Making Schools Healthy:
Meeting Environment and Health Challenges

Final publication of the SEARCH II project

SEARCH
EARCHS
ARCHSII

School Environment
and Respiratory Health
of Children

The SEARCH initiative is supported by the Italian Ministry for the Environment, Land and Sea (IMELS)

Credits

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December 2013

Executive summary

Background

The SEARCH initiative, an environment and health research project, was financially and technically supported by the Italian Ministry for the Environment, Land and Sea (IMELS) through the Italian Trust Fund (ITF). It was implemented within the international frameworks of the EU Action Plan on Environment and Health; and the World Health Organization's Children's Environment and Health Action Plan for Europe (WHO CEHAPE), Priority Goal 3 on air quality and children's health.

The pan-European SEARCH II project, the second phase of the SEARCH initiative, was developed in order to expand the monitoring of children's health and air quality, and to assess energy use in selected schools in 10 countries. Four new countries (Belarus, Kazakhstan, Tajikistan and Ukraine) joined the six countries that participated in SEARCH I (Albania, Bosnia and Herzegovina, Hungary, Italy, Serbia and Slovakia).

The outcome of the second phase was a list of recommendations for improving the school environment, buildings and energy consumption based on an analysis of environmental, energy and health data from the 10 countries.

The SEARCH initiative is implemented by the Regional Environmental Center for Central and Eastern Europe (REC) in the framework of the REC's Health and Environment Topic Area, which is involved in several environmental health projects and works with WHO Europe, the European Environment Agency (EEA), the European Commission's Joint Research Centre (JRC), and many national environmental health institutes in Europe. The SEARCH II partnership comprised over 50 individual national experts from 10 countries in Europe and Eastern Europe, Caucasus and Central Asia (EECCA). From diverse professional backgrounds, these experts work in a range of fields including environment and health and energy efficiency.

Main findings

The extensive database containing information on 7,860 children from 388 classrooms in 100 schools in 10 countries created a unique opportunity to study a wide variety of school indoor and outdoor environments, to measure outdoor and indoor concentrations of several air pollutants, and to study the associations between the school environment and children's health.

Sources of indoor concentrations of NO_2 and, to a lesser extent, PM_{10}, were outdoor pollution (mainly traffic), while volatile organic compounds (VOCs) and formaldehyde were mainly emitted from indoor sources.

The health status of children from the various countries was assessed and compared. Asthmatic symptoms and doctor-diagnosed allergies were found to be significantly less frequent in the four new SEARCH II countries than in the six SEARCH I countries.

The results of the spirometry tests confirmed that the great majority of children have normal respiratory function, and this situation must be maintained in the coming years alongside further improvements to the environment in which they live.

The large database allowed statistically significant associations to be found between the school environment and children's health. Some of these associations may be accidental and difficult to interpret, but most provide information and well-documented facts that can be used to determine new interventions in order to ensure a healthier school environment and improve children's respiratory health.

On the basis of the results, some obvious examples of effective interventions can be highlighted: overcrowding in the classrooms should be avoided; windows should be opened during every break, and some should be kept open during teaching time; and plastic (PVC) flooring and water-resistant paints, for example, should be avoided. Schools should not be built along roads with busy traffic or in areas heavily polluted from any other sources.

The comfort assessment was a useful tool for collecting information from children about their perceptions of the school environment. The children's objective perceptions were well supported by objective measurements of temperature, relative humidity and CO_2 concentrations. According to the assessments, 48 percent of children thought the classroom was warmer than optimal (children considered the air temperature to be too high above 22°C). This finding may be significant from an energy-saving perspective. Further evidence was found that good air quality during lessons significantly depends on the ventilation regime during breaks. After adjustment for gender and age, logistic regression analysis revealed that when the air in the classroom was of poor quality, the risk of headaches increased by 96 percent, and even with neutral air quality by 31 percent, compared to good air quality.

Average primary energy consumption in the 95 analysed schools was 220.9 kWh/m^{2}a. The calculated primary energy consumption was generally 1.7 times higher than the reference value, thus it can be concluded that the modernisation of the building structures and HVAC systems offers a very large energy-saving potential, and recommendations were made for such modernisation. Modernisation could potentially reduce average total primary energy consumption from 220.9 kWh/m^{2}a to 108.0 kWh/m^{2}a, a saving of more than half the primary energy consumption. Improving the thermal characteristics of the building envelope would result in lower heating energy consumption, and would also improve children's perceptions of comfort.

Linking energy, comfort and health symptoms

In the framework of the SEARCH II project, a combined comfort index (the SEARCH II Index) was developed in order to create a simple and readily understandable synthesis of several physical parameters as perceived by the children who completed the comfort questionnaires. This index can help schools to optimise children's comfort and school energy consumption. The SEARCH II Index was based on ratings attributed to children's perceptions of thermal comfort, indoor air quality, noise and lighting in the classroom, using questions from the comfort questionnaire. The index was pilot tested during the SEARCH II project and should be validated in practice through well-designed studies assessing the effectiveness of interventions before and after modernisation that have an impact on children's comfort.

Introduction

The SEARCH initiative

The SEARCH initiative is an environment and health research project implemented within the international frameworks of the EU Action Plan on Environment and Health; and the World Health Organization's Children's Environment and Health Action Plan for Europe (WHO CEHAPE), Priority Goal 3 on air quality and children's health. The initiative contributes to the European legal and policy framework for sustainability in schools, since children's health and educational potential depend on the quality of the school environment. The initiative was generously supported by the Italian Ministry for the Environment, Land and Sea (IMELS).

The SEARCH initiative was implemented in three phases: a pilot phase (involving Italy and Hungary) from 2003 to 2004; the first phase from 2006 to 2010; and a second phase from 2010 to 2013. The first phase (SEARCH I) led to the creation of a comprehensive environment and health database through assessments carried out in six countries (Albania, Bosnia and Herzegovina, Hungary, Italy, Serbia and Slovakia). Based on the SEARCH I conclusions and recommendations, the initiative was reaffirmed and expanded at the Fifth Ministerial Conference on Environment and Health, held in Parma, Italy, in 2010.

The second phase, SEARCH II, with its pan-European perspective, expanded the monitoring of children's health and air quality and assessed energy use in selected schools in 10 countries. It included the design of environment and health capacity-building programmes for school staff and training for local implementation, and four new countries (Belarus, Kazakhstan, Tajikistan and Ukraine) joined the six SEARCH I countries. Recommendations were compiled for improving the school environment, school buildings and energy consumption, based on analyses of countries' environmental, energy and health data.

The project was supported by the Italian Trust Fund (ITF), a targeted contribution of IMELS to the Regional Environmental Center for Central and Eastern Europe (REC). The institutional mandate of IMELS includes the protection and restoration of the environment, with the aim of ensuring high quality of life, enhancing the sustainable use of natural resources and preventing and controlling environmental pollution through legislation and cooperation with strategic sectors. The SEARCH II project was also supported by the Institute for Environmental Protection and Research (ISPRA), Italy, a public body under the aegis of IMELS. The REC is the implementing agency for the whole of the SEARCH initiative and a vast number of other major environment-related projects. The SEARCH projects were implemented in the framework of the REC's Health and Environment Topic Area, which participates in several environment and health projects and works with WHO Europe, the European Environment Agency (EEA), the Joint Research Centre (JRC) of the European Commission, and many national environment and health institutes.

The SEARCH initiative builds on the strong research partnership between Italy and Hungary. The Italian research team, in cooperation with Hungary's National Institute of Environmental Health (NIEH), designed the research and assessed the environmental health data.

The SEARCH II partnership comprises over 50 individual national experts from 10 countries in Europe and Eastern Europe, Caucasus and Central Asia (EECCA). With diverse professional backgrounds, these experts work in a range of fields including environment, health and energy efficiency. The project is also supported and recognised by ministries of the environment, health and education, non-governmental organisations, state agencies for the environment and public health, national institutes, technical universities, foundations, companies and individual consultants.

The SEARCH II project

The SEARCH II project extended the geographical scope of the SEARCH initiative to Belarus, Kazakhstan, Tajikistan and Ukraine in order to assess the relationship between the school environment and children's health in a broader context. The project also introduced a new component: the assessment of energy use in school buildings and the impact of building materials on children's health in order to compile recommendations for improving the quality of school environments and school buildings and improving energy efficiency based on an analysis of data from the 10 participating countries. The second phase of the initiative built on the successful awareness-raising initiatives carried out under SEARCH I for the prevention of respiratory diseases, particularly among children.

The SEARCH II project included three components: environmental monitoring in schools; health and comfort assessments of children; and the monitoring of energy use in schools. According to the project methodology, 10 schools per country were selected, with approximately 100 children per school. The children were aged between 8 and 11, and the selection was based on building characteristics (new/old and light/traditional construction) and on the extent of pollution in the environment. The monitoring and assessments were carried out via measurements of exposure levels, questionnaires and lung function measurements.

Concentrations of selected pollutants (CO, CO_2, PM_{10}, benzene, toluene, ethylbenzene and xylenes [BTEX] and formaldehyde), as well as relative humidity and temperature, were monitored during the heating season (November 2011–April 2012) both inside and outside the selected schools in order to establish children's exposure levels. Environmental health data were collected via questionnaires on the school environment (building type, neighbourhood, heating, maintenance etc.); and questionnaires on classroom characteristics (floor and wall coverings, windows, ventilation, number of children in the classroom, furniture etc.). The questionnaires were completed by the local environmental health experts involved in the monitoring. Parents of children at the selected schools were invited to complete health questionnaires anonymously, and decisions to decline were respected. The health questionnaires made it possible to gather information on each child's past and present health status and home environment (heating, building type, smoking and other lifestyle factors, living density, floor and wall coverings, and the family's socioeconomic status).

The comfort questionnaires were completed by the children and gathered information on the children's perception of comfort in the classroom. The energy questionnaire gathered information on the school building and energy consumption. The collection of information via the energy questionnaire was combined with the monitoring of temperature and relative humidity using data loggers over 10 days (three data loggers inside the school and one outside). The energy questionnaire and other questionnaires can be found at **search.rec.org/outcomes**.

Active health testing took the form of lung function measurements (spirometry), which were carried out only with parental consent.

In the framework of the SEARCH I project, Hungary, Italy and Slovakia published environmental health training materials for school staff, and Albania, Bosnia and Herzegovina and Serbia drafted similar training materials. Under SEARCH II, the four new countries required materials adapted to their local needs.

Chapter 1: **Environment and health assessments**

Environment and health assessments were undertaken in order to evaluate associations between the school environment and children's health in 10 countries. Assessments were carried out in Albania, Bosnia and Herzegovina, Hungary, Italy, Serbia and Slovakia under SEARCH I between October 2007 and March 2008; and in Belarus, Kazakhstan, Tajikistan and Ukraine under SEARCH II between October 2011 and April 2012.

School building characteristics

Environment and health data were collected during two phases of the SEARCH initiative: in Albania, Bosnia and Herzegovina, Hungary, Italy, Serbia and Slovakia under SEARCH I (October 2007 to March 2008); and in Belarus, Kazakhstan, Tajikistan and Ukraine under SEARCH II (October 2011 to April 2012). Data were collected from 10 schools per country, thus a total of 100 schools were involved in the study. Most of the participating schools were built originally for use as schools and were constructed mainly from brick and concrete. Some of the schools were built partly from adobe and wood in Bosnia and Herzegovina; and from wood in Ukraine. Sources of pollution (especially industrial facilities) were found in the vicinity of 17 percent of the schools. The distribution of the schools in each country in relation to traffic density is presented in Table 1. Of the total schools, 40 percent were located in areas with high or very high traffic density. The figure was even higher in Albania and Bosnia and Herzegovina (70 percent in each country) and Hungary (60 percent). It should be borne in mind that air pollution caused by traffic has been shown to have a negative impact on children's health.

Classroom characteristics

Most of the investigated classrooms were situated on the first or second floor of the school building. Only two classrooms in one country were situated below ground level, and a total of eight classrooms in two countries were located on the fourth floor. Almost one-third of investigated classrooms were oriented towards the street. Additional information about the distribution of classrooms by floor level and orientation in each country can be found at **search.rec.org/outcomes**.

There were big differences among the countries with respect to the number of children per classroom. The average floor space in this study was 2.02 m^2/child. All the classrooms in Albania and 60 percent of the classrooms in Bosnia and Herzegovina had less than

TABLE 1 **Distribution of schools in relation to traffic density (%)**

Country	Low	Moderate	High	Very high
Albania	0	30	70	0
Belarus	60	20	0	20
Bosnia and Herzegovina	0	30	20	50
Hungary	10	30	50	10
Italy	10	80	10	0
Kazakhstan	33	11	56	0
Serbia	11	45	22	22
Slovakia	30	50	10	10
Tajikistan	30	30	30	10
Ukraine	40	40	10	10
Average	**22.4**	**36.7**	**27.6**	**13.3**

Cleaning practices can be seen as another important potential risk factor in terms of children's health. After cleaning, appropriate ventilation is essential in order to reduce possible emissions from the cleaning materials used.

2 m^2 of floor space per child (for details see **search.rec.org/outcomes**).

The type of floor covering used varied between and within countries. The most commonly found was plastic flooring, which was used in over 40 percent of the monitored classrooms and which can be associated with health risks among children. The second most frequently used type of floor covering was wood, which was found in 31 percent of the investigated classrooms. Concrete flooring, or concrete covered by carpet, were less frequently used in classrooms (15 percent).

Various types of wall covering were used in classrooms: the most frequently used type was water-soluble paint (58 percent), while water-resistant paint was used in a quarter of the classrooms. Wallpaper and whitewash were far less frequently used (18.6 and 16 percent respectively). Wood panelling was used in only 6.5 percent of the classrooms. From a health perspective, water-resistant paints can contribute to a higher risk of respiratory disease.

The size of the openable windows in the classrooms is an important factor in terms of natural ventilation. In the monitored classrooms, the size of the openable windows also varied considerably. A quarter of the investigated classrooms (an average of 25.7 percent) had openable windows smaller than 2 m^2, which can be regarded as the minimum size of window that allows appropriate natural ventilation.

Cleaning practices can be seen as another important potential risk factor in terms of children's health. After cleaning, appropriate ventilation is essential in order to reduce possible emissions from the cleaning materials used.

Most of the classrooms (an average of 87.7 percent) were cleaned in the evening, and many of them (an average of 39.1 percent) were also cleaned at noon. The most frequently used means of cleaning was a mop (an average of 72.6 percent). Vacuum cleaners were used in an average of only 7.7 percent of the classrooms (see **search.rec.org/outcomes**).

The monitoring of indoor air pollution in classrooms

The levels of indoor air pollutants measured in the investigated classrooms in the 100 selected schools from the 10 participating SEARCH countries are presented in Table 2. The same environmental monitoring methodology was used in all the classrooms. According to the project protocol, the same equipment was used during the SEARCH I and SEARCH II environmental monitoring. Further information can be found on the project website (**search.rec.org**).

The selected pollutants were measured inside and outside schools in the participating countries during the heating season. The concentrations of BTEX (benzene, toluene, ethylbenzene and xylenes), NO_2 and formalde-

TABLE 2 **Summary of indoor air measurements in schools under SEARCH I and II**

Pollutant	ALB	BIH	BLR	HUN	ITA	KAZ	SRB	SVK	TJK	UKR
PM_{10} (µg/m³)	69	102	28	56	82	65	81	80	91	33
Formaldehyde (µg/m³)	5.61	7.13	7.50	2.41	33.07	10.40	1.73	8.71	12.90	11.50
Benzene (µg/m³)	4.06	6.29	2	2.16	1.95	6.30	5.94	4.84	7.40	2.50
Toluene (µg/m³)	15.45	27.58	6.20	4.56	5.01	18.10	21.94	29.47	17.40	4.90
Ethylbenzene (µg/m³)	1.24	1.60	0.90	1.64	1.82	1.60	1.60	1.38	1.50	0.80
Xylenes (µg/m³)	5.03	7.65	5.90	7.04	7.10	9.10	7.65	5.07	7	4.30
NO_2 (µg/m³)	12	21	9.90	16	19	17.30	21	14	13	12

TABLE 3 **Guidelines and recommendations for concentrations of pollutants in the indoor air**

SUBSTANCE	UNIT	VALUE	AVERAGING TIME	REFERENCES
Formaldehyde	µg/m³	100	30 minutes	WHO Guidelines for Indoor Air Quality: Selected Pollutants, 2010
Benzene	µg/m³	No safe level of exposure can be recommended		WHO Guidelines for Indoor Air Quality: Selected Pollutants, 2010
		5	annual	Directive 2008/50/EC
Toluene	µg/m³	260	1 week	WHO Air Quality Guidelines for Europe, 2nd edition (2000) – Outdoor
NO_2	µg/m³	200	1 hour	WHO Guidelines for Indoor Air Quality: Selected Pollutants, 2010
		40	annual	
PM_{10}	µg/m³	50	24 hours	WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulphur Dioxide (2005) – Outdoor
CO_2	ppm	700 ppm difference between indoor and outdoor concentrations		ASHRAE 62.1-2004

hyde were examined using a passive sampling method (Radiello-type samplers). One sampling point per classroom was designated for indoor measurements and one for outdoor measurements. Samples were collected in classrooms where the children spent most of their time. The passive samplers were placed at a height of 1.5 to 2 m in the classrooms. Outdoors, the passive samplers were placed on the wall of the building closest to the classroom window. Exposed BTEX samples were analysed using the GC-FID method; NO_2 samples by spectrophotometer, and formaldehyde samples using HPLC apparatus in Hungary.

The determination of physical parameters, CO_2, CO and PM_{10} was performed via real-time monitoring using the TSI IAQ-Calc Indoor Air Quality Meter (Model 7545-CO/CO_2/RH/T) and a Haz-Dust particulate matter (PM_{10}) air monitor. Continuous monitoring over one day during the teaching period was carried out in each classroom and measurements were made of five-minute averages without interval. In parallel, outdoor air pollution was also measured. The monitor was used for 10 minutes outdoors in the morning and again in the afternoon.

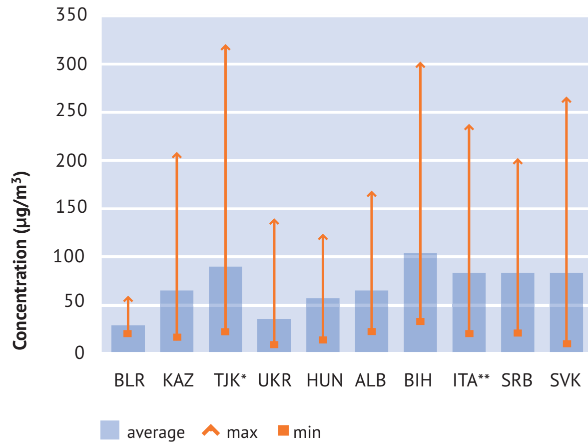
Results of air quality measurements

In practice, indoor exposure levels are assessed on the basis of existing guidelines and recommendations. Unfortunately, it was not possible to evaluate indoor air pollution measured during SEARCH I and II in this way due to the differences between the sampling times used in the SEARCH initiative and those specified in the guidelines and recommendations.

Each EU member state sets limit values for workplace environments, but only some member states have guideline values for public places, and limit values for private spaces are very rare. The WHO and other recommendations are presented in Table 3.

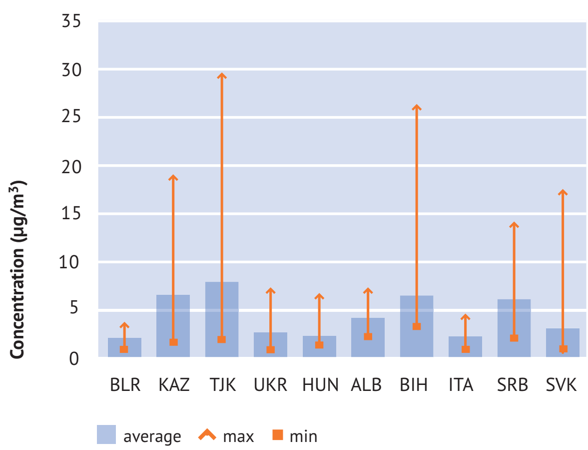
Indoor concentrations of PM_{10} measured in the classrooms during teaching hours are shown in Figure 1. (In Tajikistan, the measurements were made every 5 minutes, and in Italy during 24 hours.)

FIGURE 1: Average one-day indoor PM_{10} concentrations measured in classrooms in the 10 SEARCH countries during teaching hours



*5-minute sampling
**24-hour sampling

FIGURE 2: Indoor levels of benzene measured over four days in classrooms in the 10 SEARCH countries



Average concentrations varied between 28 and 102 µg/m^3, although the maximum values were three to four times higher. The lowest concentrations were measured in Belarus and Ukraine. In the other countries, PM_{10} pollution was very high: in 51 to 98 percent of the examined classrooms PM_{10} concentrations exceeded 50 µg/m^3.

Concentrations of BTEX (benzene, toluene, ethylbenzene and xylenes) in the classrooms, measured over four days, are presented in Figures 2 to 5.

Average benzene concentrations varied between 1.95 and 7.4 µg/m^3. The lowest concentrations were found in Belarus, Ukraine, Hungary, Albania and Italy, where the average level was no higher than 5 µg/m^3. In 33 to 61 percent of classrooms in Kazakhstan, Tajikistan, Bosnia and Herzegovina, Serbia and Slovakia, the measured benzene concentrations exceeded 5 µg/m^3.

Average concentrations of toluene showed a wide range (4.6 to 29.5 µg/m^3). The highest maximum values were measured in Serbia and Slovakia, where the values were higher than 260 µg/m^3.

Concentrations of ethylbenzene were in the range of 0.8 and 1.82 µg/m^3 and maximum values were not high in most of the countries. The highest levels of ethylbenzene pollution were measured in some classrooms in Italy and Hungary (10.88 and 12.9 µg/m^3).

Average concentrations of xylenes varied between 4.3 and 9.1 µg/m^3, and maximum values were in the range of 15.9 to 69.3 µg/m^3. The highest value was measured in a Hungarian classroom.

Concentrations of NO_2 and formaldehyde measured over four days in the classrooms are shown in Figures 6 and 7.

Average concentrations of NO_2 varied between 9.9 and 22.1 µg/m^3, and the maximum value exceeded 40 µg/m^3 in Kazakhstan, Bosnia and Herzegovina and Italy.

Average concentrations of formaldehyde varied between 1.7 and 33.07 µg/m^3, although maximum values between five and six times higher were also recorded. The highest level of formaldehyde pollution was found in classrooms in Italy.

FIGURE 3: **Indoor levels of toluene measured over four days in classrooms in the 10 SEARCH countries**

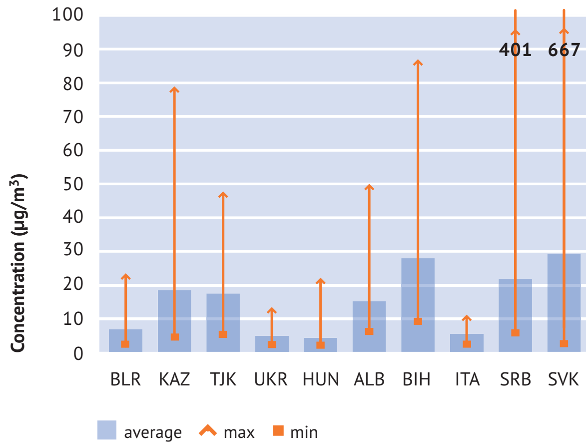


FIGURE 4: **Indoor levels of ethylbenzene measured over four days in classrooms in the 10 SEARCH countries**

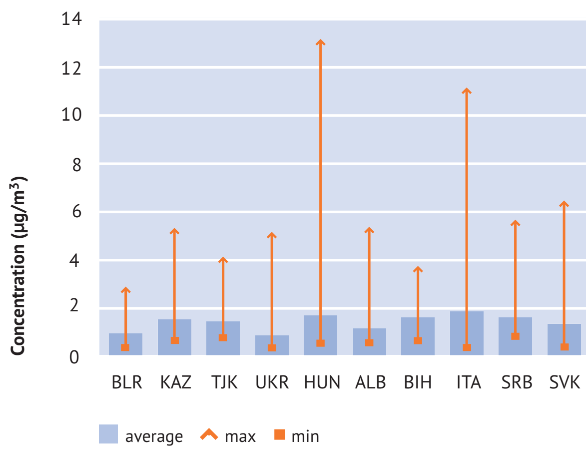


FIGURE 5: **Indoor levels of xylenes measured over four days in classrooms in the 10 SEARCH countries**

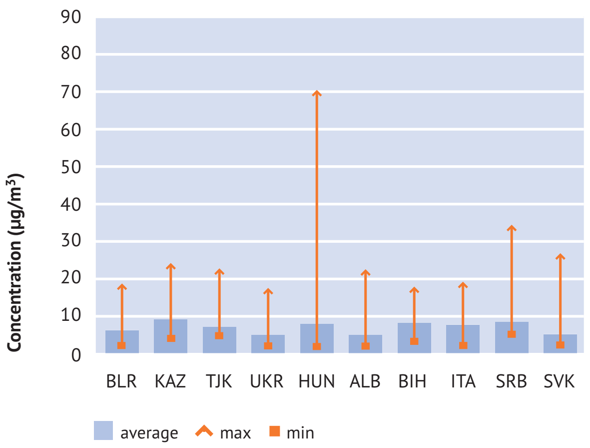


FIGURE 7: **Indoor levels of formaldehyde measured over four days in classrooms in the 10 SEARCH countries**

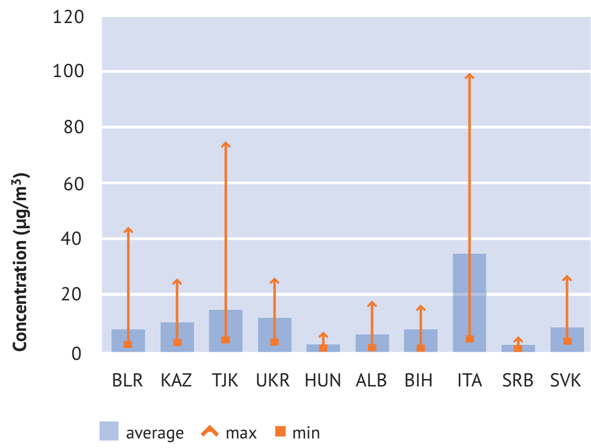


FIGURE 6: **Indoor levels of NO_2 measured over four days in classrooms in the 10 SEARCH countries**

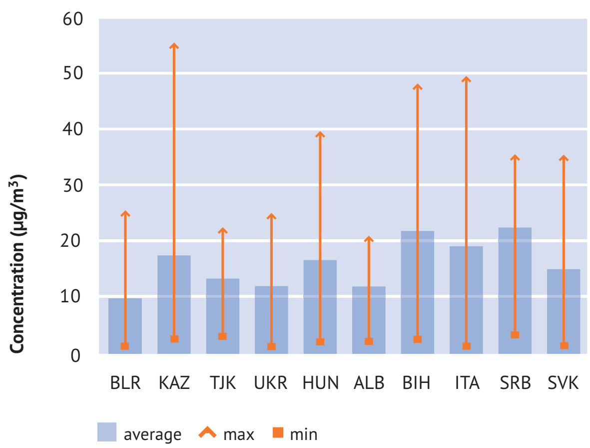
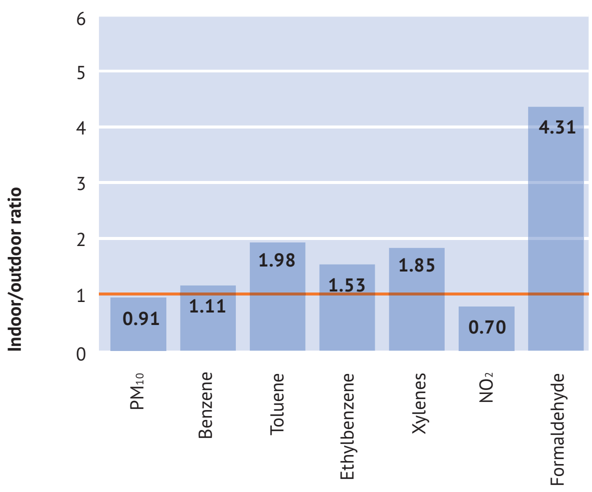


FIGURE 8: **Relationship between concentrations measured inside the classrooms and outside the schools in the 10 SEARCH countries**



The relationship between indoor and outdoor concentrations is illustrated in Figure 8. The results shown in the figure suggest that the main source of NO_2 pollution was the ambient air, and that formaldehyde was primarily emitted from indoor sources.

Health status of children

Children's health status was evaluated via health questionnaires completed by their parents. These questionnaires gathered information on the children's past and present health status, perinatal conditions, parents' respiratory health, smoking habits in the family, home environment and families' socioeconomic status. The children's health questionnaire, along with the school, classroom, comfort and energy questionnaires used in the SEARCH initiative, are available at **search.rec.org/outcomes**.

In addition, spirometry tests were used to monitor children's lung function. Nearly half the parents of the participating children agreed to the spirometry test. Carrying out so many spirometry tests in different countries was extremely challenging, and many countries lacked skilled technicians at the start of the project. Before the field activities in the schools, local technical experts participated in an environment and health training, held at the REC in Hungary in May 2011,

TABLE 4 **Prevalence (%) of children with a chronic cough, by country**

Country	Regular morning cough	Regular day/night cough	Chronic cough >3 months	Regular cough with phlegm	Any regular/ chronic cough
Albania (n=1,019)	18.7	20.8	7.7	41.6	53.6
Belarus (n=625)	9.1	5.8	1.0	2.2	12.6
Bosnia and Herzegovina (n=865)	10.9	10.6	3.2	10.8	24.3
Hungary (n=704)	8.4	6.5	3.3	3.6	13.4
Italy (n=915)	13.2	11.8	3.5	8.5	22.8
Kazakhstan (n=602)	17.3	10.6	1.3	5.5	25.4
Serbia (n=735)	10.5	9.9	3.1	9.4	21.5
Slovakia (n=825)	14.7	10.7	2.6	4.9	24.1
Tajikistan (n=888)	22.1	15.5	1.6	4.4	29.6
Ukraine (n=682)	16.3	16.6	18.6	16.7	41.1
Total (n=7,860) average	**14.4**	**12.3**	**4.6**	**11.8**	**27.9**

where they were introduced to the spirometry equipment. The majority of the tests were not done "professionally", although we consider that it was still worthwhile performing them. The majority of the acceptable tests, and almost all of the less acceptable tests (from a scientific point of view) were normal, or can be considered as normal, implying that the children's respiratory health was globally good, mainly because they were young, non-smokers, and had been well cared for by their families.

The questionnaires completed by the parents provided information on respiratory and other symptoms (i.e. indications of health problems but not actual diseases) that could be related to the school (or home) environment. This information included, for example, whether a child usually had a cough in autumn/winter, had had asthmatic symptoms (wheezing) in the last 12 months, had any allergy, and had an allergy confirmed by a doctor.

Table 4 shows that more than a quarter of the participating children often had a cough, although only 5 percent of children had a chronic cough that lasted for more than three months (considered as a symptom of chronic bronchitis in adults). The table also shows a significant heterogeneity in prevalence among the countries.

TABLE 5 **Prevalence (%) of children with asthmatic symptoms in the last 12 months, by country**

Country	Wheezing after exercise <12 months	Dry cough at night <12 months	Woken up by wheezing <12 months	Any wheezing <12 months
Albania (n=1,019)	6.5	14.2	7.4	22.8
Belarus (n=625)	9.0	14.9	2.2	21.4
Bosnia and Herzegovina (n=865)	8.9	15.3	5.1	23.1
Hungary (n=704)	8.2	10.9	2.0	16.9
Italy (n=915)	11.5	13.9	3.6	23.4
Kazakhstan (n=602)	6.3	5.8	1.5	14.0
Serbia (n=735)	9.4	13.9	6.0	22.9
Slovakia (n=825)	8.0	14.9	5.5	23.2
Tajikistan (n=888)	6.8	9.4	2.8	20.5
Ukraine (n=682)	8.2	8.2	0.2	16.6
Total (n=7,860) average	**8.3**	**12.4**	**3.9**	**20.8**

TABLE 6 **Prevalence (%) of children with asthma diagnosed by a doctor ever and treated for asthma in the last 12 months, by country**

Country	Asthma diagnosed ever	Asthma treatment <12 months
Albania (n=990)	11.8	5.7
Belarus (n=622)	4.0	2.2
Bosnia and Herzegovina (n=796)	11.0	6.8
Hungary (n=695)	7.1	3.7
Italy (n=856)	12.2	7.9
Kazakhstan (n=582)	5.8	5.2
Serbia (n=719)	12.8	9.3
Slovakia (n=797)	7.3	6.4
Tajikistan (n=812)	10.9	9.7
Ukraine (n=672)	4.0	3.1
Total (n=7,541) average	**9.1**	**6.2**

Wheezing was reported by the parents of one in five children (Table 5). The prevalence of the most severe symptom — that of being woken up by wheezing — was only 3.9 percent, and was significantly lower in the four EECCA countries than in the six SEARCH I countries.

In general, a similar difference can be observed in the prevalence of doctor-diagnosed asthma (Table 6), although there is a relatively high proportion (4.06 percent, and 8.6 percent in Tajikistan) of missing answers.

The prevalence of the various types of doctor-diagnosed allergy (Table 7) was also significantly lower in the four EECCA countries than in the other six countries, a finding that is in line with earlier studies carried out in Eastern and Western European countries (e.g. the significant difference found by von Mutius et al. in the 1990s between East and West Germany, which was confirmed in various subsequently published papers).

Other questions related to the children's health concerned allergic symptoms other than those of the res-

TABLE 7 **Prevalence (%) of children with doctor-diagnosed allergies, by country**

Country	House dust mite	Animal fur, feathers	Pollen	Mould	Food	Drug	Any
Albania (n=1,019)	13.2	4.9	5.9	5.1	5.3	5.0	19.4
Belarus (n=625)	4.0	2.6	5.8	1.6	12.5	7.7	21.8
Bosnia and Herzegovina (n=865)	10.1	5.3	10.3	3.7	2.5	4.3	18.0
Hungary (n=704)	9.5	9.7	12.2	7.2	8.8	10.8	23.70
Italy (n=915)	8.9	4.4	8.9	3.2	4.9	3.4	17.5
Kazakhstan (n=602)	1.0	1.2	3.2	0.2	6.2	6.2	15.5
Serbia (n=735)	10.1	5.6	11.8	4.1	2.6	4.5	17.4
Slovakia (n=825)	9.7	6.8	14.9	5.1	5.9	4.6	28.9
Tajikistan (n=888)	2.6	2.3	2.1	1.8	4.3	3.0	6.60
Ukraine (n=682)	3.2	3.1	4.7	1.5	7.5	10.3	15.4
Total (n=7,860) average	**7.6**	**4.6**	**8.0**	**3.5**	**5.8**	**5.7**	**18.3**

The health questionnaires gathered information on children's past and present health status, perinatal conditions, parents' respiratory health, smoking habits in the family, home environment and families' socioeconomic status.

piratory tract (skin rashes, eczema, allergic oedema, conjunctivitis) and some respiratory tract–related symptoms (runny or blocked nose, hay fever, earache, sinusitis and complications of these) experienced for at least two weeks in the last 12 months (Table 8). There was also a significant heterogeneity in the prevalence of these physical symptoms, although the difference between the SEARCH I and SEARCH II countries mentioned above was evident only in the case of some symptoms (e.g. allergic oedema, conjunctivitis or hay fever).

Mental health is an important aspect of human health, as influenced by various endogenous and environmental factors. The prevalence of certain psychological symptoms was therefore also evaluated in order to see if such symptoms might also reflect the impact of the school environment on health (Table 9). The high prevalence of symptoms of depression (the presence of a sleep disorder, fatigue or social withdrawal/reserve) deserves specific attention: one in every four children showed signs of such symptoms for at least two weeks during the last 12 months.

TABLE 8 **Prevalence (%) of children with physical symptoms, by country**

Country	Skin rash, eczema	Allergic oedema	Conjunctivitis	Blocked/ runny nose	Hay fever	Earache	Sinusitis	Complications (earache/ sinusitis)
Albania (n=1,019)	6.6	6.0	10.5	45.9	7.8	22.6	3.4	24.5
Belarus (n=625)	14.7	1.8	5.6	47.2	3.8	8.5	4.3	11.5
Bosnia and Herzegovina (n=865)	10.1	3.7	5.1	48.1	3.9	8.1	3.8	10.6
Hungary (n=704)	15.6	2.3	8.2	34.8	6.1	6.7	4.0	9.9
Italy (n=915)	9.7	3.7	6.9	27.8	3.2	10.7	7.0	15.5
Kazakhstan (n=602)	6.0	1.3	2.7	35.7	2.2	6.6	2.3	8.6
Serbia (n=735)	12.1	3.5	4.9	49.7	3.1	9.0	4.2	11.7
Slovakia (n=825)	19.2	2.9	5.1	46.3	3.8	10.6	21.1	27.2
Tajikistan (n=888)	2.1	1.9	1.5	23.1	0.8	9.8	3.2	11.8
Ukraine (n=682)	11.4	2.6	3.7	63.1	2.8	5.6	13.3	15.7
Total (n=7,860) average	**10.5**	**3.1**	**5.6**	**41.7**	**3.8**	**10.4**	**6.7**	**15.3**

Associations between measured air pollutants and children's health

Associations between the measured air pollutants or other characteristics of the school environment and children's health were analysed using linear or logistic regression, Student's t-test, or the non-parametric Mann-Whitney test. For the logistic regression analysis, we calculated the adjusted (corrected) associations (odds ratios) using age, gender, parental smoking at home, living density at home, and country as correction factors. Statistical significance was established at a probability level of 0.05 ($p<0.05$), although borderline significance ($p<0.1$) was also mentioned (p: ~).

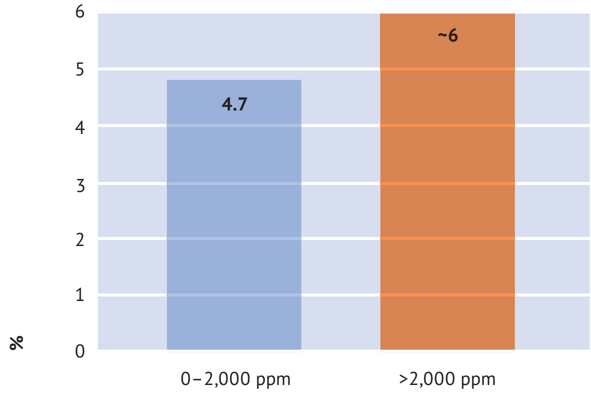
One of the asthma-related symptoms (wheezing after exercise) was significantly associated with indoor CO_2 concentrations measured in the classrooms: children in classrooms with CO_2 concentrations above 2,000 ppm experienced a 99 percent increased risk of wheezing after exercise, compared to those in classrooms with lower indoor levels of CO_2 (Figure 9). In the figure, cOR

TABLE 9 **Prevalence (%) of children with psychological symptoms, by country**

Country	Sleep disorder	Fatigue	Attention deficit disorder	Irritability	Anxiety	Social withdrawal (reserve)	Any of the 3 depression symptoms*
Albania (n=1,019)	9.0	21.8	2.1	19.0	6.3	9.1	29.7
Belarus (n=625)	5.3	25.8	9.4	21.3	7.8	3.5	28.5
Bosnia and Herzegovina (n=865)	3.9	12.4	9.3	11.3	8.6	4.9	15.7
Hungary (n=704)	4.1	13.2	9.8	15.8	6.8	6.4	18.6
Italy (n=915)	6.7	26.9	14.9	18.1	18.0	7.7	30.7
Kazakhstan (n=602)	4.8	24.6	15.3	17.4	8.5	2.7	26.1
Serbia (n=735)	5.7	14.0	10.2	12.4	7.9	5.2	18.6
Slovakia (n=825)	3.3	16.6	13.0	12.9	6.7	4.9	19.6
Tajikistan (n=888)	5.9	11.0	8.7	10.8	9.4	4.3	15.7
Ukraine (n=682)	8.2	32.7	21.7	30.5	23.9	23.5	46.5
Total (n=7,860) average	**5.8**	**19.6**	**11.0**	**16.6**	**10.3**	**7.2**	**24.7**

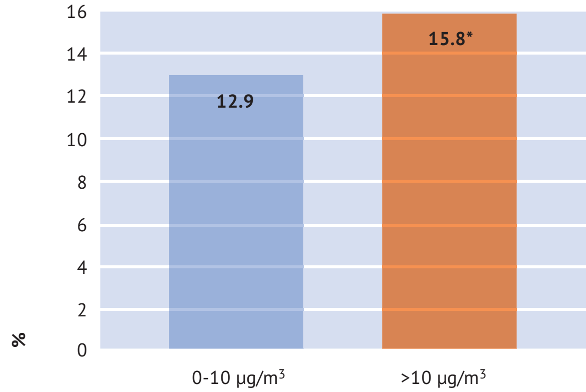
* (sleep disorder, fatigue, social withdrawal)

FIGURE 9: **Prevalence (%) of children wheezing after exercise in classrooms with indoor concentrations of CO_2 below or above 2,000 ppm**



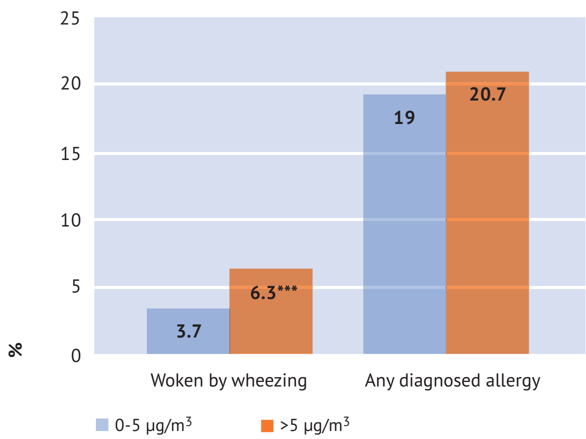
+cOR=1.99** (95% CI: 1.19–3.34)
+corrected for age, gender, parental smoking, living density at home, and country
~p<0.1 **p<0.01

FIGURE 11: **Prevalence (%) of children with regular day/night cough in classrooms with indoor concentrations of xylenes below or above 10 µg/m³**



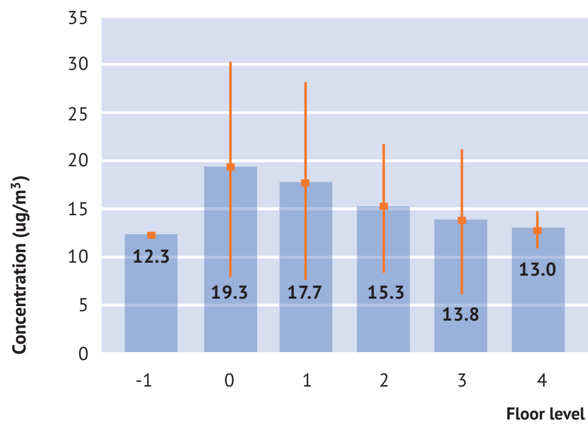
+cOR=1.37* (95% CI: 1.05-1.78)
+corrected for age, gender, parental smoking, living density at home, and country
*p<0.05

FIGURE 10: **Prevalence of children woken by wheezing or with any doctor-diagnosed allergy in classrooms with indoor concentrations of benzene below or above 5 µg/m³**



+cOR=1.52* (95% CI: 1.07–2.16)
+cOR=1.20~ (95% CI: 0.97–1.48)
+corrected for age, gender, parental smoking, living density at home, and country
~p<0.1 *p<0.05 ***p<0.001

FIGURE 12: **Mean concentrations of NO_2 measured in classrooms on different floors of the school building**

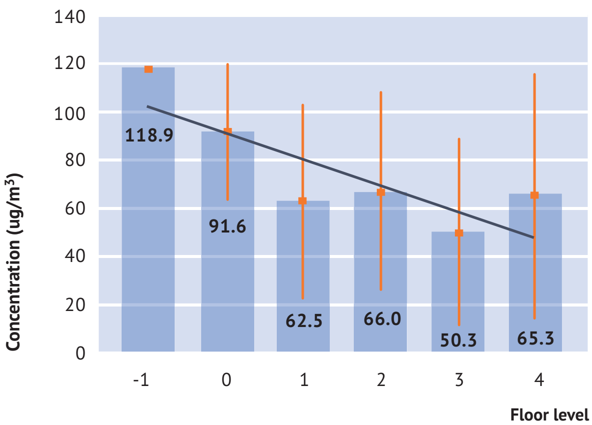


is the corrected odds ratio. Odds refers to the ratio of probability of occurrence of an event to that of non-occurrence: OR=1.0 means there is no difference. OR=1.88 means an 88 percent increase in risk. CI=95% (confidence intervals) means a 95 percent probability that the given value is within the given range.

Significant differences can be observed in the prevalence of children woken up by wheezing and of children with any doctor-diagnosed allergy between classrooms with indoor benzene concentrations above or below 5 µg/m³ (Figure 10).

Similar differences were found with respect to the prevalence of children with a regular day/night cough between classrooms with indoor concentrations of xylenes above or below 10 µg/m³ (Figure 11).

FIGURE 13: **Mean concentrations of PM_{10} measured in classrooms on different floors of the school building**



Associations between school characteristics and children's health

Determinants of the health status of the children varied significantly among the participating countries, thus all the analysed associations between the school environment and children's health status were corrected for country, as well as for age, gender, parental smoking and living density at home. A summary of the statistically significant ($p<0.05$, i.e. where the probability of chance is less than 5 percent) or borderline significant ($p<0.1$, where the probability of chance is less than 10 percent) associations between school and classroom characteristics and the health status of children can be found at **search.rec.org/outcomes**.

Statistically significant associations are not necessarily the most important. Below we discuss those associations that can be considered important from a public health point of view.

School location

An industrial facility in the close vicinity of the school was found to have an adverse effect on children's respiratory health (shown by the increased prevalence of children with a chronic cough, earache, upper respiratory tract complications and decreased lung function results). The distribution of the participating schools in relation to traffic density by country is shown in Table 1 (page 8). Figure 8 (page 13) shows that the primary source of NO_2, and to some extent also of PM_{10}, is outdoor air pollution. In the case of both NO_2 and PM_{10}, there is a significant decreasing trend in the measured indoor concentrations the higher the floor level (Figures 12 and 13). In the case of NO_2, the decrease is from ground floor to fourth floor, while in the case of PM_{10}, the decrease is from below the ground floor to the fourth floor.

Figure 14 shows that the mean concentrations of NO_2 measured in the classrooms depend on traffic density in the close vicinity of the school, the floor level of the classroom, and whether the classroom faces the street or the schoolyard.

FIGURE 14: **Mean indoor concentrations of NO_2 in classrooms by traffic density, street orientation and floor level**

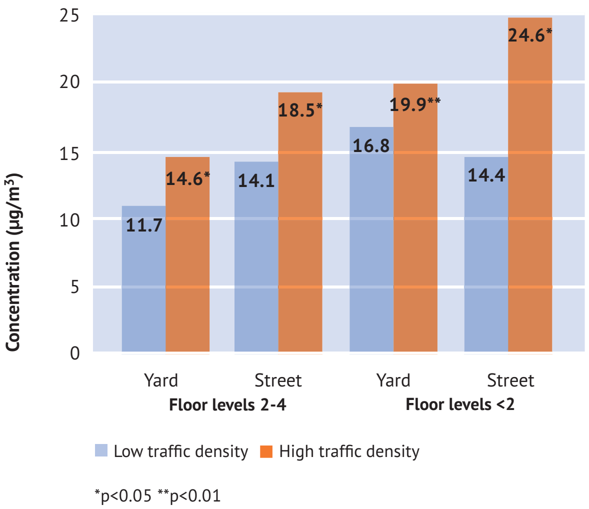
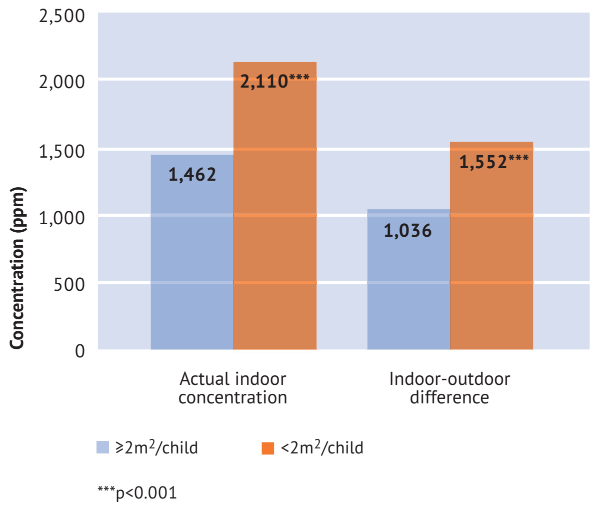


FIGURE 15: **Association between CO_2 concentration and overcrowding in classrooms**



Indoor PM_{10} concentrations were also higher on the lower floors than the higher floors, especially in areas with high traffic density (see **search.rec.org/outcomes**). There is a significant decreasing trend in the prevalence of doctor-diagnosed pollen and house dust mite allergies the higher the floor level. Figures showing the prevalence of children with such allergies in classrooms on various floor levels can be found at **search.rec.org/outcomes**.

Classroom crowdedness

As mentioned above, the mean floor space in this study was 2.02 m^2/child. A table showing the distribution of classrooms with floor space of less than 2 m^2/child by country can be found at **search.rec.org/outcomes**.

Overcrowding in the classrooms (i.e. floor space of less than 2 m^2/child) resulted in a significant increase in the measured indoor concentrations of several pollutants, including CO_2, benzene, toluene and PM_{10} (Figures 15, 16 and 17).

Classroom occupancy is an important parameter in all countries. The prevalence of children with chronic cough symptoms is significantly higher in overcrowded classrooms. Further discussion of the potential health risks of overcrowding can be found at **search.rec.org/outcomes**.

Floor covering

The use of plastic flooring was found to be associated with a significantly increased risk of doctor-diagnosed allergies (Figure 18) and decreased lung function in some countries.

On the other hand, a higher prevalence of children

FIGURE 16: **Association between indoor concentrations of benzene and toluene (µg/m³) and overcrowding in classrooms**

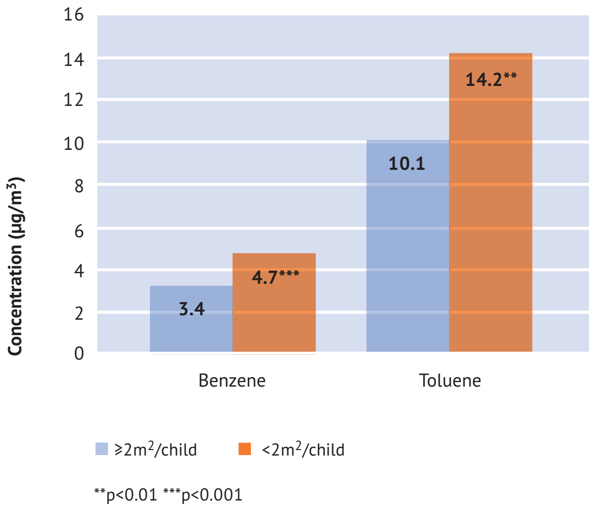
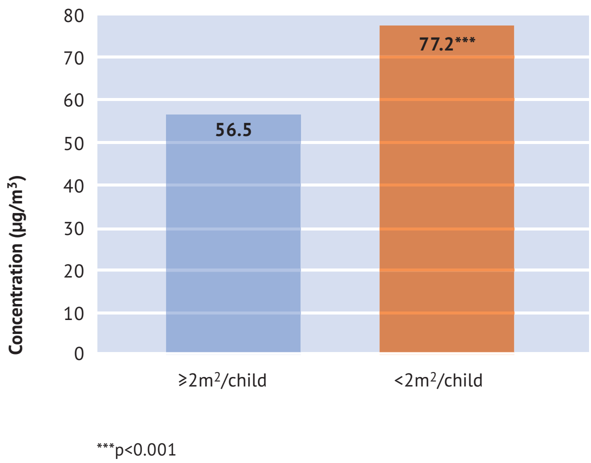


FIGURE 17: **Association between PM_{10} concentration (µg/m³) and overcrowding in classrooms**



with symptoms of depression was found in classrooms with a simple stone or concrete floor, although after adjustments these associations were no longer statistically significant.

Wall covering

The use of water-resistant paint is associated with a significantly increased risk of doctor-diagnosed asthma and allergies in the participating countries (Figure 19). (See also **search.rec.org/outcomes**.)

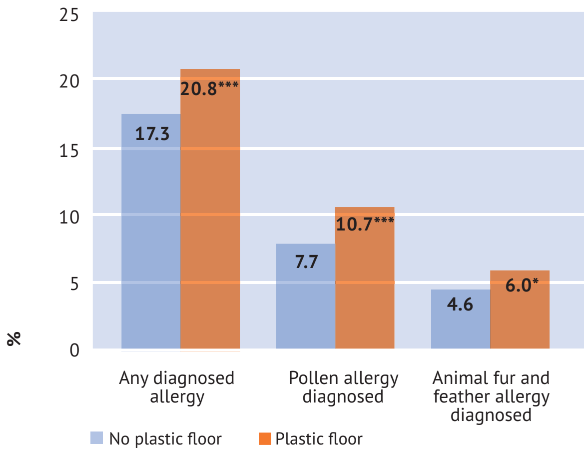
Concentrations of the measured volatile organic compounds (benzene, ethylbenzene, xylenes and toluene) were all significantly higher in classrooms with walls that had been renovated in the last two years. Concentrations were similar in classrooms that were renovated either one or two years ago (see **search.rec.org/outcomes**).

Children in classrooms with recently painted walls were at significantly higher risk of regular morning coughing than children in classrooms with walls painted more than two years ago (for more information, see **search.rec.org/outcomes**).

Ventilation

Openable windows do not in themselves protect children from chronic coughing. In classrooms where windows were not opened every break, significantly more children suffered from a chronic cough than in those classrooms that were ventilated more frequently (see **search.rec.org/outcomes**). The prevalence of chronic coughing was 50 percent higher in classrooms where the windows were not opened every break compared to classrooms where the windows were opened every break, and the prevalence of regular coughing was even higher.

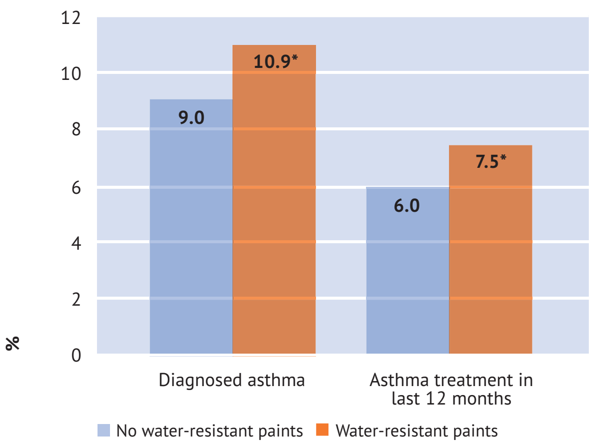
FIGURE 18: **Prevalence (%) of children with various types of diagnosed allergy in classrooms with and without plastic flooring**



+cOR=1.18~ (95% CI: 0.99–1.41)
+cOR=1.35* (95% CI: 1.07–1.69)
+cOR=1.37* (95% CI: 1.06–1.69)
+corrected for age, gender, parental smoking, living density at home, and country

~p<0.1 *p<0.05 ***p<0.001

FIGURE 19: **Prevalence (%) of children with asthma or asthmatic symptoms in classrooms with walls painted with water-resistant paints**



+cOR=1.32* (95% CI: 1.05–1.65)
+cOR=1.39* (95% CI: 1.05–1.82)
+corrected for age, gender, parental smoking, living density at home, and country

*p<0.05

Children in classrooms with windows that were regularly opened even during teaching time were significantly more protected from chronic coughing than children in classrooms where the windows could not be kept open during classes due to outdoor noise.

Time and means of cleaning

Most of the investigated asthmatic and allergic symptoms occurred more frequently in classrooms that were cleaned in the evening (87.7 percent of classrooms). Technical staff therefore need to be advised to open the windows after cleaning the classrooms in order to reduce the level of emissions from cleaning products in the indoor air.

Conclusions

- The large database containing information on 7,860 children from 388 classrooms in 100 schools in 10 countries provided a unique opportunity to study a wide variety of school indoor and outdoor environments; to measure outdoor and indoor concentrations of several air pollutants; and to investigate the associations between the school environment and children's health.
- Indoor concentrations of NO_2 and – to a lesser extent – PM_{10} originated from outdoor pollution sources (mainly traffic), while volatile organic compounds and formaldehyde were mainly emitted by indoor sources.
- The health status of children from the various countries was assessed and compared. It was observed that asthmatic symptoms and doctor-diagnosed allergies were significantly less frequent in the four new SEARCH II countries than in the six SEARCH I countries. This observation is in line with earlier findings on the difference between East and West Germany in the 1990s and can be explained by the "Western lifestyle".

The extensive database made it possible to identify several statistically significant associations between the school environment and children's health. While some associations may be difficult to interpret, most provide useful information that can help to determine new interventions in order to ensure a healthier school environment and better respiratory health for children.

- The results of the spirometry tests confirmed that the great majority of children still have normal respiratory function. The challenge is to maintain this situation in the future and to further improve the environment in which they live.
- The extensive database made it possible to identify several statistically significant associations between the school environment and children's health. Some associations may be accidental and difficult to interpret, but most provide useful information and well-documented facts that can be used to determine new interventions in order to ensure a healthier school environment and better respiratory health for children.
- The results allow us to identify some obvious examples of effective interventions: overcrowding in classrooms should be avoided; windows should be opened every break, and some should even be kept open during classes as well; plastic (PVC) flooring and water-resistant paints should be avoided; and schools should not be built alongside busy roads or in areas that are heavily polluted from other sources.

Evaluation of children's health and the home and school environment

The SEARCH II project used the same protocol, questionnaires, measuring equipment and methods that were used for the first phase, with the ultimate goal of analysing the associations between the school environment and children's health using a large, pooled database covering 10 countries and a variety of environmental factors. As the SEARCH I results per country have already been published in a small leaflet prepared for the Parma Ministerial Conference in March 2010, below we present the descriptive results related to health status and the home and school environment of children participating in the four new countries that joined the SEARCH II project.

Health status

A total of 2,797 children from the four EECCA countries participated in the SEARCH II project. Respiratory symptoms were the most common complaints: 32.5 percent of children reported suffering from this type of symptom, which is slightly more than the respective proportion in the six SEARCH I countries (28.0 percent).

The two more serious respiratory symptoms (a cough for more than three months and cough with phlegm) were several times more frequent in Ukraine than in the other three EECCA countries (for more, see **search.rec.org/outcomes**).

The data concerning the prevalence of asthmatic symptoms are very similar to those obtained during the SEARCH I study (see **search.rec.org/outcomes**), although there is a big difference in the prevalence of doctor-diagnosed asthma (10.5 percent in SEARCH I, and only 2.35 percent in SEARCH II). However, this finding is in line with earlier studies carried out by von Mutius et al. in the 1990s. The difference might also be explained by the different medical and technical resources available.

Doctor-diagnosed allergies were less frequent in the four new SEARCH II countries (15.1 percent) than in the other six countries (20.6 percent). However, there was significant heterogeneity among the four EECCA countries: in Tajikistan, the prevalence was as low as 8.0 percent, compared to 21.8 percent in Belarus. Food and drug allergies were the two leading types of allergy in all four countries, while in the SEARCH I countries allergies to house dust mites and pollen were the most frequent (about three times more frequent than in the SEARCH II countries). Additional information can be found at **search.rec.org/outcomes**.

Risk factors in the home environment

In terms of home location, 32.2 percent of children lived near a busy road, although there was a high level of variability between Belarus (51.4 percent) and Ukraine (9.4 percent). Living near to an industrial facility was most frequent in Belarus (26.7 percent), and living near to a waste disposal site was most frequent in Ukraine (24.1 percent). There was also a high level of variability in the type of dwelling: around 62 percent of children lived in multi-storey apartment buildings, with extremes in Ukraine (96.4 percent) and Tajikistan (32.6 percent). The frequency of plastic flooring in the child's room was highest in Kazakhstan (27.6 percent), while in the other three countries it was between 1.8 and 4.2 percent. In most children's rooms the walls were papered. Walls painted with synthetic paints were less frequent (the highest proportion was 6.4 percent in Kazakhstan). Visible signs of dampness or mould in homes were reported with relatively low frequency (9.8 percent for the home as a whole, and 4.1 percent for the child's room). Further discussion of this topic can be found at **search.rec.org/outcomes**.

Classroom environment

Around a third of classrooms were facing the street (more than half in Tajikistan). There was no plastic flooring in Kazakhstan, while in the other three countries plastic flooring was used in more than half the classrooms. Water-resistant paints were used most frequently in Belarus (37.7 percent). More than half the classrooms had been painted within one year, with extremes of 6.4 percent (Ukraine) and 83 percent (Tajikistan). Overcrowding (floor space of less than 2 m^2/child) was least frequent in Belarus (8 percent), while in the other three countries about half the children were in crowded classrooms (for details, see **search.rec.org/outcomes**).

In most countries, classrooms were cleaned after school hours, and sometimes between classes. With the exception of Ukraine, more than half the classrooms were cleaned twice a day (see **search.rec.org/outcomes**). Mops were used most frequently for cleaning in every country. Bleach was used only in Kazakhstan with a high frequency (89.9 percent). The frequency of windows being opened during cleaning varied between 11.3 percent in Belarus and 100 percent in Ukraine. In most cases, classroom furniture was made of medium-density fibreboard (MDF). With some exceptions in Kazakhstan, most classrooms were equipped with a blackboard.

School environment

Most of the schools were originally built as schools, and most were constructed from brick and concrete. In Kazakhstan and Tajikistan, 7 to 8 percent of children attended schools made from adobe. Renovations carried

out over the past five years concerned classrooms (65.7 percent), windows (44 percent) and lighting (46.2 percent). Heavy traffic in the vicinity of the school was reported in almost 60 percent of schools in Kazakhstan and 0 percent in Belarus. Almost all schools had a schoolyard, and most children made use of it during the breaks or after school hours. The presence of green spaces around the school was not so uniform: only 28.7 percent of schools in Ukraine compared to 100 percent in Tajikistan. In some schools, teachers were permitted to smoke in designated places, although in most schools the teachers were not allowed to smoke. There was not much variability in terms of the type of heating used in the investigated schools. In Kazakhstan, 64 percent of the children attended schools with artificial ventilation, while in the other three countries the figure was around 10 percent. In Tajikistan, 36 percent of the children attended schools in the vicinity of an industrial facility or waste disposal site, while these environmental risk factors were only minimal in the other three countries. Further discussion of this topic can be found at **search.rec.org/outcomes**.

Final remarks

It should be stressed that the investigated schools should not be regarded as representative of the countries and that the results therefore by no means reflect the situation in the individual countries. The results merely illustrate the variability of our sample survey, which helps us to study the impact of various risk factors found in the school environment on children's health.

Chapter 2: **In-depth analysis of the environmental and health data**

The database created under SEARCH I and II, containing data for 7,860 children from 388 classrooms in 100 schools in 10 countries, represents a unique opportunity to study a wide variety of school indoor and outdoor environments; outdoor and indoor concentrations of several air pollutants; and associations between the school environment and children's health.

In-depth analysis allows us to expose general problems, issues or phenomena and to explain them in detail. The extremely high levels of air pollution measured in classrooms in the SEARCH I and II countries can be considered, in our case, as the problem requiring clarification. The inclusion of extreme data in the analysis is relevant, as they might have an effect on the mean values, while at the same time the extreme values can be hidden by the mean values used in the overall analysis. The aim of the in-depth analysis was therefore to identify the potential sources of the extremely high levels of air pollution found in the classrooms; and to assess the relationship between the extremely high pollution burden in the air in the classrooms and health symptoms among the schoolchildren.

Design of the study

Definition of extreme indoor air concentrations

The first step in the study design was to define the range of extremely high indoor air pollution data within the SEARCH database. It is not possible to speak in absolute terms about extremely high concentrations compared to data published in the literature concerning schools in the participating countries.

Methodology

Overview of potential sources of emissions of indoor air pollutants

Pollutants measured in the indoor air originate from both indoor and outdoor sources. It is widely recognised that the most important indoor sources of pollution in schools are building materials, furnishings, cleaning products, toiletries, stationery and human activities. The indoor air can also be polluted by unfiltered outdoor air containing pollutants emitted primarily by traffic and industrial facilities.

Sources of information

Valuable information was provided via two questionnaires. The classroom questionnaire was used to obtain information on furnishings, consumer products, cleaning products, stationery etc., as well as occupants' behaviour and indoor activities. The school questionnaire was used to gather information on building characteristics (building materials, floor covering, classroom size and air volume, size of openable windows etc.).

Preparation of the in-depth analysis

The indoor air pollution data collected in the course of the two SEARCH projects were available for the in-depth analysis. The starting point was to identify the extremely high levels of indoor air pollution in the classrooms. These extremely high values clearly had to be in the range of outliers, thus the first step was to define those outliers.

Several approaches to identifying outliers can be found in the literature, with the recommendation to select the most appropriate method according to the subject. For the in-depth analysis of the SEARCH database, the Tukey method was considered the most appropriate.

A summary of the relevant findings in the literature, the regulatory framework for IAQ, figures, the statistical evaluation process, and the associations between environmental parameters and children's health status can be found at **search.rec.org/outcomes**.

Conclusions

Potential sources of the extremely high levels of air pollution found in the classrooms

The in-depth analysis resulted in the identification of the following possible sources of indoor air pollutants:

- overcrowding in the classrooms and carpets on the floor (benzene);

- water-resistant paints used on the walls (ethylbenzene);
- cleaning chemicals (toluene and formaldehyde); and
- ineffective air conditioning (CO_2).

The results highlight that:

- air conditioning can only be effective in combination with a continuous supply of fresh air;
- fewer cleaning chemicals should be used to clean the classrooms;
- increasing the frequency and effectiveness of ventilation in school buildings could significantly contribute to improving IAQ; and
- NO_2 is a typical ambient pollutant, while formaldehyde and CO_2 can be considered potential indoor air pollutants.

Associations between extremely high levels of indoor air pollution and health impacts on schoolchildren

The in-depth analysis suggests that:

- there is a high chance that polluted classroom air plays a role in causing symptoms among children;
- xylenes and NO_2 are among the factors causing allergies, and NO_2 may also contribute to fatigue, attention deficit disorder, irritability, anxiety and symptoms of depression;
- there is a significant association between PM_{10} and coughing every morning, and between formaldehyde and chronic cough symptoms in the last 12 months and anxiety;
- xylenes significantly increase the incidence of sleep disorders; and
- toluene and ethylbenzene contribute to the development of conjunctivitis, sinusitis and earache complications.

Chapter 3: **Comfort assessments**

Children's comfort is an important personal indicator of the quality of the indoor environment. This is particularly true of thermal comfort, which depends on temperature, humidity and ventilation in the classroom. Air quality has a significant impact on the performance of children in the classroom, and is implicated in health risks.

Evaluating children's perceptions

In the 10 participating countries, questionnaire data were gathered by the country teams and a pooled database was created by the NEIH using STATA/SE 10.0 software for the statistical analysis. A total of 6,758 children participated in the study (49.1 percent girls and 50.9 percent boys). The gender distribution of the children was fairly similar in the 10 countries. The questionnaire can be found at **search.rec.org/outcomes**. Temperature, humidity and CO_2 concentrations were monitored in classrooms in seven countries using the comfort questionnaire.

The average age of the children who participated in the comfort assessment was around 10 years. The overall mean age was 9.82 and +/- 1.31 years. The variance in age among the countries was statistically significant.

The overall time that the children who participated in the comfort assessment spent in the classroom was 24.4 hours per week, with a minimum of 21.1 hours per week and a maximum of 27.7 hours per week.

The seating distribution in the classroom in relation to door, windows, heaters or fans was similar in each country (see **search.rec.org/outcomes**).

One of the most important questions regarding the children's perception of comfort was: "Do you like your classroom?" The distribution of answers is shown in Figure 20. More than 80 percent of the children said that they liked their classroom more or less, while 11 percent considered their classroom to be adequate.

The distribution of answers related to perceived air temperature is shown in Figure 21. Around 7 percent of children felt that the classroom was not warm enough; 48 percent of the children thought that the classroom was warmer than optimal; and 44.7 percent of the children considered the temperature to be adequate.

Perceived air temperatures showed an increasing trend with increasing measured air temperatures, as expected (Figure 22), although the standard deviation was very wide, demonstrating large individual variability in perceptions of temperature. However, the results indicate that the children perceived an optimal temperature to be between 21 and 22°C.

The questionnaire also evaluated children's perception of air temperature in the classroom according to seating in relation to windows and doors. More children sitting near a window thought the temperature to be very warm than those sitting in the middle of the room. In most of the investigated classrooms the heating system was under or close to the windows, contributing to this perception among the children.

In classrooms with open windows, significantly more children perceived the temperature as good. The percentage of children who responded that they were disturbed by an open window was no different among those sitting near to (8.5 percent) or far from (8.3 percent) the window or in the middle of the room (8.4 percent). In classrooms with an open door, more children felt the temperature to be higher, although the difference was not statistically significant. The percentage of children who responded that they were disturbed by an open door was no different among those sitting near to the window (5.3 percent), near to the door (5.3 percent) or in the middle of the room (5.4 percent).

Although there were significant differences among the countries, overall children's attitudes to ventilation levels were balanced between stuffiness and draughtiness (Figure 23).

The tendency in the results of measured relative humidity corresponded to the perceived level of ventilation (Figure 24), although the relationship was not clearly linear.

In terms of air quality, Figure 25 shows that about 11 percent of the children found the air in the classroom to be bad/not fresh, even at the beginning of the teaching period, and Figure 26 shows that about 28 percent of the children found it to be bad/not fresh at the end of the teaching period.

At the time the questionnaires were completed, air quality in the classroom was perceived as quite good in most of the countries. This subjective perception was well supported by the measured CO_2 concentrations in seven countries (Figure 27).

FIGURE 20: **Distribution of responses to the question "Do you like your classroom?"**

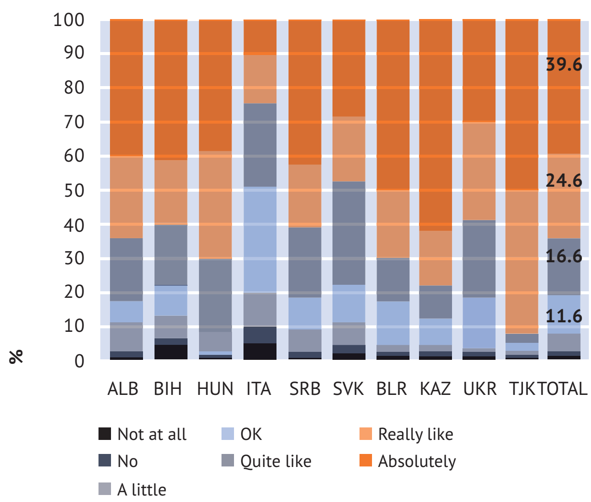


FIGURE 22: **Measured mean temperature (°C) in relation to the perceived air temperature in the classroom**

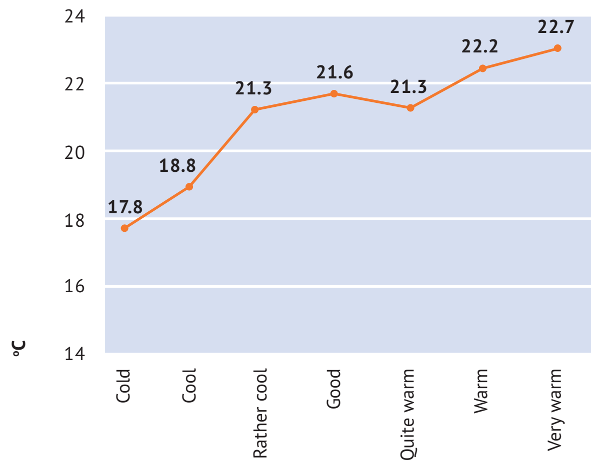


FIGURE 21: **Distribution of responses to the question "How do you perceive air temperature in the classroom?"**

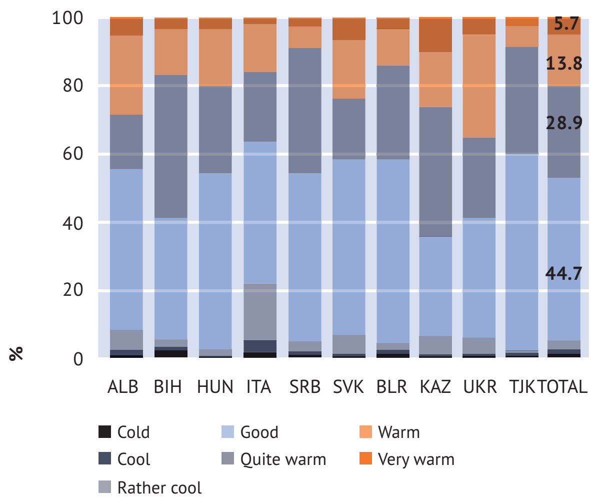


FIGURE 23: **Distribution of responses to the question "How do you perceive ventilation in the classroom?"**

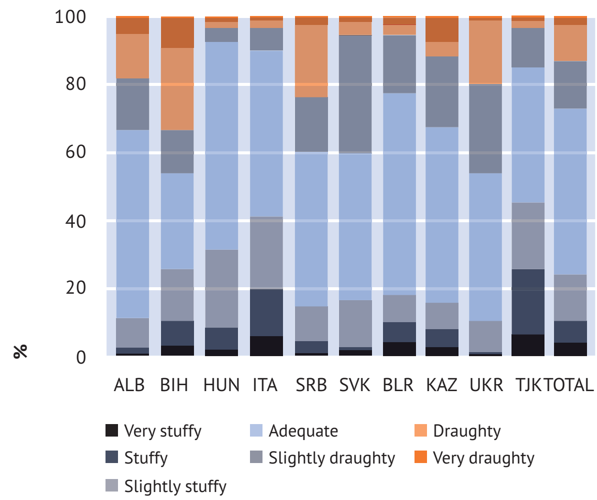


FIGURE 24: **Measured mean relative humidity (%) and perceptions of ventilation in the classroom**

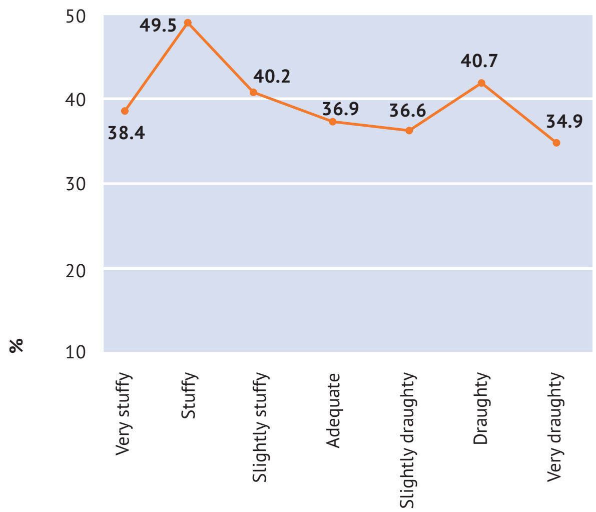


FIGURE 26: **Distribution of responses to the question "How do you perceive air freshness in the classroom at the end of the teaching period?"**

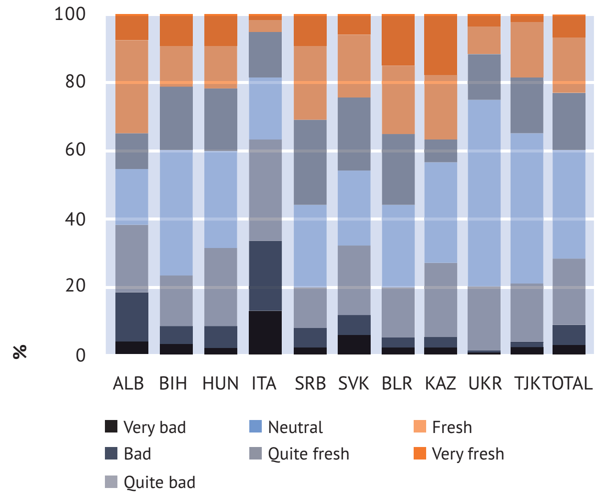


FIGURE 25: **Distribution of responses to the question "How do you perceive air freshness in the classroom at the beginning of the teaching period?**

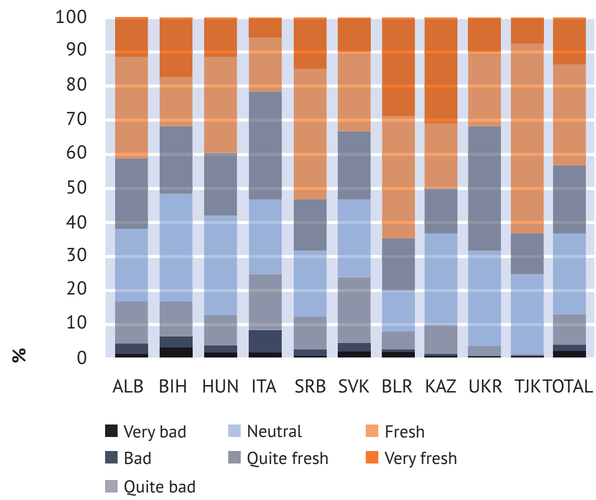
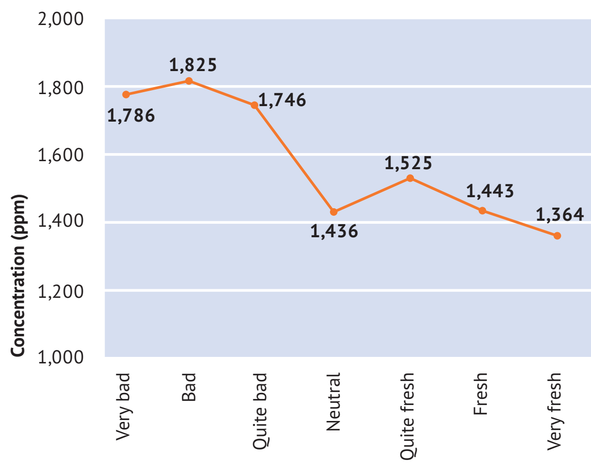


FIGURE 27: **Measured mean CO_2 concentrations and perceptions of air freshness in the classroom**



There was no significant difference in perceptions of air freshness at the time the questionnaire was completed in terms of seating in relation to windows or doors. However, significantly more children thought the air quality to be better in classrooms with open windows than in classrooms with closed windows (see search.rec.org/outcomes).

Figure 28 shows the percentage of children with a headache in relation to current perception of air quality in the classroom, associated with CO_2 concentration.

Figure 29 shows the distribution of answers to the question "Where do you usually spend your break time?" In total, 41.2 percent of children stayed in the classroom during the breaks. Although there were significant differences in perceptions of air quality during the breaks between classroom, corridor and schoolyard, most children still tended to spend the breaks inside the classroom.

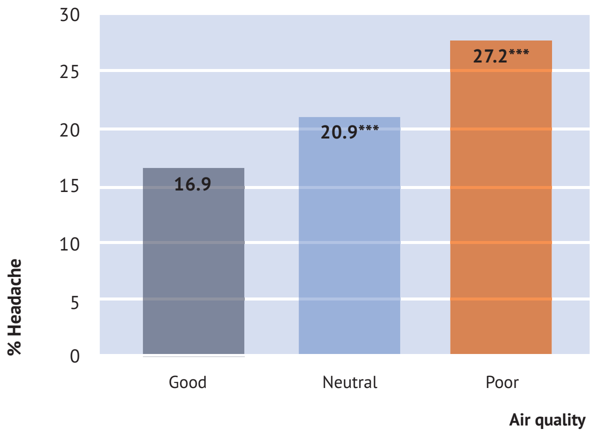
Figure 30 shows children's perceptions of air quality in relation to where they spent their break time.

Figure 31 shows the distribution of answers to the question about the perceived level of noise in the classroom at the time the questionnaire was completed. Almost one-third of the children considered the classroom to be noisy, at least to some extent. In general, one-third of the children were not disturbed by the noise. Others were disturbed in most cases by outside noise, and by inside noise in some countries (Italy and Kazakhstan) (Figure 32).

Perceptions of noise levels differed among the children who participated in the comfort assessment. Around one-third of the children were disturbed by outside noise during lessons, although more than half of the children were not disturbed significantly.

Lighting in the classroom affects children's performance at school. Figure 33 shows the distribution of answers

FIGURE 28: **Prevalence (%) of children with a headache in relation to current perception of air quality in the classroom**



aOR+=1.31*** (1.14–1.51)
aOR+=1.96*** (1.66–2.32)
+adjusted for age and gender

***p<0.001

FIGURE 29: **"Where do you usually spend your break time?"**

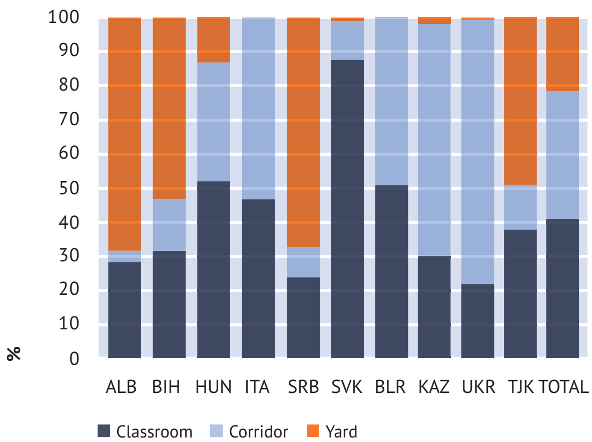


FIGURE 30: **Distribution of responses to the question "How do you perceive the air quality during break time?"**

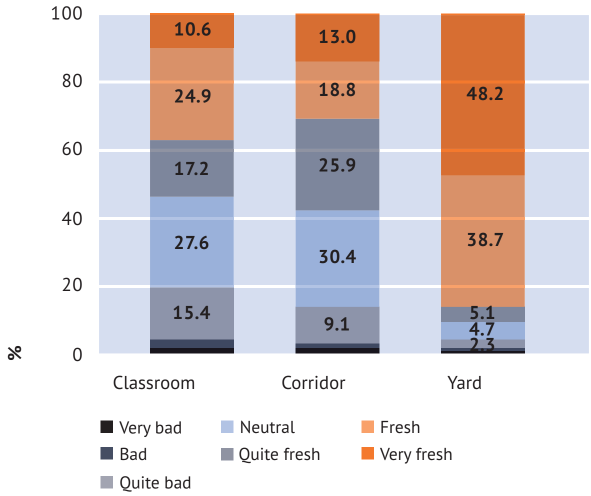
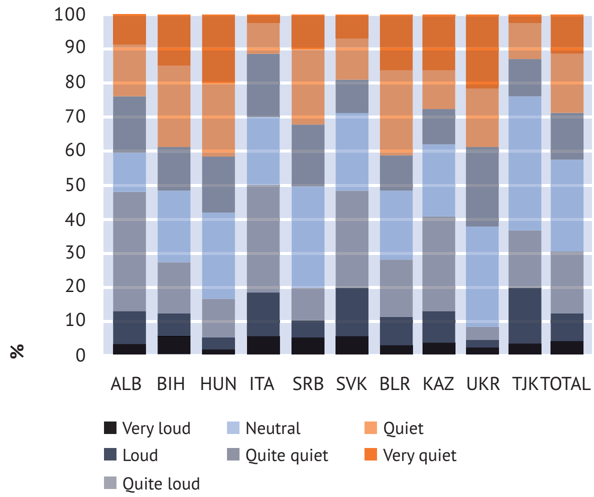


FIGURE 31: **Distribution of responses to the question "How would you rate the noise level in the classroom at the moment?"**



to the question about children's perception of lighting in the classroom. With the exception of Serbia, Italy and Slovakia, about 60 percent of children found the classroom to be lighter than optimal. With the exception of Hungary, most children claimed not to be disturbed by the light being on (Figure 34). Overall, 22 percent of children were disturbed if the light was off (Figure 35).

Conclusions

- The comfort assessment was a useful tool for collecting information from the children about their perception of the school environment.
- Objective measurements of temperature, relative humidity and CO_2 well supported the children's subjective perceptions.
- Among the most interesting findings were that:
  - 48 percent of children thought that their classroom was warmer than optimal (above 22°C was considered too warm), a finding that may be significant in terms of energy saving;
  - good air quality during the lessons significantly depended on the ventilation regime during the breaks, and although there were significant differences in perceptions of air quality during the breaks between classrooms, corridors and schoolyards, most of the children (41 percent) still spent their breaks inside the classrooms; and
  - significantly more children had headaches among those who felt the air quality to be bad (27.2 percent) or neutral (20.9 percent) than among those who felt the air quality to be good (16.9 percent). After adjustment for gender and age, logistic regression analysis showed that in the case of bad air quality the risk of headaches increased by 96 percent, and even in the case of neutral air quality by 31 percent, compared to good air quality.

FIGURE 32: **Distribution of responses to the question "What distracts your attention during lessons?"**

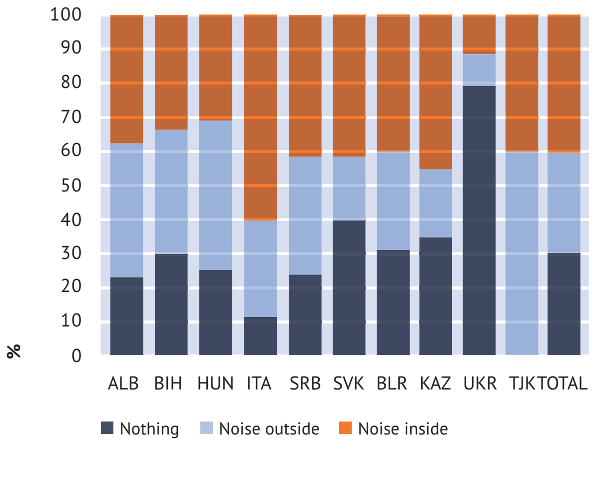


FIGURE 34: **Distribution of responses to the question "Do you find it disturbing if the light is on?"**

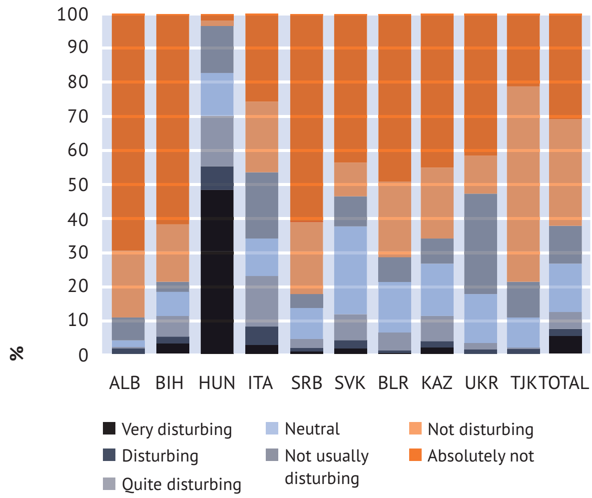


FIGURE 33: **Distribution of responses to the question "How do you perceive the lighting in the classroom?"**

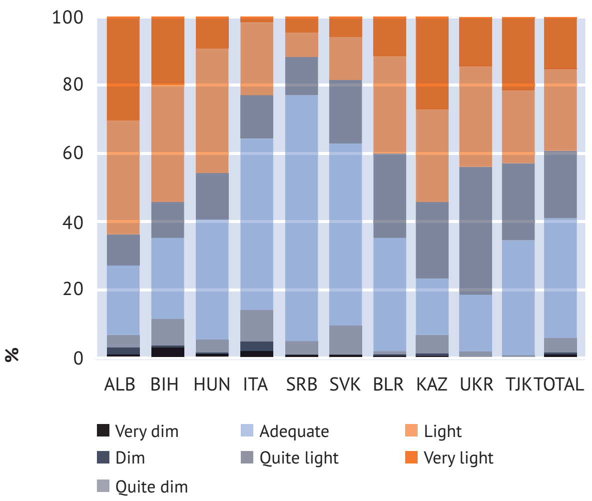
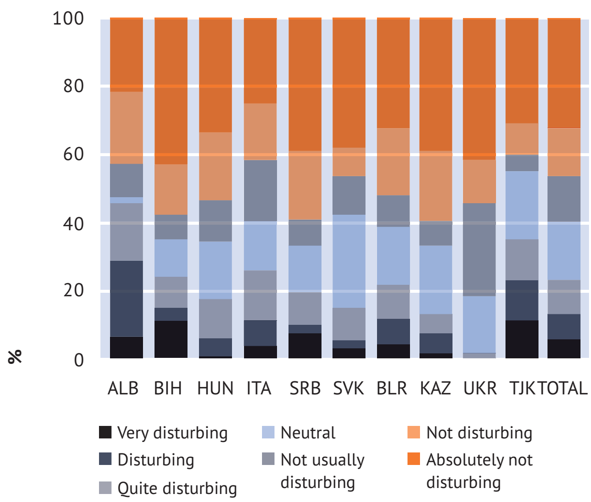


FIGURE 35: **Distribution of responses to the question "Do you find it disturbing if the light is off?"**



Chapter 4: **Assessment of energy use**

Energy consumption was assessed in school buildings in the 10 participating countries. National energy experts gathered relevant information from the schools during field visits. Data were collected on building size; construction; heating, hot water, cooling and ventilation systems; as well as annual heat and electricity consumption.

In each of the 10 participating countries, a national energy expert was appointed to collect data during field visits to the schools and preliminarily review the gathered information. The energy questionnaire (which is available at **search.rec.org/outcomes**) was developed through a process of review and discussion among all the participating energy experts and in collaboration with the REC SEARCH II management team and Comfort Consulting Ltd., Hungary. The questionnaire gathered information on:

- the total heated floor area of the building (m^2);
- the total heated air volume in the building (m^3);
- the surface area (m^2) and heat transfer coefficients (U, W/m^2K) of the external walls, windows, doors, roof etc.;
- the heating, domestic hot water (DHW), cooling and air handling systems:
  - type of heating and DHW system;
  - heating medium (water, steam);
  - heating system network (one-pipe or two-pipe system);
  - type of heating appliances;
  - type of cooling equipment (air conditioning);
  - type of air handling units;
- the control of the heating system;
- periodical temperature reductions (nights and weekends); and
- annual heat (gas, district heating, oil) and electricity consumption.

The questionnaires completed by the national energy experts were returned to the REC and Comfort Consulting Ltd. for validation and energy calculation. As a first step, the input data from the questionnaires were analysed and the distributions of the different parameters were examined. In a follow-up step, a common energy calculation method was chosen (the Hungarian TNM Decree 7/2006). The specific heat loss coefficient, total primary energy and annual gas, district heating and oil consumption were then calculated.

The calculation was initially based on the assumption that all the buildings were located in the same place (i.e. Hungary), as the goal was to compare the results from the different schools. Two indexes were created, school by school, in order to compare the buildings from the point of view of thermal characteristics: the building envelope index (qi); and the energy index (ei). In a second calculation, the calculated heat consumption data were corrected with the heating degree day factor and compared with real energy consumption, according to real location. Recommendations were given for the modernisation of the building structures and for heating, ventilation and air conditioning (HVAC) systems, based on the results of the calculations. Finally, the effect that modernisation would have on energy consumption was analysed.

Analysis of school building structure

Based on the information on school building structure collected via the 95 energy questionnaires, it was found that the heat transfer coefficients of the structures varied in the different countries due to the difference in climatic zones, national regulations and requirement values. In most of the analysed schools, the thermal characteristics of the building structures were very poor. The heat transfer coefficients of the walls varied between 0.33 and 2.6 W/m^2K, and typically between 1.0 and 2.0 W/m^2K. In most cases, the walls were not heat insulated, which meant that the heat transfer coefficients were high. Schools in Slovakia had the lowest heat transfer coefficients for the walls, with a minimum value of 0.33 W/m^2K and a maximum value of 0.82 W/m^2K. Among the 95 analysed schools, the highest heat transfer coefficients for walls were found in Ukraine (1.6 to 2.6 W/m^2K) and Serbia (1.6 to 2.45 W/m^2K). There were big differences in the heat transfer coefficients between new/modernised buildings and old buildings. In one Hungarian school, for example, one of the walls in the new section of the building had a heat transfer coefficient of 0.40 W/m²K, while walls in the old section of the same school had a high heat transfer coefficient (U = 1.72 W/m²K).

Heat transfer coefficients for roofs varied from 0.22 to 4.21 W/m²K, and were typically between 0.6 and 1.2 W/m²K. Slovakia (0.47 to 0.85 W/m²K) and Albania (0.52 to 1.12 W/m²K) had the lowest values, while in Tajikistan (1.1 to 1.54 W/m²K) and Bosnia and Herzegovina (1.1 to 1.56 W/m²K) the heat transfer coefficients for roofs were significantly higher.

Heat transfer coefficients for windows varied from 1.1 to 5.8 W/m²K. Schools in Serbia (1.47 to 2.80 W/m²K) and Kazakhstan (1.1 to 2.4 W/m²K) had the lowest values, while schools in Albania (2.5 to 4.6 W/m²K) and Italy (3.1 to 5.8 W/m²K) had the highest heat transfer coefficients.

The average heat transfer coefficient and standard deviation for walls, roofs and windows were calculated based on the 95 questionnaires. The calculated average values were surface weighted (∑A*U/∑A). The average heat transfer coefficient for external walls is 1.28 W/m²K and for roofs 0.97 W/m²K. In the case of doors and windows (Figure 36), the situation is slightly better, due to the fact that windows have already been replaced in several of the schools. The average heat transfer coefficient for windows is 2.57 W/m²K. The average values for heat transfer coefficients and standard deviations for walls, roofs, windows and doors are shown in Figure 37.

The average heat transfer coefficients for the different countries are shown in Figure 38.

FIGURE 36: **Distribution of heat transfer coefficients for windows and doors**

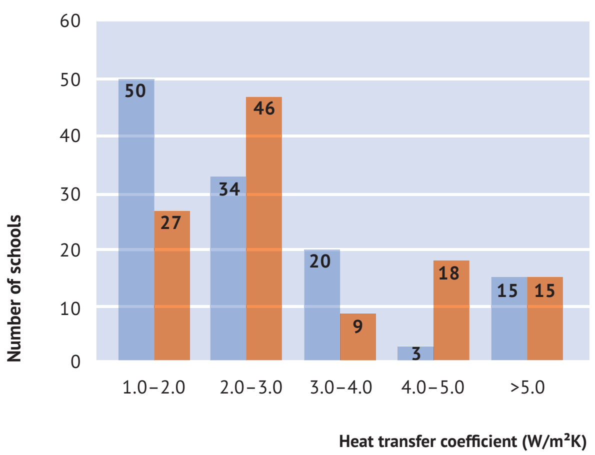


FIGURE 37: **Average heat transfer coefficients and standard deviations for the 95 analysed schools**

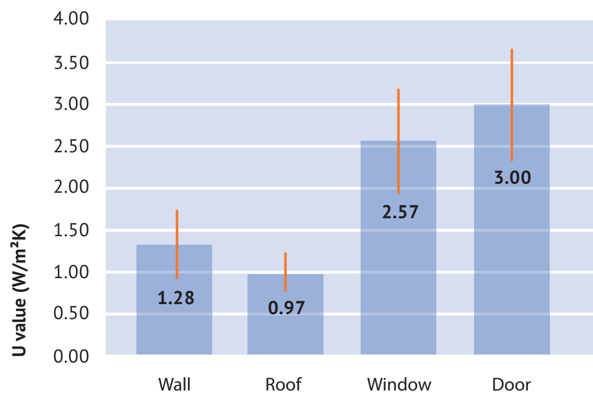


FIGURE 38: **Average heat transfer coefficients by country**

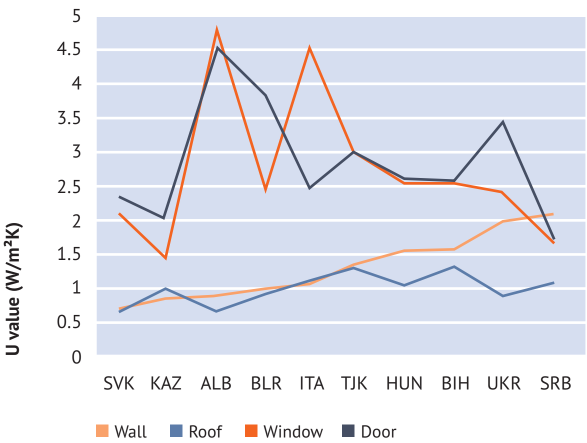
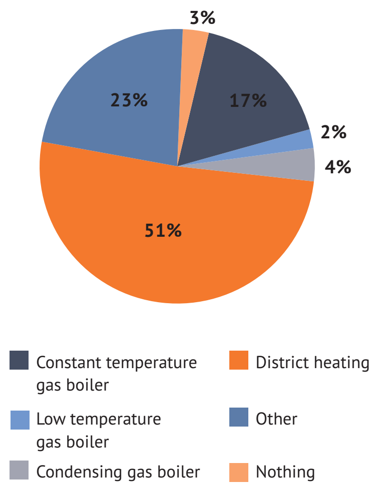


FIGURE 39: **Distribution of thermal energy production systems used for heating**

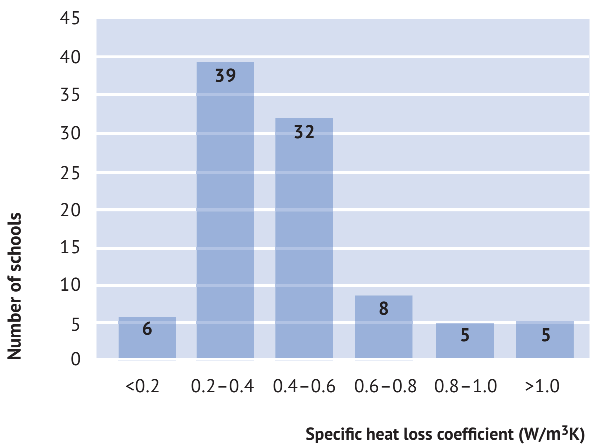


Analysis of school HVAC systems

According to the information on school HVAC systems gathered via the energy questionnaire (available at search.rec.org/outcomes), over half the analysed schools were connected to a district heating system. Constant-temperature gas boilers provided heating in 17 percent of the analysed schools; only 4 percent of the schools used condensing boilers; and 3 percent of school buildings were totally unheated. Other types of heating systems were used in 23 percent of the schools, meaning oil or coal boilers or electrical heaters (e.g. oil radiators) (Figure 39).

In the Albanian schools, heating was typically provided by oil-fired boilers, although two of the Albanian schools were unheated, and two schools used electrical heaters that provided heating in only some of the classrooms. Heating systems used in the schools in Bosnia and Herzegovina included gas and oil boilers and district heating. Hungarian schools were mainly heated by gas boilers, with only one school relying on district heating. All the schools in Kazakhstan, Belarus, Ukraine and Slovakia (with the exception of one that used a condensing gas boiler) were connected to a district heating system. In Serbia, 70 percent of the analysed schools used a district heating system, while the others had oil- or coal-fired boilers. Almost all the analysed schools in Tajikistan used electrically powered oil radiators. Some of the Italian schools had advanced HVAC systems: two had photovoltaic plants and condensing gas boilers. The other Italian schools typically had constant-temperature gas boilers, and only one had an oil-fired boiler. In schools using gas or oil boilers, the heating system was usually a two-pipe system; and in schools operating with a district heating system there was generally a one-pipe system in place, with the exception of Serbia, where all the schools had a two-pipe system. Heating appliances in the analysed schools were usually radiators with manual valves, and the heating sys-

FIGURE 40: **Distribution of specific heat loss coefficients**



tem pump had a constant speed. Only 13 schools had a variable speed pump. The questionnaires also gathered information about indoor temperature reduction settings during the heating season. In 44 percent of the analysed schools there was no periodical temperature reduction in the heating system: the temperature was maintained at the same level day and night and also at the weekend. In 42 percent of the schools the indoor temperature was lowered at night and at the weekend. In 6 percent of the schools the temperature was lowered only at the weekend, and in 4 percent of the schools it was lowered only at night.

In terms of DHW, over 60 percent of the analysed schools had no supply system; and 18 percent of the schools had an electric water heater. In 10 percent of the schools there were DHW storage tanks heated by gas or oil boiler or by a district heating system. Most of the schools had no air-conditioning system, and only some of the rooms had split units.

Energy calculations

Calculation method

The calculations were made on the basis of the data collected by the national energy experts. Several clarifications and consultations were needed in order to ensure the accuracy of the data and, eventually, of the energy calculations. There are slight differences among the SEARCH II countries in terms of the method used to calculate the overall energy performance of buildings. A common calculation method was therefore selected. In Hungary, the TNM Decree 7/2006 on the energy performance of buildings is harmonised with the Energy Performance of Buildings Directive and covers requirements, the design of the input data and the calculation method. The SEARCH II calculations were therefore made on the basis of this decree. Using a school-by-school approach, specific heat loss coefficients (W/m^{3}K), primary energy for heating, DHW supply, air handling units, cooling and lighting (kWh/m^{2}a) were calculated. Annual gas, district heating and oil consumption (kWh/a) were also calculated. The calculation was made initially based on the assumption that all the buildings were situated in the same location (Hungary) in order to be able to compare the results of the different schools. In a second step, the calculated heat consumption was corrected for each building with the heating degree day factor of the actual location. This latter calculation made it possible to compare the calculated energy consumption with the real energy consumption based on heating bills.

Specific heat loss coefficient

The specific heat loss coefficient was calculated school by school. This represents the total heat loss of the building structure, considering a 1°C difference between the indoor and outdoor temperature and a specified volume of heated air. In the initial calculation, Hungarian climate data were used for all buildings in order to be able to compare the results (see Figure 40).

Most of the analysed schools had a specific heat loss coefficient of between 0.2 and 0.6 W/m^{3}K. Within this range, the specific heat loss coefficient in the case of

39 schools was between 0.2 and 0.4 W/m³K, and in 32 schools it was between 0.4 and 0.6 W/m³K. In five schools, the specific heat loss coefficient was extremely high (over 1.0 W/m³K). An index had to be defined in order to compare the calculated specific heat loss coefficients: this is the building envelope index.

The building envelope index

In the TNM Decree 7/2006, the permitted value of the specific heat loss coefficient and the total primary energy for educational institutions are given as a function of the A/V ratio. A is the total of the external surfaces (walls+windows+roof+floor, around the heated air volume), and V is the heated air volume. These permitted values were used in SEARCH II as reference values. The building envelope index (qi) of a given school is the calculated value of the specific heat loss coefficient (q) divided by the reference value for the specific heat loss coefficient (qmax). If the qi is 1.0, then the calculated specific heat loss coefficient is equal to the reference value. If the qi is lower than 1.0, it means that the given building envelope has a better specific heat loss coefficient than the reference value, and that therefore the building envelope, in general terms, has a good level of energy efficiency. If the qi is higher than 1.0, it means that the given building structure has a worse specific heat loss coefficient than the reference value, and that therefore the building envelope, in general terms, has high specific heat loss and poor energy efficiency.

$$qi = q / qmax \quad (2)$$

qmax is calculated using the following equations:

$$A/V \leq 0.3 \quad qmax = 0.2\ [W/m^3K] \quad (3)$$

$$0.3 < A/V < 1.3 \quad qmax = 0.38\ (A/V) + 0.086\ [W/m^3K] \quad (4)$$

$$A/V \geq 1.3 \quad qmax = 0.58\ [W/m^3K] \quad (5)$$

In a school-by-school approach, the calculated values and reference values for the specific heat loss coefficient were compared in order to assign grades to the building structure. Figure 41 shows the distribution of the building envelope index. The minimum value for the building envelope index is 0.3 and the maximum is 3.98. The former building has 0.33 W/m²K outer walls, a 0.59 W/m²K roof, and 1.4 and 1.7 W/m²K windows; while the latter building has the far worse thermal characteristics of 1.51 W/m²K outer walls and roof, and 2.0 and 2.6 W/m²K windows. Only 15 percent of the buildings (14 buildings) have lower heat loss coefficients than the reference value. Nearly 50 percent have a heat loss coefficient over 1.5 times higher than the reference value. The average calculated specific heat loss coefficient is 1.64 times higher than the reference value, which means that most buildings have very poor thermal characteristics. The highest values for the building envelope index were found in schools in Tajikistan, Serbia and Bosnia and Herzegovina, and the lowest values in schools in Slovakia.

Total primary energy consumption

Total primary energy includes primary energy for heating, DHW supply, cooling, air-handling units and lighting. Primary energy was calculated for each school according to Hungarian weather conditions in order to make the results comparable. Primary energy needs were calculated according to the Hungarian TNM Decree 7/2006. Schools in Slovakia were found to have the lowest primary energy consumption (105 to 147 kWh/m²a), with an average of 127 kWh/m²a. The Slovak schools had the best building structure out of all the analysed countries: schools had two-pipe heating systems with good control equipment; almost every school lowered the heating at night and/or at weekends; and all schools except one were connected to a district heating system that had a good primary energy conversion factor, meaning that the analysed schools in Slovakia had the lowest primary energy demand. The situation was very similar in the analysed schools in Belarus, where average primary energy consumption was only slightly higher. Total primary energy consumption in schools in Bosnia and

Herzegovina, Italy, Hungary, Albania, Kazakhstan and Ukraine was between 169 and 209 kWh/m^{2}a. Serbian schools had a higher calculated primary energy consumption (290 kWh/m^{2}a), due to inappropriate building structure; the supply of DHW by electrical heaters; the use of oil-fired boilers in two schools; and the use of a coal-fired boiler in one school, with a low level of energy efficiency. Schools in Tajikistan had extremely high primary energy consumption due to high heat losses via the building structure and the use of electrical heaters (oil radiators) that have a high primary energy demand (Table 42).

The energy index

The energy index (ei) is the calculated value for total primary energy consumption in the given school (EP, measured in kWh/m^{2}a) divided by the reference value for total primary energy (EPmax). The reference value is based on the TNM Decree 7/2006 of Hungary and is given for different building types, including educational buildings, offices and residential buildings. The reference value for total primary energy is given as a function of the A/V of a building.

An ei of 1.0 means that the calculated total primary energy is equal to the reference value. If the ei is lower than 1.0, it means that the given building and its combined HVAC systems have a total primary energy consumption lower than the reference value, and that therefore the building, in general terms, has a good level of energy efficiency. If the ei is higher than 1.0, it means that the given building has a total primary energy consumption higher than the reference value, and that therefore the building, in general terms, has high annual energy consumption and poor energy efficiency.

FIGURE 41: **Building envelope index by school**

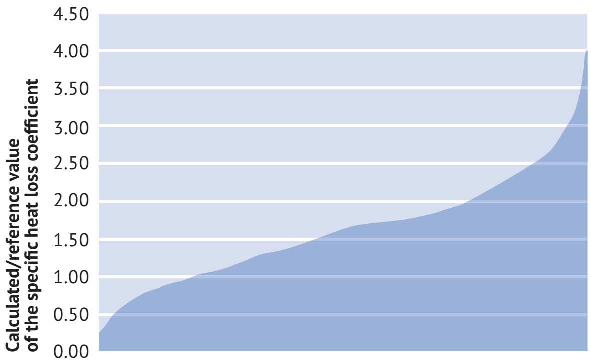
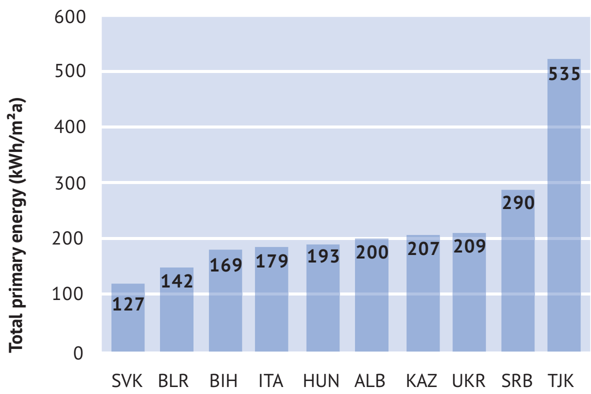


FIGURE 42: **Total calculated primary energy consumption (country averages)**



ei = EP/EPmax (6)

The EPmax is given using these equations with respect to educational buildings:

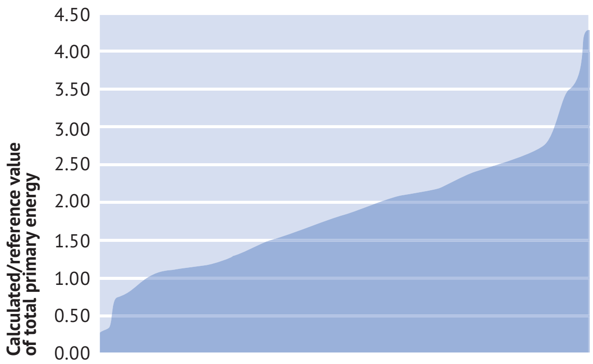
A/V ⩽ 0.3 EPmax = 90 (kWh/m²a) (7)

0.3 < A/V < 1.3 EPmax = 164 (A/V) + 40.8 (kWh/m²a) (8)

A/V ⩾ 1.3 EPmax = 254 (kWh/m²a) (9)

The calculated total primary energy is the sum of the primary energy for heating, DHW, lighting, air handling units and cooling. The average primary energy consumption was 220.9 kWh/m²a in the analysed schools. Figure 43 shows the distribution of the energy index. The calculated primary energy consumption is generally 1.7 times higher than the reference value, suggesting that the modernisation of building structures and HVAC systems offers very large energy-saving potential.

FIGURE 43: **Energy index by school**



Comparison between real and calculated energy consumption

In the second calculation, energy consumption in the buildings was calculated according to the actual location. The heating degree days for all analysed locations were provided by the national energy experts. In this calculation, the heating energy consumption of the given building was corrected (multiplied) with the heating degree day factor, which is the given heating degree day of the location divided by the Hungarian (Budapest) heating degree day.

Following the correction, the calculated and real (based on the school's energy bills) heating energy consumption were compared. Some schools were connected to a district heating system, where the heating energy consumption shown on the bill is not a measured value but is calculated based on the heated air volume in the building. In other schools, consumption data were not available. In a third group of schools, the given data were not precise. The calculated heating energy consumption and the energy consumption based on bills can therefore differ widely. The behaviour of building occupants can also have an impact on heating energy consumption:

- the indoor temperature can be adjusted to any value, although in the calculation we consider a value of 20°C;
- the actual air exchange rate may differ from the value used in the calculation: in some schools there are higher air exchange rates because windows are regularly opened, while in other schools the air exchange rate is lower because windows are rarely opened; and
- the calculated heat transfer coefficients and other input parameters may differ from the real values.

Bearing in mind that actual energy consumption usually differs from the calculated values, the correlation coefficient R2 = 0.77 for the calculated consumption and actual energy consumption is an appreciated value. The simulation models of the buildings were therefore useful for further analysis and could be considered as a basic tool for the modernisation of the building structures and HVAC systems.

Analysis of measured temperatures

Four KIMO KT 110 temperature data loggers were placed in each school: three of the data loggers were placed in classrooms to measure indoor temperatures; and one was placed outside the building to measure outdoor temperature. The data loggers recorded the temperature every 10 minutes over 7 to 10 days. The data loggers were configured by the experts, who downloaded the recorded figures that were then sent to the REC and Comfort Consulting Ltd. for further analysis.

The measurements showed how the temperature changed in the analysed classrooms during the week and weekend, and during the day and night. The measured data showed:

- whether the temperature was low, high or appropriate;
- the temperature difference between the analysed classrooms; and
- whether there was any temporary heating reduction at night and/or during the weekend.

In several of the analysed schools the measured air temperature was very low, far lower than even the minimum requirement. The lowest temperatures in classrooms during school hours were found in some schools in Albania and Tajikistan. In one extreme example, temperatures in the three analysed classrooms were 8 to 16°C, 7.8 to 14.7°C and 7.5 to 16.1°C in February 2012. Daytime temperatures were typically between 10 and 15°C, which is very cold.

In other schools, temperatures were found to be high. In one school, minimum and maximum temperatures were 22.6 and 32°C, and the temperatures in the three analysed classrooms were very different: 23.5 to 24.5°C, 26 to 27°C, and 28 to 30°C. This school used a one-pipe district heating system and it is possible that control over the heating system was not good (leading to high temperatures), and that the system was not balanced (leading to big differences in temperature between classrooms).

Recommendations for energy saving

Building structure

Recommendations were made regarding the modernisation of the building structure based on the values for the heat transfer coefficient and the calculated specific heat loss coefficient. Structures that have a heat transfer coefficient close to the reference value should not be refurbished, due to the long payback time of such an investment. When the heat transfer coefficient for external walls is between 0.6 and 0.85 W/m^{2}K, the suggestion is to add 8 cm of heat insulation to the outer surface of the walls; and when it is higher than 0.85 W/m^{2}K, the suggestion is to add 10 cm of heat insulation. When the reference heat transfer coefficient value for the roof is low, more heat insulation is needed. When the heat transfer coefficient is higher than 0.6 W/m^{2}K, the suggestion is to add 15 cm of heat insulation. Windows and doors with a heat transfer coefficient of $\leqslant$ 1.9 W/m^{2}K should not be replaced, but where U > 1.9 they should be replaced with a new structure with a heat transfer coefficient of 1.5 W/m^{2}K or even lower.

These values were approved by all the participating energy experts. In one of the countries there are several permitted values for heat transfer coefficients due to the country's different climate zones. In this case, recommendations regarding the building structure were modified in order to meet these requirements. As a result of modernisation, average heat transfer coefficients for walls would decrease from 1.28 to 0.49 W/m^{2}K; for roofs from 0.97 to 0.25 W/m^{2}K; for windows from 2.57 to 1.6 W/m^{2}K; and for doors from 3.0 to 1.57 W/m^{2}K (see Figure 44).

FIGURE 44: **Average heat transfer coefficients before and after modernisation**

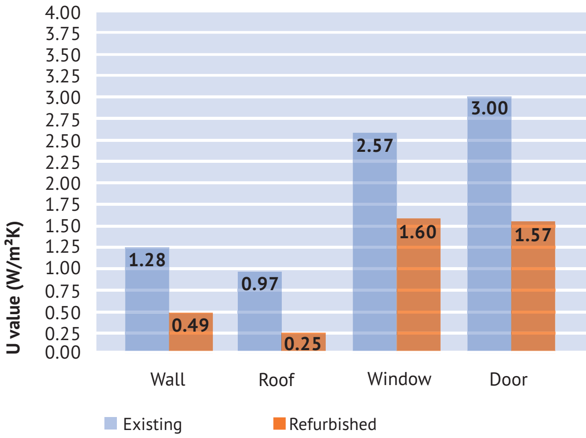
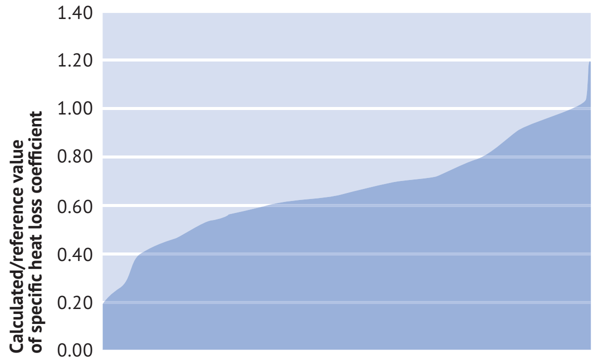


FIGURE 45: **Building envelope index after modernisation**



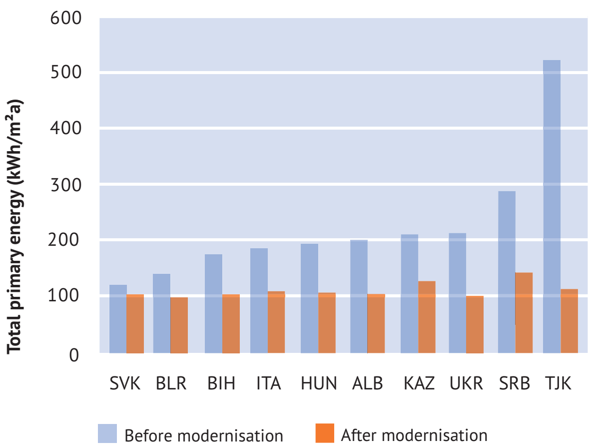
Specific heat loss coefficients were recalculated for heat-insulated structures and replacement windows. After modernisation, the calculated specific heat loss coefficient was lower than the reference value in all the schools except one, which was a temporary building for which modernisation was no longer considered. Figure 45 shows the distribution of the building envelope index after the modernisation of the building structure. A comparison of Figures 41 and 45 shows that the building envelope index is significantly lower following modernisation. Before modernisation, the average specific heat loss coefficient was 0.49 W/m^{3}K, and the average for the building envelope index was 1.64 times higher than the reference value. After modernisation, the average specific heat loss coefficient would decrease to 0.19 W/m^{3}K, and the average for the building envelope index would be 0.66 times lower than the reference value.

Better thermal characteristics of the building envelope ensure lower heating energy consumption and at the same time affect feelings of comfort. Adding heating insulation to external walls can improve perceptions of temperature among children, as the indoor surface temperature of the external walls will be higher. Replacing windows can also increase perceptions of thermal comfort, as the filtration of cold air through the new windows will be lower. However, the new windows must be regularly opened in order to ensure fresh air in the classrooms.

HVAC systems

Recommendations were also made for the modernisation of HVAC systems based on the data obtained via the energy questionnaire and the calculation of primary energy consumption. The recommendations were sent to the local energy experts, who gave their feedback on the final version, taking into consideration national standards and guidelines. The main recommendations for HVAC systems were that:

FIGURE 46: **Total primary energy consumption before and after modernisation (country averages)**



- oil boilers should be changed to condensing oil boilers;
- constant-temperature gas boilers should be changed to condensing gas boilers;
- coal-fired boilers should be changed to biomass boilers, if there is sufficient space to store the heating fuel and if a biomass supply is available near the school;
- a thermostatic valve should be fitted to every radiator;
- variable speed pumps should be used;
- balancing valves should be built into the return pipes of heating risers;
- HVAC appliances in district heating centres should be heat insulated; and
- indoor temperatures should be lowered at night and during the weekends following the modernisation of the building structure.

Analysis of the impacts of modernisation

Primary energy consumption was recalculated for the modernised building structure and HVAC systems. Before modernisation, the average total primary energy was 220.9 kWh/m^{2}a, and after modernisation the average would fall to 108.0 kWh/m^{2}a.

The total primary energy consumption shown in Figure 46 is the average of the total primary energy consumption in the schools per country. Before modernisation, schools in Slovakia had the lowest primary energy consumption (127 kWh/m^{2}a), thus they show the smallest reduction in energy consumption (21 kWh/m^{2}a, or 16 percent). In schools in Belarus, the average primary energy reduction is 44 kWh/m^{2}a (31 percent). A reduction of 40 to 45 percent can be achieved in schools in Bosnia and Herzegovina, Italy, Hungary, Albania and Kazakhstan. In Ukrainian and Serbian schools, the reduction in primary energy consumption would be over 50 percent, while the biggest reduction in primary energy consumption (80 percent) can be realised in Tajikistan.

Investment costs

The cost of modernisation, including heat insulation for walls and roofs, replacement windows and the modernisation of heating systems, naturally varies from country to country. The thermal insulation of walls costs between EUR 35 and 46 per m^2, and for roofs between EUR 36 and 50 per m^2. Replacing doors and windows involves the biggest investment, costing between EUR 180 and 200 per m^2.

The price of energy, including natural gas, oil, district heating and electricity, also varies among the analysed countries and has a big impact on the payback time of an investment. In most of the SEARCH II countries, the price of electricity, for example, is between EUR 0.08 and 0.11 per kWh, although in Tajikistan, where there are many hydroelectric power plants, electricity is far cheaper at EUR 0.027 per kWh. This is probably one of the reasons that schools in Tajikistan are heated with electricity.

Average primary energy consumption was 220.9 kWh/m^{2}a for the 95 analysed schools. The calculated primary energy consumption was generally 1.7 times higher than the reference value, thus it can be concluded that the modernisation of building structures and HVAC systems has a very large energy-saving potential.

The price of natural gas also varies significantly in the analysed countries: it is most expensive in Italy and Serbia (EUR 0.094 to 0.097 per kWh), where the price is nearly four times higher than in Tajikistan and Kazakhstan (EUR 0.023 to 0.026 per kWh).

The number of heating degree days (HDD) can also differ even within a single country, if that country has several climatic zones. A higher number of HDD results in greater heating energy consumption, thus the same modernisation of a building does not result in the same energy savings in the different climatic zones. The number of HDD therefore also has a big influence on the payback time of a modernisation investment. The highest HDD (6,286) was found in Astana, Kazakhstan, and the lowest (751) in Palermo, Italy.

The payback time for the proposed modernisations is shortest in Belarus, Kazakhstan, Serbia and Ukraine, at typically less than 10 years.

Conclusions

Data on building structures, HVAC systems and energy consumption in 95 schools were gathered and analysed. The specific heat loss coefficient, primary heating energy, energy for the DHW supply, lighting, air handling and cooling, as well as annual gas, district heating and oil consumption were calculated based on the input data. From these calculations it can be concluded that:

- only 15 percent of buildings had a lower heat loss coefficient than the reference value; and
- nearly 50 percent of buildings had a heat loss coefficient over 1.5 times higher than the reference value.

In a first calculation, all buildings were assumed to be situated in the same location. The specific heat loss coefficient and primary energy needs were calculated. Two indexes were created, school by school, in order to compare the buildings from the point of view of thermal characteristics:

- The building envelope index (qi) – the calculated value of the specific heat loss coefficient of a given school divided by the reference value of the specific heat loss coefficient. The calculated specific heat loss coefficient is generally 164 times higher than the reference value.
- The energy index (ei) – the calculated value of total primary energy consumption of a given school divided by the reference value for total primary energy consumption. The average primary energy consumption was 220.9 kWh/m^{2}a for the 95 analysed schools. The calculated primary energy

consumption was generally 1.7 times higher than the reference value, thus it can be concluded that the modernisation of building structures and HVAC systems has a very large energy-saving potential.

In the second calculation, in which the energy consumption of the buildings was calculated using the actual location, the calculated and real energy consumption were compared and the values were found to be similar. The building simulation models can therefore be considered useful for further investigations. Recommendations were made for the modernisation of the building structures and HVAC systems and discussed with the local energy experts.

The specific heat loss coefficient, building envelope index, total primary energy consumption and energy index were estimated after modernisation, school by school. Following modernisation:

- the average specific heat loss coefficient would decrease from 0.49 W/m^{3}K to 0.19 W/m^{3}K;
- the average building envelope index would decrease from 1.64 to 0.66;
- average total primary energy consumption would decrease from 220.9 kWh/m^{2}a to 108.0 kWh/m^{2}a, thus the average potential energy saving is more than half the primary energy consumption; and
- the improved thermal characteristics of the building envelope would ensure lower heating energy consumption and at the same time improve perceptions of comfort among children.

Chapter 5: **The SEARCH II index – A combined comfort index**

The combined comfort index was developed by SEARCH II experts to help schools improve children's comfort and energy consumption in school buildings. The index is based on ratings attributed to children's perceptions of thermal comfort, air quality, noise and lighting in their classrooms.

During the SEARCH II Coordination Committee meeting, held in Rome on May 22, 2012, the development of a combined comfort index (CCI) was suggested in order to create a simple and readily understandable synthesis of various physical parameters perceived by the children who completed the SEARCH II comfort questionnaire. The idea was to create a tool to help schools optimise children's comfort and the school's energy consumption.

Methods

The SEARCH II index is based on ratings attributed to the participating children's perceptions of thermal comfort, indoor air quality, noise and lighting in the classroom, using **questions from the SEARCH II comfort questionnaire**.

Initially, two methods (versions 1 and 2) were used to combine the answers to the four questions. Version 1 (CCI-1) was based on the assumption that temperature, air quality, noise and lighting were equally important in children's perception of comfort. In Version 2 (CCI-2), the various comfort factors were not taken into consideration equally but were weighted on the basis of expert opinion (air quality 40 percent; temperature 30 percent; noise 20 percent; and lighting 10 percent). In order to ensure a uniform scoring system for the answers to all four questions, the scores shown in Table 10 were used in both versions.

Version 1 was created using:
0.25* air quality scores + 0.25* temperature scores + 0.25* noise scores + 0.25* lighting scores

Version 2 was created using:
0.4* air quality scores + 0.3* temperature scores + 0.2* noise scores + 0.1* lighting scores

At the SEARCH II comfort experts' meeting, held in Szentendre, Hungary, on October 15, 2012, it was suggested that the combined comfort index should give greater weight to negative (disturbing) perceptions. Two further versions (CCI-3 and CCI-4) were therefore created. Version 3 was based on the assumption that if a child's perception was "very bad" in the case of one or more of the four factors, this should influence the index more than the other responses. (If a child's perception of air temperature, for example, was "very warm", and their perception of air quality, noise and lighting was "good", the air temperature question was to be given greater weight.) The order of the scores had to be inverted in order to leave more room to express perceptions of discomfort.

In order to ensure a uniform scoring system for answers to all four questions, the scores in Table 11 were used. Score 4 is omitted because of the weighting given to extreme values.

TABLE 10 **Scoring for comfort factors in CCI-1 and CCI-2**

Scores	Air quality	Temperature	Noise	Lighting
5 (very good)	very good (3)	very good (0)	very quiet (3)	adequate (0)
4 (good)	(quite) good (1 or 2)	quite cool or warm (-1 or +1)	(quite) quiet (1 or 2)	quite dim or light (-1 or 1)
3 (neutral)	neutral (0)	-	neutral (0)	-
2 (bad)	(quite) bad (-1 or -2)	cool or warm (-2 or 2)	(quite) loud (-1 or -2)	dim or light (-2 or 2)
1 (very bad)	very bad (-3)	cold or very warm (-3 or 3)	very loud (-3)	very dim or light (-3 or 3)

TABLE 11 **Scoring for comfort factors in CCI-3 and CCI-4**

Scores	Question B1	Air quality	Temperature	Noise	Lighting
1 (very good)	very good (3)	very good (3)	very good (0)	very quiet (3)	adequate (0)
2 (good)	(quite) good (1 or 2)	(quite) good (1 or 2)	quite cool or warm (-1 or +1)	(quite) quiet (1 or 2)	quite dim or light (-1 or 1)
3 (neutral)	neutral (0)	neutral (0)	-	neutral (0)	-
5 (bad)	(quite) bad (-1 or -2)	(quite) bad (-1 or -2)	cool or warm (-2 or 2)	(quite) loud (-1 or -2)	dim or light (-2 or 2)
6 (very bad)	very bad (-3)	very bad (-3)	cold or very warm (-3 or 3)	very loud (-3)	very dim or light (-3 or 3)

TABLE 12 **Mean values and distribution of values of the four CCIs**

	Mean	Standard deviation	Median	Min.	Max.	10th percentile	25th percentile	75th percentile	90th percentile
CCI-1	3.64	0.64	3.75	1.0	5.0	2.75	3.25	4.0	4.5
CCI-2	3.73	0.62	3.8	1.0	5.0	2.9	3.4	4.1	4.4
CCI-3	2.64	0.77	2.5	1.0	6.0	1.75	2.0	3.25	3.75
CCI-4	2.57	0.79	2.5	1.0	6.0	1.7	2.0	3.0	3.7

Version 3 was created using:
0.25* air quality scores + 0.25* temperature scores + 0.25* noise scores + 0.25* lighting scores

Version 4 was created using:
0.4* air quality scores + 0.3* temperature scores + 0.2* noise scores + 0.1* lighting scores

Results

Using the overall comfort questionnaire data from the 10 participating countries, the mean values and the distribution of the values for the four versions of the combined comfort index did not differ greatly (Table 12).

To test the performance (informative value) of the CCIs we compared the CCI values with children's responses to the question "Do you like your classroom?" (B1).

B1. **Do you like your classroom? Please indicate the relevant rating.**

-3	-2	-1	0	+1	+2	+3
Not at all	No	Quite like	Adequate	Moderately like	Very much	Completely

TABLE 13 **Spearman's correlation between scores for BI and the CCIs**

	Correlation coefficient with B1 scores
CCI-1	0.1242
CCI-2	0.2693
CCI-3	-0.1128
CCI-4	-0.2540

Table 13 shows the significant correlation coefficients found using Spearman's correlations between the scores for question BI and the CCIs.

According to the results of the regression analysis, all CCIs were significantly associated with the scores for this question (even if with a low adjusted R^2) (Table 14).

The following two conclusions can be drawn:

- The weighted indexes performed better than the unweighted ones.
- The original scoring system (CCI-1 and CCI-2) was better than the scoring weighted for extreme perceptions.

At the meeting of Italian and Hungarian experts held in Budapest on March 4, 2013, it was decided that extreme values give an unclear picture, thus only CCI-1 and CCI-2 were considered in the following procedures.

The following observations were also made:

- Statistical analysis showed that both CCI-1 and CCI-2 scores were significantly different according to gender and age.
- There was significant heterogeneity between CCI-1 and CCI-2 among countries.
- Both CCI-1 and CCI-2 were significantly associated with headaches among children (Question B7b). There was not much difference in the correlation coefficients between the two CCIs (CCI-1: -0.1245; CCI-2: -0.1353)

TABLE 14 **Association of CCIs with question BI**

	Coefficient	Standard error	adjR^2	P>(t)	95% conf. intervals	
CCI-1	0.39416	0.02696	0.0312	0.0000	0.34131	0.44702
CCI-2	0.68242	0.02599	0.0945	0.0000	0.63147	0.73336
CCI-3	-0.28879	0.02031	0.0296	0.0000	-0.32861	-0.24899
CCI-4	-0.50733	0.01967	0.0915	0.0000	-0.54589	-0.46876

TABLE 15 **Spearman's correlation between CCIs and measured values**

	Temperature (°C)	Relative humidity (%)	CO_2 (ppm)
CCI-1	0.0314	-0.0908***	0.0337
CCI-2	0.0063	-0.1346***	0.0073

*** p<0.001

TABLE 16 **Correlation coefficients of associations between the qi and ei and the CCIs**

Country	Building envelope index (qi)		Energy index (ei)	
	CCI-1	CCI-2	CCI-1	CCI-2
1	0.1123	0.2166**	- 0.1734**	- 0.0838
2	0.1449***	0.0511	0.1357***	0.1429***
3	0.1304**	0.1457***	0.2360***	0.1747***
4	- 0.0310	- 0.0605	- 0.1338**	- 0.2006***
5	0.1201**	0.0998*	- 0.1288**	- 0.1122**
6	- 0.0684	- 0.0864*	0.0198	- 0.0035
7	- 0.0324	- 0.0035	- 0.0528	- 0.0173
8	-0.0393	- 0.0552	0.0179	- 0.0655
9	- 0.0230	- 0.0568	- 0.0505	- 0.0998**
10	-	-	0.0827*	- 0.1335***

* p<0.05 ** p<0.01 *** p<0.001

- Spearman's correlation analysis between CCIs and the measured values for temperature, relative humidity and CO_2 concentrations are shown in Table 15. Coefficients were highest for (and statistically significant only in the case of) relative humidity.

Linking energy and comfort

Experts from Comfort Consulting Ltd. analysed the data on energy consumption from all the SEARCH schools and created two indexes: the building envelope index (qi) and the energy consumption index (ei). The correlation coefficients of the associations between these two indexes and the combined comfort indexes (CCI-1 and CCI-2) were very low (Table 16).

During regression analysis it turned out that when the country variable was included in the models, countries were extremely strong determinants. It was therefore worth doing further correlation analyses, stratified by country. In some cases, the results provided higher correlation coefficients than during the overall analysis, although their interpretation needs further consideration.

Linking energy, comfort and health

As the comfort and health questionnaires provided data about the same children in the same classrooms and during the same period as the assessments of energy consumption and building characteristics, it was worth investigating the associations between these parameters in the case of the four participating EECCA countries.

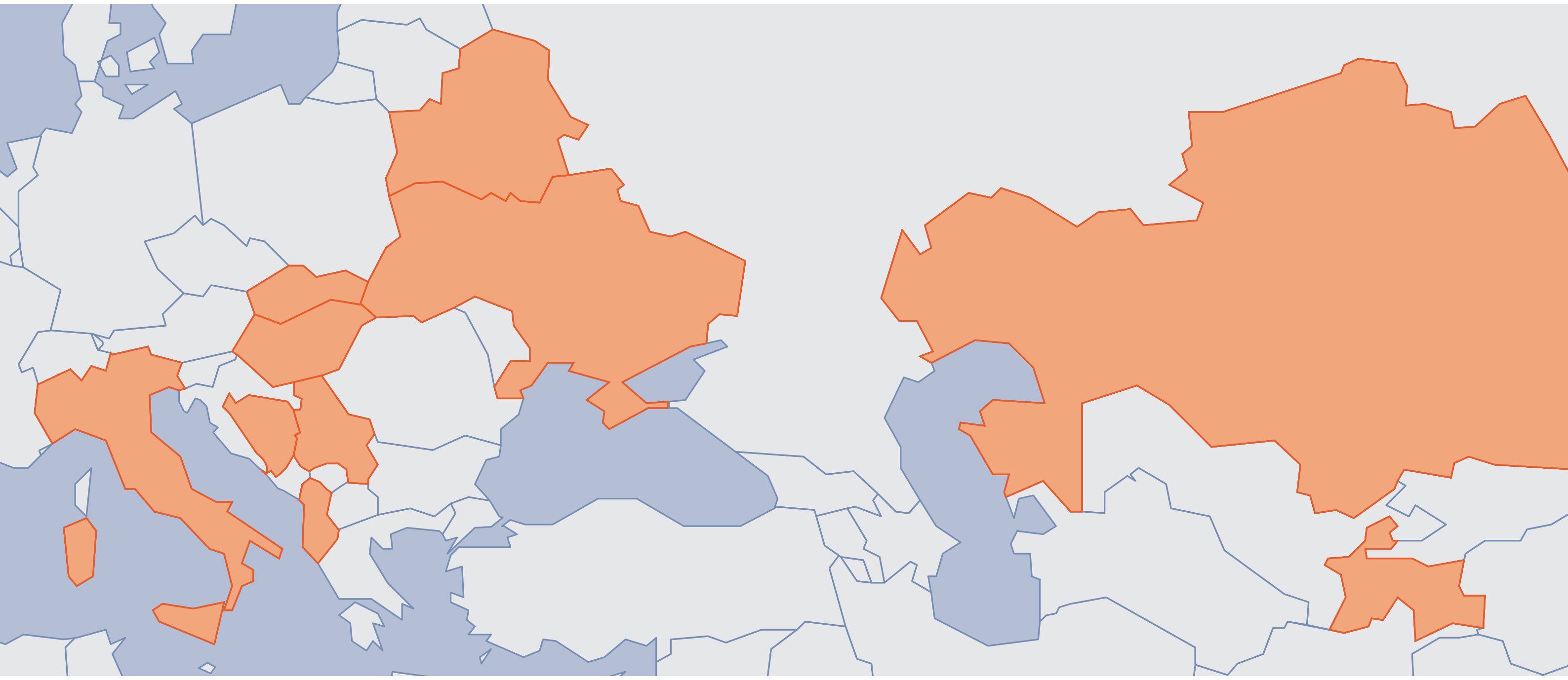
The pairwise correlation coefficients of these variables show that the combined comfort indexes were significantly correlated with both of the energy indexes. The correlation coefficients for CCI-2 were twice as high as for CCI-1. With the exception of any wheezing during the last 12 months, none of the investigated health symptoms correlated significantly with the combined comfort indexes. However, most of the respiratory and chronic cough symptoms were significantly correlated with the energy indexes.

Summary

- In the framework of the SEARCH II project, a combined comfort index (the SEARCH II index) was developed in order to create a simple and readily understandable synthesis of various physical parameters perceived by children (who completed the comfort questionnaires), which can help schools to optimise children's comfort and energy consumption in the school.
- The SEARCH II index was based on the rating of participating children's perceptions of thermal comfort, indoor air quality, noise and lighting in the classroom, using questions from the comfort questionnaire.
- Weighted and non-weighted indexes were tested for correlations with measured values for temperature, relative humidity and CO_2 concentrations, as well as with the reported prevalence (frequency) of health symptoms and with the building envelope index and energy index. The weighted combined comfort index (perceived air quality 40 percent; perceived air temperature 30 percent; perceived noise 20 percent; and perceived lighting 10 percent) was found to be a useful indicator of perceived indoor comfort.
- The SEARCH II index was pilot tested in the SEARCH II project and should be validated in practice through well-designed studies to assess the effectiveness of interventions before and after modernisation that might affect children's comfort.

References

- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality.
- Andersson, M, L. Modig, L. Hedman, B. Forsberg, E. Rönmark (2011). "Heavy vehicle traffic is related to wheeze among schoolchildren: A population-based study in an area with low traffic flows." *Environ Health* 13 (10) 91.
- Berti, G., E. Migliore, E. Cadum, G. Ciccone, M. Bugiani, C. Galassi, A. Biggeri, G. Viegi (2005). "Outdoor risk factors and adverse effects on respiratory health in childhood." Gruppo Collaborativo SIDRIA-2. *Epidemiol Prev.* March-April, 29 (2 Suppl): 62–6.
- Chang, J., R.J. Delfino, D. Gillen, T. Tjoa, B. Nickerson and D. Cooper (2009). "Repeated respiratory hospital encounters among children with asthma and residential proximity to traffic." *Occup. Environ. Med.* Feb. 66(2): 90–8.
- Concerted Action: Energy Performance of Buildings. Country reports. **www.epbd-ca.org/Medias/Pdf/CA3-BOOK-2012-ebook-201310.pdf**
- Csobod, E., P. Rudnai and E. Vaskovi (2010). *School Environment and Respiratory Health of Children (SEARCH).* Regional Environmental Center for Central and Eastern Europe, Hungary.
- Daisey, J. M., W. J. Angell and M. G. Apte (2003). "Indoor air quality, ventilation and health symptoms in schools: An analysis of existing information." *Indoor Air,* Volume 13, Issue 1, pages 53–64.
- Eroshina, K., K. Danishevski, P. Wilkinson and M. McKee (2004). "Environmental and social factors as determinants of respiratory dysfunction in junior schoolchildren in Moscow." *J Public Health* (Oxford), June, 26(2): 197–204.
- Flemish Government (2004). Decree of June 11, 2004, providing measures aimed at controlling health risks caused by indoor pollutants. *Belgian Official Journal*, October 19, 2004.
- Fromme, H., D. Twardella, S. Dietrich, D. Heitmann, R. Schierl, B. Liebl and H. Ru. (2007). "Particulate matter in the indoor air of classrooms. Exploratory results from Munich and the surrounding area." *Atmospheric Environment* 41: 854–866.
- Gasparini, G., E. Colaiacomo, L. Sinisi, F. de Maio and S. Frateiacci (2010). *Air quality in schools: Everybody's Duty and Children's Right.* Italian Ministry for the Environment, Land and Sea.
- German Federal Environment Agency: **www.umweltbundesamt.de/en/topics/health/environmental-impact-on-people/indoor-air-hygiene**
- Gonzalez-Barcala, F.J., S. Pertega, L. Garnelo, T.P. Castro, M. Sampedro, J.S. Lastres, M.A. San Jose Gonzalez, L. Bamonde, L. Valdes, J.M. Carreira and A.L. Silvarrey (2013). "Truck traffic–related air pollution associated with asthma symptoms in young boys: A cross-sectional study." *Public Health* 127(3): 275–81.
- Health Canada. Residential Indoor Air Quality Guidelines. **www.hc-sc.gc.ca**
- Janssen, N.A., B. Brunekreef, P. van Vliet, F. Aarts, K. Meliefste, H. Harssema and P. Fischer (2003). "The relationship between air pollution from heavy traffic and allergic sensitization, bronchial hyperresponsiveness, and respiratory symptoms in Dutch schoolchildren." *Environ Health Perspect.* Sept., 111(12): 1512–8.
- Koistinen, K., D. Kotzias, S. Kephalopoulos, C. Schlitt, P. Carrer, M. Jantunen, S. Kirchner, J. McLaughlin, L. Molhave, E. O. Fernandes and B. Seifert (2008). "The INDEX project: Executive summary of a European Union project on indoor air pollutants." *Allergy* 63: 810–819.
- Lim-Kyu, L., Y. Chung-Sik, K. Ju-Hyn, K. Bokyung and K. Junghwam (2012). "A study of volatile organic compound concentrations in a new school building over a one-year period." *Toxicology and Environmental Health Sciences,* Volume 4, Issue 4, pp 248–255.
- Office of Environmental Health Hazard Assessment (2001). *Prioritization of Toxic Air Contaminants.* **www.oehha.org/air/toxic_contaminants/pdf_zip/formaldehyde_final.pdf**
- Panatto, D., D. Amicizia, L. Marensi, R. Tatarek, M. Bosi, V. Tofanelli, F. Valerio, T. Sasso and R. Gasparini (2011). "Air pollution and related respiratory diseases: The experience of a local health authority in Liguria (north Italy)." *J. Prev. Med. Hyg.* March, 52(1): 26–31.
- Rosenlund, M., F. Forastiere, D. Porta, M. De Sario, C. Badaloni and C.A. Perucci (2009). "Traffic-related air pollution in relation to respiratory symptoms, allergic sensitisation and lung function in schoolchildren." *Thorax,* July 64(7): 573–80.
- Sofuoglu, S.C., G. Aslan, F. Inal and A. Sofuoglu (2011). "An assessment of indoor air concentrations and health risks of volatile organic compounds in three primary schools." *International Journal of Hygiene and Environmental Health,* Volume 214, Issue 1, pp. 36–46.
- Wheeler, A.J., S.L. Wong, C. Khoury and J. Zhu (2013). "Predictors of indoor BTEX concentrations in Canadian residences." Component of Statistics Canada Catalogue No. 82-003-X, Health Reports.
- *WHO Guidelines for Indoor Air Quality: Selected pollutants*. (2010). The WHO European Centre for Environment and Health, Bonn Office. ISBN 978 92 890 0213 4.
- Wichmann, F.A., A. Muller, L.E. Busi, N. Cianni, L. Massolo, U. Schlink, A. Porta and P.D. Sly (2009). "Increased asthma and respiratory symptoms in children exposed to petrochemical pollution." *J. Allergy Clin. Immunol.* March 123(3): 632–8.
- Zora, J.E., S.E. Sarnat, A.U. Raysoni, B.A. Johnson, W.W. Li, R. Greenwald, F. Holguin, T.H. Stock and J.A. Sarnat (2013). "Associations between urban air pollution and pediatric asthma control in El Paso, Texas." *Sci Total Environ* (15), 448: 56–65.



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