INTERNATIONAL ENERGY AGENCY
Energy conservation in buildings and community systems programme

Technical Note AIVC 63

Ventilation in the Czech Republic

Air Infiltration and Ventilation Centre
Operating Agent and Management
INIVE EEIG
Boulevard Poincaré 79
B-1060 Brussels
Belgium

INTERNATIONAL ENERGY AGENCY
Energy Conservation in Buildings and
Community Systems Programme

Technical Note AIVC 63

Ventilation in the Czech Republic

P. Charvat

June 2008

This report is part of the work of the IEA Energy Conservation in Buildings & Community Systems Programme - Annex V Air Infiltration and Ventilation Centre

Pavel Charvat
Department of Thermodynamics & Environmental Engineering
Faculty of Mechanical Engineering
Brno University of Technology
Technicka 2896/2, 616 69 Brno
Czech Republic

E-mail: charvat@fme.vutbr.cz

Document AIC-TN63
ISBN 2-930471-26-3

Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the twenty-four IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy research development and demonstration (RD&D).

Energy Conservation in Buildings and Community Systems

The IEA sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use in buildings, including comparison of existing computer programs, building monitoring, comparison of calculation methods as well as air quality and studies of occupancy.

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but also identifies new areas where collaborative effort may be beneficial.

To date the following have been initiated by the Executive Committee (completed projects are identified by *):

1 Load Energy Determination of Buildings *
2 Ekistics and Advanced Community Energy Systems *
3 Energy Conservation in Residential Buildings *
4 Glasgow Commercial Building Monitoring *
5 Air Infiltration and Ventilation Centre
6 Energy Systems and Design of Communities *
7 Local Government Energy Planning *
8 Inhabitant Behaviour with Regard to Ventilation *
9 Minimum Ventilation Rates *
10 Building HVAC Systems Simulation *
11 Energy Auditing *
12 Windows and Fenestration *
13 Energy Management in Hospitals*
14 Condensation *
15 Energy Efficiency in Schools *
16 BEMS – 1: Energy Management Procedures *
17 BEMS – 2: Evaluation and Emulation Techniques *
18 Demand Controlled Ventilation Systems *
19 Low Slope Roof Systems *
20 Air Flow Patterns within Buildings *
21 Thermal Modelling *
22 Energy Efficient communities *
23 Multizone Air Flow Modelling (COMIS)*
24 Heat Air and Moisture Transfer in Envelopes *
25 Real Time HEVAC Simulation *
26 Energy Efficient Ventilation of Large Enclosures *
27 Evaluation and Demonstration of Residential Ventilation Systems *
28 Low Energy Cooling Systems *

29 Daylight in Buildings *
30 Bringing Simulation to Application *
31 Energy Related Environmental Impact of Buildings *
32 Integral Building Envelope Performance Assessment *
33 Advanced Local Energy Planning *
34 Computer-aided Evaluation of HVAC Systems Performance *
35 Design of Energy Hybrid Ventilation (HYBVENT) *
36 Retrofitting of Educational Buildings *
36 WG Annex 36 Working Group Extension 'The Energy Concept Adviser' *
37 Low Exergy Systems for Heating and Cooling of Buildings *
38 Solar Sustainable Housing *
39 High Performance Insulation systems (HiPTI) *
40 Commissioning Building HVAC Systems for Improved Energy Performance *
41 Whole Building Heat, Air and Moisture Response (MOIST-EN)
42 The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (COGEN-SIM)
43 Testing and Validation of Building Energy Simulation Tools
44 Integrating Environmentally Responsive Elements in Buildings
45 Energy-Efficient Future Electric Lighting for Buildings
46 Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)
47 Cost Effective Commissioning of Existing and Low Energy Buildings
48 Heat Pumping and Reversible Air Conditioning
49 Low Exergy Systems for High Performance Buildings and Communities
50 Prefabricated Systems for Low Energy Renovation of Residential Buildings

Annex V: Air Infiltration and Ventilation Centre

The Air Infiltration and Ventilation Centre was established by the Executive Committee following unanimous agreement that more needed to be understood about the impact of air change on energy use and indoor air quality. The purpose of the Centre is to promote an understanding of the complex behaviour of air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.

The Participants in this task are Belgium, Czech Republic, Denmark, France, Greece, Japan, Republic of Korea, Netherlands, Norway and United States of America.

Contents

Blank page

1 Basic information about the Czech Republic

1.1 Geography, population and economy

The Czech Republic is located in the centre of Europe. The area of the Czech Republic is 78,866 km^2 and its population is about 10.4 million people. The Czech Republic was part of former Czechoslovakia until 1993 and it has been a member state of the European Union since May 2004. The Czech Republic is an industrialized country enjoying a decent gross domestic product (GDP) growth (6.6 percent in 2007). The GDP per capita is currently at about 82 percent of the average of the 27 EU member states.

The map of the Czech Republic can be seen in Figure 1. The Czech Republic is a landlocked country. The shortest distance from the Czech borders to the Baltic Sea is 326 km and 332 km to the Adriatic Sea. Only 1 percent of the area of the Czech Republic lies at an altitude higher than 1000 m, 32 percent of the area lies between 500 m and 1000 m, and 67 percent of the area lies at an altitude lower than 500 m. The highest mountain of the Czech Republic (Snezka) is 1602 m high.

The largest cities in the Czech Republic are Prague (1.2 million), Brno (0.37 million), Ostrava (0.31 million), Plzen (0.16 million) and Olomouc (0.1 million).

The former Czechoslovakia boasted with its steel production that exceeded one ton of produced steel per person in 1988 when the steel production peaked. The decrease in steel production, application of energy efficient production technologies and use of nuclear energy have helped the Czech Republic to fulfil its Kyoto protocol commitment of reducing greenhouse gas emissions by 8 percent from their 1990 level. The greenhouse gas emissions were down 26 percent in 2007.

The Czech Republic has experienced migration of people from country to cities in last 50 years. This trend brought about the need for new housing construction. The prefabricated reinforced-concrete apartment buildings were built in mass scale from the early 1960s to the early 1990s. These building have become a sad icon of the urban development in communist Czechoslovakia. Though the expected life-span of the prefabricated reinforced concrete buildings was 30 years, many buildings older than 40 years are still inhabited.

Figure 1 Map of the Czech Republic (www.wikipedia.org)

1.2 Climate

Thanks to its mid-continental location the Czech Republic has a moderate climate with four distinct seasons. The difference between summer and winter temperatures is rather high. The highest temperature recorded in Prague was 40.2°C (1983) and the lowest temperature was -31.1 (1956). The selected meteorological data for three largest cities in the Czech Republic are in the Table 1.
(source: the Czech Hydrometeorological Institute www.chmu.cz)

a) Mean air temperature (°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av
Prague	-2.4	-0.9	3.0	7.7	12.7	15.9	17.5	17.0	13.3	8.3	2.9	-0.6	7.9
Brno	-2.5	-0.3	3.8	9.0	13.9	17.0	18.5	18.1	14.3	9.1	3.5	-0.6	8.7
Ostrava	-2.4	-0.7	3.2	8.2	13.2	16.4	17.8	17.2	13.6	8.9	3.7	-0.4	8.2

b) Solar radiation incident on horizontal surface (kWh/m²)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Prague	21	37	71	114	148	145	143	136	87	57	25	15	996
Brno	25	44	82	116	158	159	172	144	96	65	28	20	1107
Ostrava	24	41	75	109	151	153	159	136	85	60	28	18	1037

The mean air temperature has deviated from the above mentioned normals in the last couple of years, as can be seen in Table 2. Detailed meteorological data is necessary when new calculation techniques for energy performance of buildings (such as computational energy simulations) are used. So far, hour-by-hour meteorological data for different locations in the Czech Republic are not publicly available. That is one of the reasons why energy simulations have not been used by professionals working in the field of building construction.

Table 2 *Mean annual temperatures between 1998 and 2007 (source: the Czech Hydrometeorological Institute www.chmu.cz)*

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Prague	8.7	8.9	9.6	8.3	8.3	9.0	8.6	8.5	9.1	9.9
Brno	9.6	9.9	10.8	9.2	9.2	9.9	9.4	8.9	9.1	10.6
Ostrava	9.0	9.3	10.1	8.6	8.6	9.1	9.0	8.4	9.1	9.9

Climatic conditions influence the distribution of energy consumptions in buildings. Space heating accounts for most of the energy use in buildings in the Czech Republic (approximately 70%). Space cooling has been rather rare and it is mostly used in commercial buildings (banks, supermarkets, restaurants, airports, etc.).

1.3 Dwelling stock

The last census in the Czech Republic took place on March 1, 2001. Various data on the housing stock were collected in the census. The basic structure of the housing stock in the Czech Republic in the year 2001 is shown in Table 3.

Table 3 *Residential building stock in 2001*

<table>
<tr><td colspan="3">Buildings in total</td><td>1 969 018</td></tr>
<tr><td colspan="3">Inhabited buildings</td><td>1 630 705</td></tr>
<tr><td rowspan="9">Inhabited buildings</td><td colspan="2">Family houses</td><td>1 406 806</td></tr>
<tr><td colspan="2">Apartment buildings</td><td>195 270</td></tr>
<tr><td rowspan="3">Ownership</td><td>private</td><td>1 397 924</td></tr>
<tr><td>municipality, state</td><td>79 066</td></tr>
<tr><td>cooperatives</td><td>41 808</td></tr>
<tr><td rowspan="4">Buildings built</td><td>before 1919</td><td>260 357</td></tr>
<tr><td>1920-1945</td><td>320 902</td></tr>
<tr><td>1946-1980</td><td>637 736</td></tr>
<tr><td>1981-2001</td><td>388 380</td></tr>
</table>

Even though the number of family houses is much higher than the number of apartment buildings the majority of the population lives in apartments (as can be seen in Table 4).

Table 4 *Dwelling stock*

Dwellings in total	4 366 293
Permanently inhabited dwellings	3 827 678
Dwellings in family houses	1 632 131
Dwellings in apartment buildings	2 160 730
Percentage of population living in family houses	45.7 %
Percentage of population living in apartment building	52.2 %

The discrepancy between the total number of dwellings and the number of permanently inhabited dwellings does not mean that there was half a million of uninhabited dwelling in the Czech Republic in 2001. A dwelling is considered permanently inhabited if someone refers to it as a place of permanent residence. If neither the owner nor the tenants use the dwelling address as their place of permanent residence (e.g. students renting an apartment while studying in a city) the dwellings shows in the statistics as “uninhabited”. The percentages of people living in family houses and apartment buildings do not add up to 100 percent. It is because some people permanently live in assisted living centres and similar kinds of facilities that do not fit into category of residential buildings. Some people also live in cottages and other recreational types of buildings, which do not fall into the category of family houses. There are also people living in mobile and temporary dwellings (less than 3500 people in 2001).

The habitable floor area of an average dwelling in the Czech Republic is smaller than in Western European countries. The habitable floor areas of dwellings are shown in the Table 5. The dwellings in the Czech Republic typically have a kitchen as a separate room. However, a space efficient solution where the kitchen is a part of the living room (open kitchen) has mostly been used since the mid 1990s.

Table 5 *Habitable area of dwellings*

	Average habitable floor area of a dwelling [m²]							
	in total	year of construction or retrofitting						
		before 1899	1900-1919	1920-1945	1946-1970	1971-1980	1981-1990	1991-2001
Family houses	63.0	54.8	55.9	57.0	57.9	66.1	73.7	77.6
Apartment buildings	39.4	45.1	44.7	38.4	37.6	38.8	41.5	39.9
FH +AB	49.5	51.7	51.3	49.8	44.4	48.3	52.7	60.9

The habitable floor area of newly built dwellings is getting larger. The average habitable area of the dwellings built in 2007 was 70.4 m^2 (97.1 m^2 in family houses and 50.7 m^2 in apartment buildings). The total number of newly built dwellings was 41,649 in 2007. That is less than 1 percent of the total dwelling stock, and it shows that the pace of the dwelling stock renewal remains relatively slow.

1.4 Building construction materials

A typical family house built between 1960 and 1990 in the Czech Republic (Czechoslovakia at that time) is a two-storey building with either a flat roof or pitched roof. Many houses from that period have a technical basement in addition to the two above-ground stories. The red bricks and cinder blocs are the most common construction materials of load-bearing walls in these houses.

A typical apartment building built in the same time period was a prefabricated reinforced-concrete building. Around 95 percent of the apartment buildings built between 1970 and 1990 are prefabricated reinforced-concrete buildings.

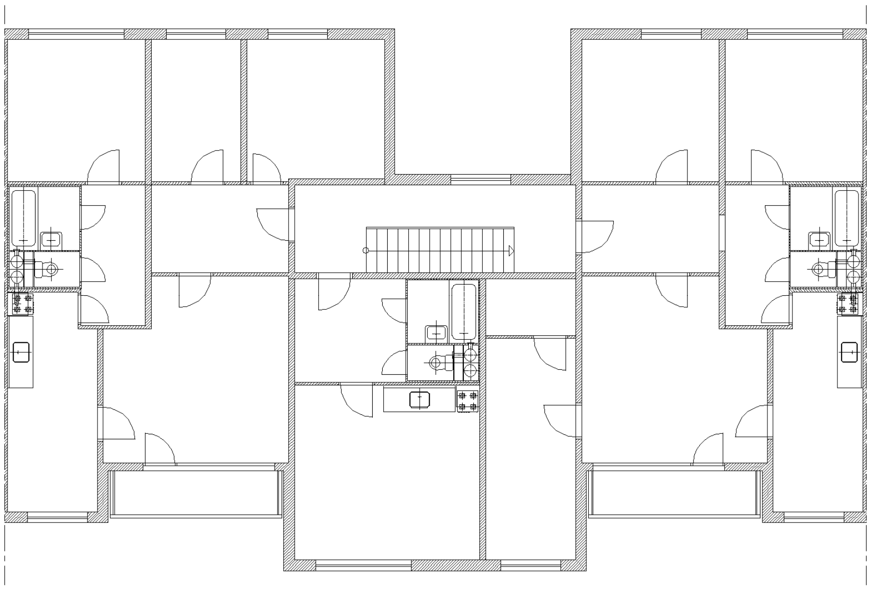

Figure 2 *Floor plan of a prefabricated reinforced concrete building*

The prefabricated reinforced-concrete apartment buildings still represent the biggest portion of the dwelling stock. Figure 2 shows a floor plan of a prefabricated reinforced-concrete apartment building built in early 1980s. The building has 4 storeys (each storey with the same floor plan). The prefabricated concrete buildings were usually built in long rows along the streets in towns and cities (one row consisting of several buildings attached to one another). Some of these rows are hundreds of meters long. The prefabricated concrete buildings usually have between 4 and 12 storeys. The buildings with more than 4 stories have elevators. The floor plan in Figure 2 presents the smallest and the biggest type of an apartment that can be found in prefabricated concrete buildings. The biggest apartment has a living room and three bedrooms; the smallest apartment is a studio with an open kitchen. Most of the apartments in prefabricated concrete buildings have one or two bedrooms.

New construction materials and building technologies became available with the fall of the Iron Curtain and the building industry has changed significantly. The most visible change was in the area of the apartment building construction, where the technology of prefabricated reinforced-concrete buildings was completely abandoned.

The significant changes occurred also in the construction of detached dwellings. The perforated blocs of burnt clay and the light-concrete blocks have become the main construction material for houses. High demand for non-expensive housing has brought about a space-efficient house design. Many new houses only have a ground floor and a habitable attic. The ground floor is usually built of masonry and the attic is of a wood-frame construction thermally insulated with mineral wool. Wood as the main construction material is still not very common in the Czech Republic. The load-bearing walls of homes commissioned in 2007 were mostly made of masonry (92% of detached dwellings, 72.8% of apartment buildings). The use of wood for load-bearing walls is still rare. Only 3.9% of dwellings built in 2007 had load-bearing walls made of wood.

1.5 Building heating systems

Most buildings (apartments, offices, schools, hospitals etc.) in the Czech Republic use block or district heating. District heating is typically used in areas with high building and population density (cities and bigger towns). The district heating plants usually produce both heat and electricity and they have the thermal output of tens or even hundreds of MW (co-generation is mandatory for the plants with thermal output higher than 4 MW). Approximately 45 percent of apartment buildings built in 2005 used district heating. Block heating is used in urban areas where district heating is not available. Natural gas fired boilers are usually used in block heating plants. The thermal output of a block heating plant rarely exceeds 1 MW.

A central heating system using water circulation is a typical space heating system in residential buildings, office buildings, schools, hospitals and many other types of buildings. The buildings with central heating systems that are not connected to a block or district heating system usually use a gas boiler as the heat source. The low-temperature heating systems are mostly installed in new buildings and the buildings undergoing energy retrofits. As a consequence the condensing gas boilers are gaining more and more market share. The market share of condensing boilers was estimated at 10% in 2005. The main distributors acknowledge that the sales of condensing boilers follow the trend of increasing prices of natural gas.

Electric space heating is also rather common,particularly in family houses. Electric heating systems were massively installed in the 1990s when the government tried to reduce air pollution originating from coal-fired boilers and heaters. It is estimated that direct electrical heating is used in 340,000 dwellings and that the total output of direct electric heating exceeds 1 GW (the total peak output of all power plants in the Czech Republic is around 17 GW). Off-peak electric heating with water thermal storage (storage electric heating) is becoming popular in low-energy houses. The storage electric heating is used with both water circulation and warm air heating systems. Warm air heating has been very rare in the Czech Republic, but its popularity is increasing with the popularity of low-energy and passive housing concepts. Many new low-energy houses have a combined system of ventilation and warm air heating what significantly reduces investment costs.

1.6 Thermal bridges, condensation and mould growth

Water vapour condensation in buildings usually occurs on windows, which are the weakest part of the building envelope. Condensed moisture can easily be cleaned from both glazing and frames and there are usually no problems with mould growth on windows. However, wooden frames of windows can rot off when they are exposed to moisture for a long period of time. The heaters (radiators, convectors) are typically mounted on the wall under the windows in order to reduce draft risk and also moisture condensation on windows. The radiators positioned below windows also compensates for lower radiant temperature of window glazing. The floor-mounted convectors are nowadays used under

French doors and glazed walls (conservatories, indoor polls, etc.) If warm air heating is used the floor air supply outlets are usually located beneath the windows as well.

The most problematic spots for condensation and mould growth are corners of external walls, concrete lintels above doors and windows, ceilings at the highest floors and external walls behind furniture. A typical example of a thermal bridge in a building construction in the Czech Republic is a joint of a floor (usually a concrete slab) and an external wall (mostly masonry). The thermal bridge and its elimination by application of additional thermal insulation can be seen in Fig. 3.

It is not recommended to place furniture (such as wardrobes and cabinets) next to external walls if these are not thermally insulated. The restricted air movement in a gap behind the furniture leads to a low value of heat transfer coefficient. That has a consequence in low wall surface temperature and high water vapour condensation. The condensed moisture cannot easily re-evaporate and mould growth is commonplace.

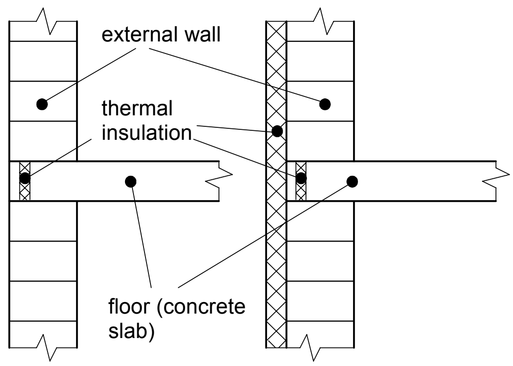

***Figure 3** Thermal bridge and its elimination*

2 Ventilation standards, requirements and regulations

Technical standards in the Czech Republic are generally not mandatory. The standards are mostly used as guidelines and provide methodology for calculations. A standard becomes mandatory when a law or decree refers to it for further specifications. The mandatory standards usually deal with occupational safety and health and other safety issues e.g. fire protection of buildings.

2.1 Czech Standard Institute

The Czech Standards Institute (CNI) is the national institution for standardisation. The CNI is a member of CEN, the European Committee for Standardisation. Original Czech standards, designated CSN (e.g. CSN 73 0540), are only produced in the areas where European or international standards do not exist and they make up approximately 10% of the overall annual production of technical standards in the Czech Republic. The European and international standards (designated e.g. EN, ETSI, ISO, IEC), adopted to the Czech standards system become Czech standards and are designated CSN EN, CSN ISO, CSN EN ISO, CSN IEC, CSN ETS (e.g. CSN EN 115, CSN ISO 1735 , CSN EN ISO 9001, CSN IEC 61713, CSN ETS 300 976). These standards make up approximately 90% of the overall annual development of technical standards in the Czech Republic.

2.2 Indoor air quality

The IAQ is dealt with in several decrees and regulations. Regulation 6/2003 sets the limits for concentrations of pollutants in educational facilities, health care facilities, social care facilities, retail facilities, accommodation facilities, and other facilities where large numbers of people gather.

Table 6 *Concentration limits*

Hourly concentrations (µg/m3)			
nitrogen dioxide NO_2	100	toluene C_7H_8	300
dust PM10	150	xylene C_8H_{10}	200
dust PM2.5	80	styrene C_8H_8	40
carbon monoxide CO	5 000	ethylbenzene C_8H_8	200
ozone O_3	100	formaldehyde H_2CO	60
ammonia NH_3	200	trichlorethylene C_2HCl_3	150
benzene C6H6	7	tetrachloroethylene C_2Cl_4	150

Regulation 6/2003 also deals with biological contaminants. It refers to the standards ISO 4833:1991 *Microbiology - General guidance for the enumeration of micro-organisms* and CSN ISO 7954:1987 *Microbiology - General guidance for enumeration of yeasts and moulds* for further specifications of sampling techniques.

Radon is another pollutant that occurs in buildings in the Czech Republic. Coal ash used to be added to cinder blocs used in building construction. Coal contains radionuclides that remain in coal ash when coal is burned in power plants. Nowadays, penetration of radon from soil into a building is the main radon related hazard.

2.3 Energy performance of buildings

Space heating accounts for most of the energy use in the building sector in the Czech Republic. Space (mechanical) cooling has been rather rare and it is mostly used in commercial types of buildings (banks, supermarkets, restaurants, airports, etc.). Mechanical cooling is rarely used in residential buildings, schools and hospitals.

The final energy consumption by sectors in the Czech Republic in 2006 can be seen in Fig. 4a and the energy consumption of households in Fig. 4b.

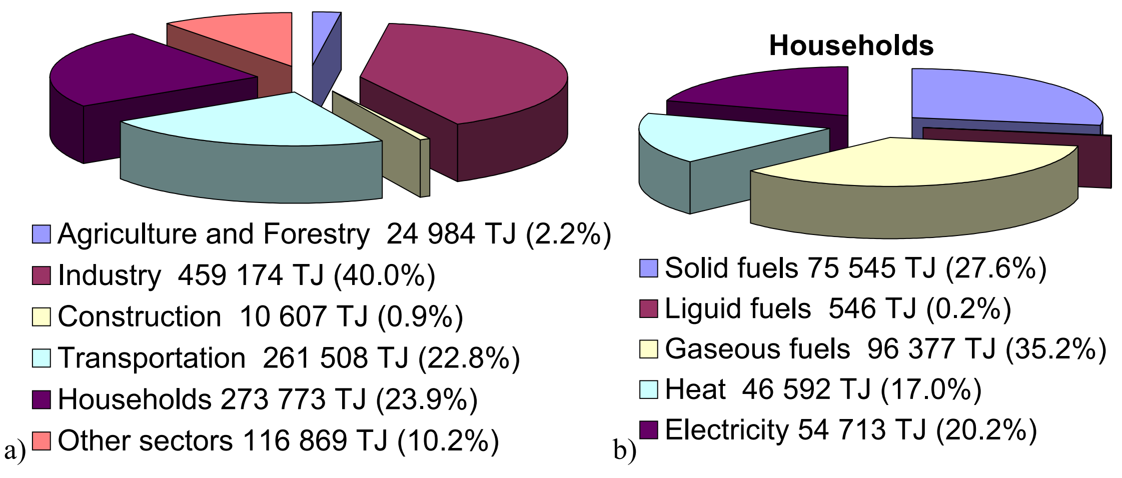

Figure 4 *Energy consumption in the year 2006 (source: Czech Statistical Office)*

The design outdoor temperature for space heating systems varies from -12°C to -18°C (CSN EN 12831:2003 *Heating systems in buildings - Method for calculation of the design heat load*). The building regulations require certain U-values (heat transmission coefficient [W/m²K]) for the building envelope (see Table 7). The standard 73 0540 *Thermal protection of buildings – Part 2: Requirements* sets the requirement of heat recovery with the efficiency of at least 60 % for all newly built buildings with a hygienic air change rate $n \geq 2$ hour^{-1} for 8 hours or more a day.

The Czech Republic, as an EU member state , has adopted the requirements and recommendations of the European directive 2002/91 *Energy Performance of Building* in its legislation. The Energy

Management Act 406/2006, which was adopted by the Czech Parliament on March 29, 2006, sets the framework for energy use not only in the building sector, but also in some other areas. The Energy Management Act itself does not provide methodology for energy performance assessments or energy labelling. These are provided by subsequent decrees. The decree 148/2007 that came into force on July 1, 2007 provides the methodology for the assessment of energy performance of buildings and sets the classification of the buildings according to their energy consumption (kWh per m^2 of floor area per year).

The decree specifies several categories of buildings according to their purpose and 7 classes of buildings according to their energy consumption (classes A to G). The class C building is set as a reference building. The energy consumption of a building has to fall into classes A to C to comply with the requirements of the decree. The buildings of the classes D to G are considered non-complying. The buildings of energy class D to G shall be upgraded to at least class C when undergoing major renovation.

***Table** 7 Required and recommended U-values for typical building structures*

Building structure	Type of structure	Required U-value [$W.m^{-2}.K^{-1}$]	Recommend. U-value [$W.m^{-2}.K^{-1}$]
Flat roofs, pitched roofs (tilt ≤ 45°) Floors adjacent to exterior		0.24	0.16
Ceilings adjacent to unheated non-insulated attics Exterior walls with wall heating		0.30	0.20
External walls Walls adjacent to unheated non-insulated attics Pitched roofs (tilt >45°)	light-weight	0.30	0.20
	mass	0.38	0.25
Walls and ceilings adjacent to unheated spaces		0.60	0.40
Walls between adjacent buildings Ceilings between spaces with a temperature difference lower than 10 K		1.05	0.70
Windows and external doors (including the frame) U-value < 2.0 $W.m^{-2}.K^{-1}$ (metal frames) U-value < 1.7 $W.m^{-2}.K^{-1}$ (frames made of other material)		1.7	1.20

***Table 8** Building energy classes (kWh/m^2 a)*

	A	B	C	D	E	F	G
Family houses	< 51	51 - 97	98 - 142	143-191	192-240	241-286	> 286
Apartment buildings	< 43	43 - 82	83-120	121-162	163-205	206-245	> 245
Hotels Restaurants	< 102	102-200	201-294	295-389	390-488	489-590	> 590
Administration buildings	< 62	62 - 123	124 - 179	180-236	237-293	294-345	> 345
Hospitals	<109	109-210	211 - 310	311-415	416-520	521-625	> 625
Educational facilities	< 47	47 - 89	90 - 130	131-174	175-220	221-265	> 265
Sport facilities	< 53	53 - 102	103 - 145	146-194	195-245	246-297	> 297
Commercial Retail	< 67	67 - 121	122-183	184-241	242-300	301-362	> 362

The Czech Republic has had the legislation dealing with energy audits of buildings and energy systems before implementing the EPBD. There is a well established network of energy auditors in the country and that makes the practical implementation of the EPBD easier. The assessment of energy performance of a building can be relatively expensive and it would probably not serve the purpose to impose such a burden on every building owner. The energy certification will be obligatory (from January 1, 2009) for the newly built buildings and the buildings with a floor area of more than 1000 m^2 undergoing a renovation that has an impact on their energy consumption. The energy certificate of a new building with the floor area larger than 1000 m^2 has to contain an analysis of technical, ecological and economical feasibility of utilisation of renewable energy sources, combined heat and power, centralised/district heating and cooling (if cooling is necessary).

2.4 Building air leakage

The building air leakage measurements are not required by the Czech building regulations but the Czech Republic has already adopted the standard CSN EN 13 829 *Thermal performance of building - Determination of air permeability of buildings - Fan pressurisation method*. The Czech standard CSN 73 0540 *Thermal protection of buildings – Part 2: Requirements* specifies recommended $n_{50,N}$ values with regard to building ventilation (see Table 9). The subscript N is often used in the Czech standards in order to distinguish between the values recommended or required by a standard and the actually measured values (the Czech word for standard is “norma”). In this case the actual airtightness of a building should be better or equal to that recommended by the standard ($n_{50} \leq n_{50,N}$).

Table 9 *Recommended $n_{50,N}$ values*

Building ventilation	**$n_{50,N}$ [hour^{-1}]**
Natural or combined	4.5
Mechanical	1.5
Mechanical with heat recovery	1.0
Mechanical with heat recovery (buildings with very low energy consumption for heating – passive houses)	0.6

Standard CSN 73 0540 also specifies requirements and recommendations for air permeability of the openings in buildings that are mechanically ventilated or air-conditioned. The air change rate due to air infiltration calculated under winter design conditions (with the mechanical system shut down) is recommended to be $n < 0.1$ hour^{-1}. The standard specifies the limits for air permeability factors of joints for the building openings and light-weight building envelopes. The air permeability factors of the building openings and light-weight envelopes i_{LV} have to be lower than the allowed air permeability factors $i_{LV,N}$. The limits of air permeability factors are in Table 10.

There has not been a broader study performed into the air leakage of buildings and not much information is available on the air leakage of the building stock. There are, however, some indications that buildings are becoming more airtight. The building ventilation systems (such as natural and fan assisted ventilation systems) mostly rely on the air leakage of the envelope for supply of fresh air. The windows and other openings account for most of the air leakage, because the external walls are usually made of concrete or masonry. Making windows more airtight by applying different kinds of window gaskets is a non-expensive way how to reduce air infiltration. Reduced air infiltration has a positive impact on energy consumption but it can negatively influence indoor air quality. Many energy retrofits of buildings involve either making the windows more airtight or replacing them with new ones. Modern plastic-frame or wood-frame windows have low U-values and are quite airtight. The new windows usually have the glazing U-value of 1.1 $W.m^{-1}.K^{-1}$ and the air permeability factor $i_{LV} = 0.1 \cdot 10^{-4}$ $m^3.s^{-1}.m^{-1}.Pa^{-0.67}$. Since air supply devices are almost never used (even in newly built apartment buildings) some part of the window gasket in the upper part of the window is often removed to provide a pathway for outdoor air. However, air leakage is usually insufficient to provide the necessary ventilation rates in a natural ventilation mode (e.g. passive stack ventilation) and additional ventilation by opening windows is necessary. The exhaust fans are mostly manually controlled and they are usually used during cooking or bathroom use. It is often necessary to open windows in order to achieve sufficient ventilation rates when the fans are switched on (especially during or after cooking and showering). Most new operable windows have a so-called microventilation position in which the window is not tightly closed. The air permeability of a window in the microventilation position is much higher than in the closed position. However, it is an occupant who has to make use of this feature of a window.

Table 10 *Limits of air permeability factors of joints*

Building opening		Air permeability factor of joints $i_{LV,N}$ [$m^3/(s \cdot m \cdot Pa^{0.67})$]	
		Natural or combined ventilation	Mechanical ventilation or air-conditioning
Entrance door into an air lock of a building at total height of the above-ground part of a building h ≤ 8 m		$1.60 \cdot 10^{-4}$	$0.87 \cdot 10^{-4}$
Other entrance doors Doors between separate parts of a building		$0.87 \cdot 10^{-4}$	$0.30 \cdot 10^{-4}$
Other external windows and doors at total height of the above-ground part of a building h	h ≤ 8 m 8 < h ≤ 20 m 20 < h ≤ 30 m h > 30 m	$0.87 \cdot 10^{-4}$ $0.60 \cdot 10^{-4}$ $0.30 \cdot 10^{-4}$ $0.10 \cdot 10^{-4}$	$0.10 \cdot 10^{-4}$
Light-weight envelopes including door and windows		$0.05 \cdot 10^{-4}$	$0.05 \cdot 10^{-4}$

3 Office buildings and other occupational environments

Office buildings in the Czech Republic usually have enclosed offices. Open plan offices are not yet common and can mostly be found in new office buildings of foreign companies. The type of a ventilation system installed in an office building depends very much on the year of construction or renovation of a building.

Old office buildings (those built before 1960) mostly use natural ventilation by opening windows, though mechanical exhausts are usually used in restrooms. The windows or glazed parts of the facades of old office buildings do not exceed 30 or 40 percent of the facade area. The increasing area of glazing brought about high solar gains and the need for mechanical cooling. Many office buildings built since the 1970s use balanced mechanical ventilation as part of air-conditioning systems. There are no skyscrapers (buildings taller than 150 m) in the Czech Republic. Leaving aside church steeples only two buildings in the Czech Republic exceed 100 m in height. Both of them are 27-story office buildings.

Ventilation requirements for occupational environments are specified in the decree 361/2007 *Occupational Health*. The decree sets the minimum flow rates of fresh air for workplaces divided by the activity of people. Table 11 summarises the ventilation requirements of the decree 361/2007 with regard to metabolic rates. The decree specifies 8 categories of physical activity of people - metabolic rates. The metabolic rate in case of light work in a sitting position (administrative work, typing, work in control rooms and labs) is MR ≤ 80 $W.m^{-2}$. Manual work in a sitting position (driving, assembling small components, work of cashiers) requires slightly higher physical activity: 81 $W.m^{-2}$ < MR ≤ 105 $W.m^{-2}$. Work with MR > 200 $W.m^{-2}$ usually takes place outside of buildings (construction work, logging, work in ironworks, mining). Some other examples of metabolic rates can be found in the standard ISO 7730:2005 *Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*

Table 11 *Ventilation requirements for occupational environments*

Metabolic rate	Ventilation rate (m^3/h per person)
MR ≤ 105 $W.m^{-2}$	50
105 $W.m^{-2}$ < MR ≤ 200 $W.m^{-2}$	70
MR > 200 $W.m^{-2}$	90

Minimum air flow rates increase lore if there are other sources of pollution in a room (heat, odours, smoking, etc.). The total flow rate of fresh air is determined from the maximum number of people using the space simultaneously. The flow rates have to be increased with regard to the estimated presence of people (0.2 - 0.3 person/m^2) in case of workplaces with the access of public (such as shops).

Minimum flow rates of fresh air can be reduced when the outdoor temperature is higher than 26°C or lower than 0°C, but not more than to 50 % of required values.

Mechanical ventilation has to be used when natural ventilation is not able to provide ventilation rates needed to protect health of the workers throughout the year. The amount of fresh air supplied to the workplace has to be sufficient to keep the exposure of the workers to the pollutants bellow the limits. At the same time, the requirement of the air flow rate of fresh air per person has to be met. Circulation air has to be cleaned in a way that the concentration of pollutants in the air supplied to the workplace does not exceed 5 % of the limits for exposure. If warm air heating or air-conditioning is used then the air supplied to the workplace shall contain at least 15 % of fresh air. At the same time the requirements for minimum flow rates of fresh air per person have to be fulfilled.

At workplaces with a special requirement on air cleanliness and a small number of workers the fraction of fresh air can be reduced as shown in Table 12.

Table 12 *Reduction of fresh air fraction*

V/n	1000	1500	2000	2500	3000	4000
p [%]	10	8	6.5	5.5	5	4

where

V [m^3/h] is the air flow rate supplied to the work place
n [1] number of persons in the room
p [%] is the fraction of fresh air

The decree 361/2007 *Occupational Health* specifies the limit concentrations of air pollutants and the methods of their measurements. The limits for over 400 pollutants (mostly chemicals) are specified in the decree.

4 Residential buildings

While the ventilation requirements for occupational environments are quite specific in Czech legislation the requirements for residential buildings are mostly at the level of recommendations. The standard CSN 73 4301 *Residential buildings* introduces terms “direct” and “indirect” ventilation. Direct ventilation means that fresh air enters directly a ventilated room. Direct ventilation can be provided by operable windows, vents, air supply ductworks, etc. Indirect ventilation means that fresh air enters the room via adjacent room. All habitable rooms (living rooms, bedrooms, studies, kitchen-diners, etc.) have to be directly ventilated.

One exhaust duct cannot be used to extract air from rooms with different purposes (kitchen, food pantry, bathroom, toilet, etc.) and from more than one apartment per storey. In the case of mechanical ventilation or in some exceptional cases, one duct can be used for exhaust air from bathroom and toilet.

The standard CSN 73 0540 *Thermal protection of buildings – Part 2: Requirements* gives some recommendation about the ventilation rates in habitable rooms. The minimum flow rate of fresh air is set to 15 $m^3.h^{-1}$ per person when the metabolic rate (physical activity of people) is $MR \leq 80\ W.m^{-2}$ and up to 25 $m^3.h^{-1}$ per person for metabolic rates $MR \geq 80\ W.m^{-2}$. The air change rate in a room is usually between n = 0.3 $hour^{-1}$ and n = 0.6 $hour^{-1}$. The air change rate of n = 0.5 $hour^{-1}$ is mostly considered for the calculation of ventilation heat losses of residential buildings.

4.1 Apartment buildings

The apartment buildings built before 1960 mostly have natural ventilation systems. Outdoor air enters the building through the air leakage pathways or through opened windows. Exhaust air is extracted by passive stacks. Some buildings from the 1950s have asbestos-cement air supply tubes on each floor running from the external facades to the food pantries and toilets. Separate exhaust stacks are used for the pantry, kitchen, bathroom and toilet. This solution is rather complicated and gets more complicated with increasing number of stories.

A building concept involving a vertical installation shaft was introduced in 1950s. The apartment buildings from this period have a separate stack for each kitchen, but a common stack for toilets and bathrooms. Food pantries located in kitchens are ventilated by vents in the facade (air supply vent at the floor and the exhaust vent at the ceiling). This purely natural ventilation system did not perform very well. The main problem was ventilation of kitchens where simple passive stacks could not provide sufficient air change rates during cooking. Additional ventilation by opening windows was necessary in such situations.

The big step forward was made in the 1960s when a mechanical exhaust ventilation system with a central fan on the roof was introduced. These systems use a shunt ductwork that consists of a main duct (collector) and two shunt ducts. The shunt duct extracting air from a kitchen is connected to the main duct just under the ceiling. The shunt duct extracting air from the bathroom and toilet is connected to the main duct at the level of an upper storey. Fresh air is supplied to a kitchen through air leakage pathways or by open windows. The gaps beneath the door allow the air to flow into a bathroom and toilet. The ventilation system can operate in the regime of natural or mechanical ventilation. The occupants switch on the fan manually using a switch located in a kitchen. The main disadvantage of the system is a rather complicated and unreliable adjustment of air flows. The air volumes extracted from different floors of a building can vary very much. Another problem is the noise and pollution transfer between apartments.

An improved mechanical exhaust ventilation system with a central fan was installed in apartment buildings in 1980s. The system has two vertical exhaust ducts; one for kitchens and one for the bathrooms and toilets. The air flow rate regulators are installed at the exhausts in kitchens, bathrooms and toilets. The regulators are supposed to maintain following flow rates of extracted air: 100 $m^3.h^{-1}$ in a kitchen, 75 $m^3.h^{-1}$ in a bathroom and 25 $m^3.h^{-1}$ in a toilet. Air flow measurements and adjustments were rarely (if ever) done when the buildings were commissioned and the ventilation systems mostly perform badly. One of the main disadvantages of the mechanical exhaust system with a central fan is that if the fan is switched on it ventilates all the apartments connected to the exhaust ducts, so individual control of ventilation is not possible.

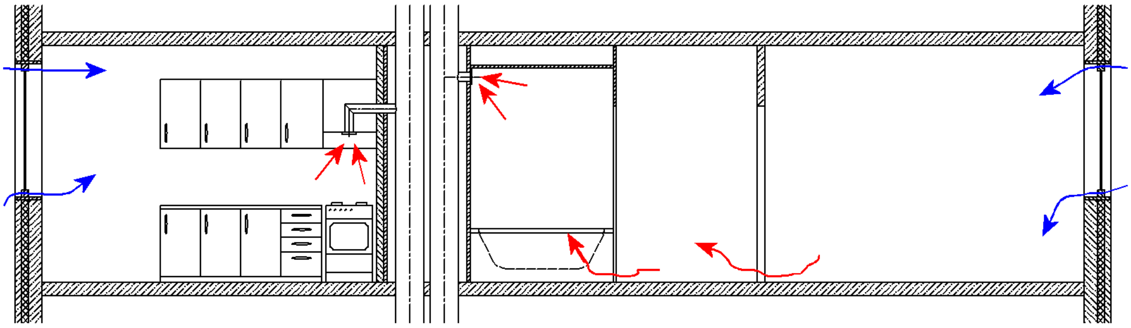

***Figure 5** Air supply and exhaust in an apartment with mechanical exhaust ventilation*

A mechanical exhaust system with small axial exhaust fans was also installed in the apartment buildings in the 1980s. The system has two vertical exhaust ducts, one for kitchens and one for bathrooms and toilets. The exhaust fans are installed in the kitchens, bathrooms and toilets and they can be switched on and off separately. That allows more flexible control of ventilation rates than in the case of a central fan.

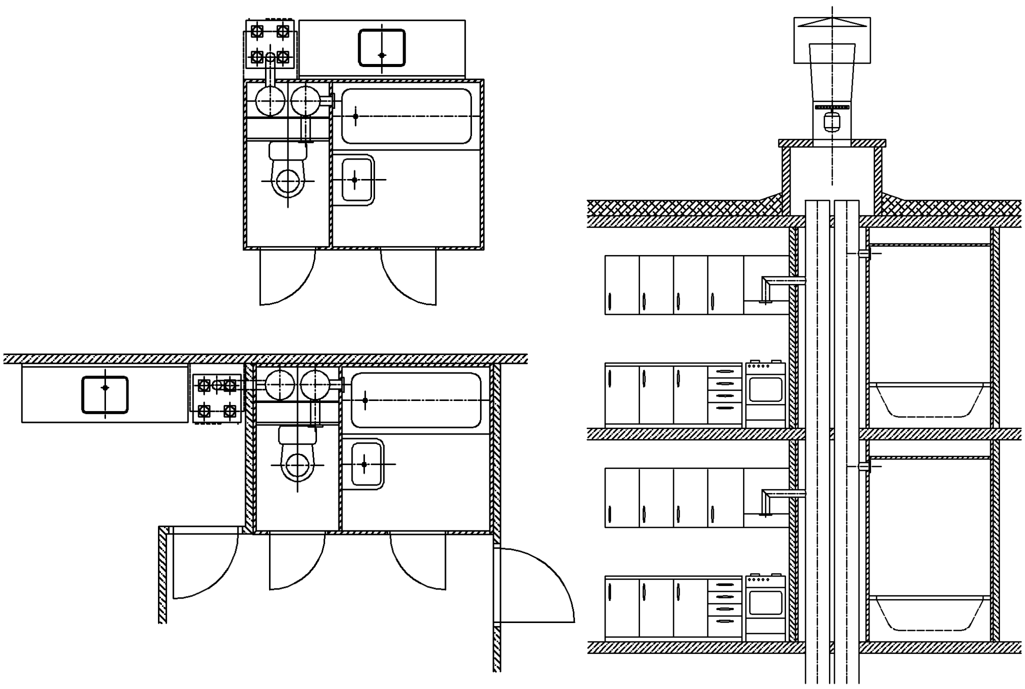

***Figure 6** Mechanical exhaust ventilation with a central fan*

The mass production of prefabricated concrete buildings ended in early 1990s and that was also the end of the "standardised" ventilation systems in apartment buildings.

A variety of ventilation systems have been used in apartment buildings nowadays. Most of the apartment buildings built after 1990 have exhaust fans in bathrooms and toilets and ventilation cooker hoods in kitchens. The apartment buildings do not usually have purpose provided air supply openings and air leakage pathways and window openings are still the only ways for outside air to enter a building. Some buildings with mechanical ventilation systems with heat recovery have been built in the 2000s, but these are not numerous. Nearly all apartment buildings are nowadays built by developers and then sold to clients (owners). The developers try to minimise costs by not going beyond the requirements of building regulations. If building regulations do not require installation of a whole-building or a whole-apartment ventilation system not many people would be willing to spend extra money to install such systems.

4.2 Detached dwellings

The situation in the ventilation of detached dwellings is very similar to the situation in apartment buildings. Most family houses are ventilated by opening windows. Mechanical exhaust is required in bathrooms that do not have operable windows (cannot be “directly” ventilated). Mechanical ventilation with heat recovery (MVHR) is only used in low-energy and passive houses that are still not numerous in the Czech Republic. The awareness of people about the importance of ventilation and its impact on energy performance of building is increasing in the Czech Republic, but so far not many people build for themselves low-energy homes fitted with MVHR.

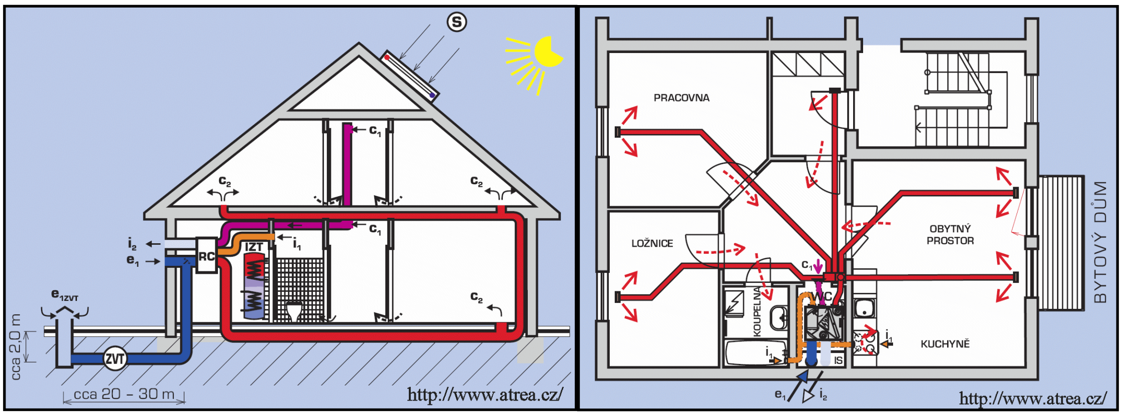

Figure 7 *Mechanical ventilation with heat recovery used for warm air heating (Pracovna = Study, Kuchyne = Kitchen, Loznice = Bedroom, Obytny prostor = Living Area, Koupelna = Bathroom)*

The combination of MVHR and warm air heating (and possibly cooling) is a way to integrate mechanical ventilation into a building with relatively low costs. The central heating with water circulation that is commonly used in detached dwellings is not necessary when a combination of MVHR and warm air heating is used. An example of MVHR used for warm air heating (in combination with a ground heat exchanger and solar collectors) can be seen in Fig. 7.

4.3 Gas appliances

Many gas household appliances use oxygen from indoor air for combustion and release combustion products into the indoor space. Carbon monoxide poisoning can be a threat if not enough combustion air is supplied to the appliance. The technical rules for gas appliances TPG 800 00 introduces three categories of gas appliances with regard to where the combustion air comes from and where the combustion products are released.

Category A

The category A gas appliances are the appliances that use air from a room for combustion and also release the combustion products into the room (e.g. gas cookers, gas ovens, some gas water heaters, etc.). These appliances can only be installed in “directly” ventilated rooms (rooms with operable windows, vents or other types of air supply). The minimum required volume of the room is 20 m^3 in case of a multi-room dwelling and 50 m^3 in case of a single-room dwelling. The required room volumes can be reduced by 25% if mechanical exhaust is installed in a room with the gas appliance. The minimum air change rate of $n = 1\ hr^{-1}$ is required for the rooms with the category A gas appliances. The air change rate has to be achieved with the closed windows and doors.

Category B
The category B gas appliances are the appliances that take combustion air from the room but release combustion products to the outdoors (e.g. some gas boilers and gas heaters). These appliances can be installed in "directly" or "indirectly" ventilated rooms. The requirements for the appliances with the rated thermal output lower than 50 kW are as follows: the required volume of the room is 1 m^3 per 1 kW of the rated thermal output and the required flow rate of make-up air is 1.6 m^3/hour per 1 kW of the rated output. One of the following measures shall be applied if the requirements cannot be fulfilled:
- the room with the gas appliance has to be connected to the adjacent "directly" ventilated room by non-closable opening(s) in a door or wall
- the gas appliance has to be enclosed in a space (box) connected by an opening to the outdoors (the size of the opening has to be 0.001 m^2 per 1 kW of the rated thermal output but minimum 0.02 m^2)
- the room with the appliance has to be connected to the outdoors by a non-closable opening located close to the floor level

Category C
The category C gas appliances are enclosed devices that draw combustion air from the outdoors and release the combustion products to the outdoors (e.g. some gas boilers, gas heaters). There are no special ventilation requirements for the rooms with the category C gas appliances.

5 Schools

Almost all classrooms in the Czech schools are naturally ventilated by opening windows. The school buildings are usually quite old because the Czech population is stagnating and there is no demand for new school buildings. The requirements on microclimate in schools are set in the regulation 410/2005 *Hygienic requirements on the educational facilities for children and adolescents.* The air flow rates for various rooms in a school are in Table 13.

Table 13 Required air flow rates in schools

	Air flow rate [$m^3.hour^{-1}$]
Classrooms	20-30 per student
Gyms	20 per student
Locker rooms	20 per locker
Washrooms	30 per washbowl
Showers	150-200 per shower
Toilets	50 per toilet bowl 25 per urinal

6 Swimming halls

The requirements on microclimate in swimming halls are set in the decree of the Czech Ministry of Health 464/2002 *Hygienic requirements on swimming pools, saunas and outdoor playgrounds*. Air change rate of at least $n = 2\ hour^{-1}$ is required for the swimming halls, $n \geq 8\ hour^{-1}$ for showers, and $n \geq 5\ hour^{-1}$ for the locker rooms. The air change rate for other rooms shall be sufficient to maintain relative humidity under the limit values. The limit value of relative humidity in the swimming hall is RH ≤ 65 %, in the showers RH ≤ 85 % and in other spaces RH ≤ 50 %.

7 Cleanrooms

Ventilation plays an essential role in maintaining air cleanliness in cleanrooms. The Czech Republic used to have its own standards for cleanrooms. These standards CSN 12 5310 and CSN 12 5311 were issued in the year 1984, but were replaced by the international standard CSN EN ISO 14644 in the year 2000.

7.1 Fire protection of buildings – smoke and heat control systems

Smoke and heat control systems represent a specific area of building ventilation. The main purpose of these systems is to provide safe escape routes for the building occupants and also the access for fire-fighters. Smoke is much more dangerous than the fire itself and smoke control is the primary objective of ventilation in case of fire. The Czech standard CSN 73 0802 *Fire protection of buildings – Non industrial buildings* sets some requirements on ventilation for smoke and heat control in protected escape routes. The Czech Republic has also adopted the European standard EN 12101 *Smoke and heat control systems* (CSN EN 12101).

Even though ventilation requirements for residential buildings are generally quite loose the fire protection regulations are binding and their fulfilment is thoroughly checked in the building commissioning process. The Czech standard CSN 73 0802 distinguishes between three categories of protected escape routes. The protected escape route shall always be a separate fire compartment.

7.2 Protected escape routes of category A

The protected escape routes of the category A are the simplest and the most common protected escape routes in buildings. These escape routes have to be separated from other fire compartments by fire door and other fire resistant closures of openings. The category A escape routes can be ventilated naturally or mechanically.

Natural ventilation:

a) operable openings (windows, doors or other) with the area of 2 m^2 shall be at every floor (1 m^2 if the openings allow cross ventilation); in case of the escape routes with the floor-plan area higher than 20 m^2 at a story, the openings shall have the area of 10 % of the floor-plan area for single-sided ventilation and 5 % for cross ventilation,
b) opening of at least 2 m^2 at the highest point of the escape route (stairwell) and the same size opening for supply of fresh air at the entrance floor or lower,
c) vents at every storey with the air supply vent at the floor and the exhaust vent at the ceiling

Mechanical ventilation:
Supply of fresh air with the air change rate of at least n = 10 hod^{-1} has to be provided for at least 10 minutes regardless of the location of the fire.

7.3 Protected escape routes of category B

There are two kinds of protected escape routes of category B:

Escape route with a ventilated fire-fighting lobby
This escape route is similar to the escape route of category A but has a ventilated fire-fighting lobby on every storey. The fire-fighting lobbies shall be fitted with smoke-tight doors. Ventilation of the fire-fighting lobby can be provided by an operable window with the area of 1.4 m^2 or vents with the dimensions of at least 500 mm by 300 mm (air supply vent at the floor, air exhaust vent at the ceiling). The other parts of the escape route shall be ventilated in the same manner as in case of the category A escape routes. It is, however, recommended to use larger ventilation openings and higher air flow rates. If mechanical ventilation is used then the supply of fresh air shall be provided for at least 30 minutes.

Escape route with pressurization
The pressure differential between the escape route and adjacent fire compartments shall be at least 25 Pa. If there is an automatic fire extinguishing system installed in the adjacent fire compartments then the pressure differential can be 12.5 Pa. The air flow rate of fresh air shall provide the air change rate of at least $n = 15\ hod^{-1}$. The pressure differential shall not exceed 100 Pa. The supply of fresh air shall be provided for at least 30 minutes (45 minutes if the escape route is to be used by fire fighters).

7.4 Protected escape routes of category C

Mechanical ventilation (pressurisation) is required for the escape routes of the category C together with fire-fighting lobbies with smoke-tight doors.

The pressure differential between the protected escape route and the fire-fighting lobby shall be at least 25 Pa and the pressure differential between the fire-fighting lobby and adjacent fire compartments shall also be at least 25 Pa. The pressure differentials can be reduced to 12.5 Pa if an automatic fire extinguishing system is installed in the fire compartments. The pressure differentials shall not exceed 100 Pa.

The flow rate of fresh air shall be either

a) 15 times the volume of the protected escape route ($n = 15\ h^{-1}$)

or

b) shall be determined from the minimum pressure differentials when 5% of the total door area is open (but at least two doors open), other openings (like vents) shall also be included in the calculations.

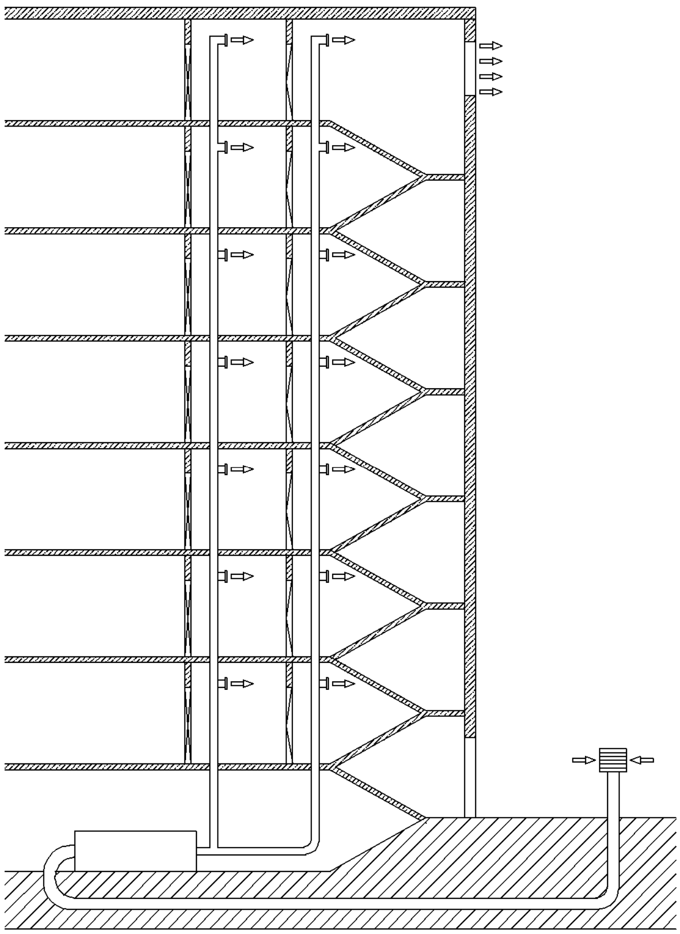

Figure 8 *Ventilation of a protected escape route of category C*

The fire ventilation system shall be able to supply fresh air to the escape route for at least 45 minutes (60 minutes if the route is to be used by fire-fighters).
The air supply ductwork is not required when the air is supplied (the fan is positioned) at the lowest level of the escape route (stairwell) and the stairwell is lower than 45 m. The ductwork is required when the fan is at the upper level of the escape route or a route is taller than 45 m.

8 Summary and a look ahead

The current Czech legislation is not really a driver for change in building ventilation since it still considers natural ventilation by opening windows satisfactory in many (most) situations. Mechanical exhausts installed in residential buildings are not intended as the whole-house or whole-apartment ventilation systems. The fans are manually controlled and they are usually used only during cooking or bathroom use. The exhaust systems with central fan installed in most apartment buildings do not allow “customisation” of ventilation - when a fan is switched on it extracts air from all apartments connected to the ducts. The mechanical exhausts with separate fans that are used in houses and newer apartment buildings are rather noisy because the fans have relatively small diameters (usually between 100 mm and 150 mm) and they run at high speeds. The mechanical exhaust systems with the central fan can relatively easy be modified to a multi-fan arrangement. The main problem of mechanical exhaust ventilation in buildings is the lack of purpose provided and controllable air supply openings. Exhaust ventilation simply relies on air leakage of the building envelope. Almost all new operable windows are equipped with circumferential hardware that allows so called micro-ventilation. The window it is not tightly closed in the micro-ventilation position and outdoor air can infiltrate into a building.

Mechanical ventilation with heat recovery still remains rare in the residential sector and no big change can be expected in the near future. No statistics are available on the ventilation systems in buildings but it can be estimated that less than 5 percent of newly built detached dwellings are equipped with mechanical ventilation with heat recovery. Mechanical ventilation with heat recovery in apartment buildings is quite exceptional. The main barriers in market penetration of balanced mechanical ventilation in the residential sector are high costs of the systems and a low additional value perceived by an average customer. The cost of a typical installation of a balanced ventilation system in a new detached dwelling is comparable with the cost of a small car. The mechanical ventilation systems with heat recovery become more competitive when they are also used for space heating (warm air heating).

Balanced mechanical ventilation is typical for commercial buildings (shopping malls, banks, restaurants, etc.) However, balanced mechanical ventilation is often used in some parts of naturally ventilated buildings in order to meet ventilation requirements (e.g. kitchens, cafeterias, lecture halls or auditoriums in school buildings, operation theatres and labs in hospitals, etc.). The future improvements of balanced mechanical ventilation will probably involve higher efficiency of heat recovery and better control of ventilation rates. Integration of control and monitoring of different building systems and services becomes an issue in larger building and building complexes (e.g. university campuses). Building Management Systems are not yet commonly used in buildings but their application seems unavoidable in future as the building technologies become more and more sophisticated.

9 References

[1] Decree 361/2007 Occupational Health

[2] Decree 108/2001 Hygienic requirements on schools, pre-school facilities and some school facilities

[3] Decree 464/2002 Hygienic requirements on swimming pools, saunas and outdoor playgrounds

[4] ISO 7730:2005 Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria

[5] CSN 73 0540 - Thermal protection of buildings

[6] CSN 73 4301 - Residential buildings

[7] CSN EN 12101 Smoke and heat control systems

[8] CSN EN 13053 Ventilation for buildings. Air handling units. Ratings and performance for units, components and sections

[9] CSN EN 13141 Ventilation for buildings- Performance testing of components/products for residential ventilation

[10] CSN EN 779 Particulate air filters for general ventilation

[11] CSN 730802 Fire protection of building – non-industrial buildings

[12] CSN EN 13829 Thermal performance of building - Determination of air permeability of buildings - Fan pressurization method

[13] Czech Republic: www.czech.cz

[14] Czech Standards Institute: www.cni.cz

[15] Czech Statistical Office: www.czso.cz

[16] Czech Hydrometeorological Institute: www.chmi.cz/

[17] Czech Ministry of Industry and Trade: www.mpo.cz/

The Air Infiltration and Ventilation Centre was inaugurated through the International Energy Agency and is funded by the following countries:

Belgium, Czech Republic, Denmark, France, Greece, Japan, Republic of Korea, Netherlands, Norway and United States of America.

The Centre provides technical support in air infiltration and ventilation research and application. The aim is to provide an understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.

Air Infiltration and Ventilation Centre
Operating Agent and Management
INIVE EEIG
Lozenberg 7
B-1932 Sint-Stevens-Woluwe
Belgium

www.aivc.org

Tel: +32 2 655 77 11
Fax: +32 2 653 07 29
inive@bbri.be
www.inive.org