of the issues and involvement of actors fully justify the need and the urgency for such initiative.

The most important question that emerged from this IAQ policy assessment is:"Is there a need for preparing a EU Green Paper on IAQ? If so, what should be its objective and which IAQ issues should it enclose? And, finally, how could a technically and economically feasible policy be formulated and implemented to bring with it maximum public health benefit and individual risk reduction with minimum unwanted interferences".

In the following we will try to answer the first two questions.

Yes, there is a need for a EU Green Paper on IAQ. The preparation of the Green Paper should be carefully coordinated with other legislative tools of policies related to IAQ (that is REACH, GPSD, CPD and EPBD). It should in general give sufficient priority of the IAQ issues in all urban development, building materials, technologies, equipment and household products related policies to ensure that IAQ is rather improved than deteriorated in implementing respective policies. Specifically it should associate IAQ into the energy efficiency procedures of EPDB.

The ultimate objective of the EU Green Paper on IAQ should be healthy IAQ. Other objectives would follow from this according to the EnVIE concept, i.e. to health damaging indoor exposures and further to the sources where the indoor exposures originate from, and/or to technologies which can cut the pathway from sources to exposures. The Green Paper should formulate criteria and framework for regulating both the sources and the exposure mitigating technologies, and for the management of the buildings to ensure healthy IAQ. On the other hand, it may not be advisable to include into the Green Paper on IAQ issues that have no implications on construction technology, building materials or equipment or which are progressively being dealt with elsewhere (e.g. smoking).

The Green Paper on IAQ should:

- Enable an objective dialogue among all relevant stakeholders (including industries, NGOs, medical doctors, building owners, consumer associations, architects, general public), the European Parliament and the European Commission;
- Propose strategies and priorities to enhance the existing policies;
- Clarify, harmonize, streamline and coordinate the action of the various actors dealing with IAQ matters;
- Promote the hollistic view needed for the management of the built environment in tune with new values such those ultimately associated with the concept of sustainability.

The EU Green Paper on IAQ should prepare the ground for effectively dealing with and putting in place the following issues:

Documentation requirements and responsibility assignment

Provide systematic documentation and operating, inspection and maintenance manuals for buildings 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.

Design criteria for new buildings and renovations

Building structures and materials: Apply tight building envelopes. Avoid spaces, structures and materials which would not dry by convective airflows. Mandate radon safe construction for all new buildings.

Heating: Ban all unflued combustion heaters, equip gas stoves with exhaust hoods and fans, mandate CO detectors for all spaces with combustion devices (integrate with EPBD procedures). Recommend in favour of district heating and against local solid fuel combustion.

Ventilation: Apply balanced ventilation and air cleaning for all new/renovated buildings when ambient air quality is below WHO AQG (integrate with EPBD).

Water systems, moisture management: Provide kitchens, bath- and laundry rooms with controlled extract ventilation, bath- and laundry rooms also with waterproofed surfaces.

Inspection and maintenance of existing buildings

Foresee regular maintenance and inspection for all combustion devices, for all ventilation and air conditioning systems, and for all water and drainage systems.

Effective implementation of the framework of actions to be proposed by a EU Green Paper on IAQ requires the following harmonised protocols and guidelines, which should be prepared as **Technical Guidance Documents**:

- European harmonised protocols for IAQ testing, reporting and labelling for building materials, equipment and products;
- European harmonised criteria and procedures for IAQ monitoring and reporting for the residential and occupational building stock;
- European health based ventilation guidelines to control exposure to pollutants from indoor and outdoor sources, indoor moisture and ensure healthy indoor temperature;
- European moisture control guidelines for building design and maintenance, to prevent persistent dampness and hidden and visible mould growth.

11. EnVIE Exploitation

Corresponding to the need of a comprehensive approach to tackle IAQ, and recognizing the importance of gathering the contributions of other policies and tools related to IAQ, EnVIE felt the need to propose, as major step forward, a Green Paper on IAQ. The set of recommendations on its wide coverage of the issues and involvement of actors fully justify the need and the urgency for such initiative. The actions associated with the proposed initiative will constitute the “exploitable result” of EnVIE Project.