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Trends in the Czech building ventilation market and drivers for change

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1 Introduction

The Czech Republic is a landlocked country 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 the 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 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 Czech Republic is a signatory of the Kyoto protocol with the obligation to reduce its greenhouse gas emissions by 8 percent from 1990 levels. The greenhouse gas emissions were down 26 percent in 2007.

The building ventilation market in the Czech Republic concentrates around commercial buildings (shopping malls, banks, movie theatres, restaurants, airports, etc.), where balanced mechanical ventilation with heat recovery is mostly used (usually as part of the central air-conditioning systems). The balanced mechanical ventilation systems are also used in newly built private office buildings, which very often have glass facades. The school buildings are usually naturally ventilated. Balanced mechanical ventilation is commonly used in lecture halls at universities but rarely used in offices and classrooms.

The regulations for residential ventilation are rather loose with natural ventilation by opening windows considered satisfactory in most situations.

Thanks to its mid-continental location the Czech Republic has a moderate climate with four distinct seasons. Space heating accounts for most of the energy use in the building sector. Space cooling has been rather rare and it is mostly used in commercial buildings. 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. 1.

Industry accounts for the largest portion of final energy use. The share of transportation is lower than in other developed countries. Households account roughly for one quarter of the final energy use. The pie chart in Fig. 2 shows the breakdown of energy use in households.

The coal-fired and wood-fired boilers are still quite common in family houses in the country what makes the share of solid fuel consumption in households relatively high.

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 Czech housing stock can be seen in Table 1.

The discrepancy between the total number of dwellings and the number of permanently inhabited dwellings does not mean that there were half a million uninhabited dwelling in the Czech Republic in 2001. A dwelling is considered permanently inhabited if someone refers to it as the place of permanent residence. If neither the owners nor the tenants use the dwelling as their place of permanent residence (e.g. students renting an apartment while studying in a city) the dwellings shows in the statistics as not permanently inhabited.

2 Standards and regulations

Technical standards in the Czech Republic are generally not mandatory. The standards are mostly used as guidelines and they 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 standardization. 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 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.

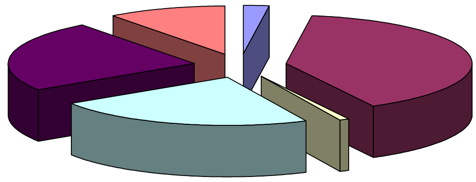

Figure 1: Final energy consumption in 2006 (source: Czech Statistical Office)

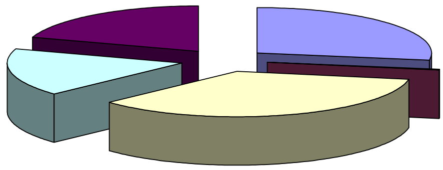

Figure 2: Final energy consumption of households in 2006 (source: Czech Statistical Office)

Table 1: Housing stock in the Czech Republic (source: Czech Statistical Office)

Family houses	1 406 806
Apartment buildings	195 270
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 %

2.2 Energy performance of buildings

The design outdoor temperature for space heating systems varies from -12°C to -18°C in the Czech Republic (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]) of the building structures. The standard CSN 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} during 8 hours or more a day.

The Czech Republic, as a member state of the EU, 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, sets the framework for energy use not only in the building sector, but also in some other areas. The Energy Management Act 406/2006 itself does not provide methodology for energy performance assessments or energy labelling. These are provided by subsequent decrees. The decree 148/2007 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 eight categories of buildings according to their purpose (residential, administrative, hospital, etc.) and 7 classes of buildings according to the energy consumption (classes A to G). 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.

2.3 Indoor air quality

The IAQ is dealt with in several decrees and regulations. Regulation 6/2003 sets the limits for concentrations of pollutants (Table 2) in educational facilities, health care facilities, social care facilities, retail facilities, accommodation facilities, and other facilities where large numbers of people gather.

Table 2: Concentration limits

Hourly concentrations (µg/m^3)	
Nitrogen dioxide NO_2	100
dust PM10	150
dust PM2.5	80
carbon monoxide CO	5 000
ozone O_3	100
ammonia NH_3	200
Benzene C_6H_6	7
toluene C_7H_8	300
xylene C_8H_{10}	200
styrene C_8H_8	40
ethylbenzene C_8H_8	200
formaldehyde H_2CO	60
trichlorethylene C_2HCl_3	150
tetrachloroethylene C_2Cl_4	150

Regulation 6/2003 also deals with the biological contaminants. It refers to the standards CSN 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 the sampling techniques.

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

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 standard CSN EN 13829 *Thermal performance of building - Determination of air permeability of buildings - Fan pressurization 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 (Table 3). 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 3: 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

The standard CSN 73 0540 also specifies requirements and recommendations for air permeability of the openings in mechanically ventilated or air-conditioned buildings. 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 CSN 73 0540 specifies the limits for air permeability factors of joints for the building openings and light-weight building envelopes.

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 air tight.

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 air leakage because the external walls are usually made of concrete or masonry what makes them rather airtight. Making windows more airtight by application of different kinds of window gaskets is a non-expensive way to reduce air leakage. Reduced air leakage has a positive impact on energy consumption but it can negatively influence indoor air quality. Many energy retrofits of buildings involve either the sealing of existing windows or replacing them with new ones.

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.

3 Building ventilation

3.1 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 exhaust ventilation is usually used in restrooms. 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 according to the activity of people. Table 4 summarizes the ventilation requirements of the decree 361/2007 with regard to the 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}. The 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}.
The work with the 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 4: Ventilation requirements for occupational environments

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

The minimum air flow rates shall be further increased 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).The 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 the required values.

Mechanical ventilation has to be used when natural ventilation is probably not able to provide ventilation rates needed to protect the 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 bellow the specified limits. At the same time, the requirement of the air flow rate of fresh air per person has to be met. Circulated 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 follows:

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.

3.2 Residential buildings

While the ventilation requirements for occupational environments are quite specific in the 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 is supplied directly into a ventilated room. Indirect ventilation means that fresh air enters the room via adjacent room. Direct ventilation can be provided by operable windows, vents, air supply ductworks, etc. 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 exhaust duct can be used for both the 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 $0.3\ hour^{-1} < n < 0.6\ hour^{-1}$. The air change rate of $n = 0.5\ hour^{-1}$ is mostly considered for calculation of ventilation heat losses of residential buildings.

As can be seen in Table 1 the majority of the Czech population lives in apartment buildings, even though the newly built detached dwellings outnumbered the newly built dwellings in apartment buildings in the last decade. Prefabricated reinforced-concrete apartment buildings that were built on a mass scale from the early 1960s to the early 1990s still represent the majority of apartment building stock. It is estimated that there are almost 1.2 million dwellings in the prefabricated reinforced concrete buildings. Though the expected life-span of the prefabricated reinforced concrete buildings was 30 years, many buildings older than 40 years are still inhabited. These buildings are typically equipped with mechanical exhaust ventilation with a central fan (Fig. 3). The mechanical exhaust ventilation system uses two exhaust ducts; one for the kitchens and one for the bathrooms and toilets. The occupants switch the fan on manually using switches in kitchens, bathrooms and toilets. The main disadvantage of the central fan system is that when the fan is switched on it ventilates all apartments connected to the exhaust ducts. Another big problem is balancing of air flow rates extracted from apartments at different stories

The apartments in prefabricated buildings usually have a food pantry located in a kitchen that is naturally ventilated by two vents in the external wall (one at the floor and the other at the ceiling).

Newly built apartment buildings mostly have mechanical exhaust ventilation similar to that in Fig. 3, but with individual fans in every apartment (ventilation range hoods in kitchens and exhaust fans in bathrooms and toilets). Such an arrangement allows better control of ventilation rates.

The situation in the ventilation of detached dwellings is rather similar to the situation in apartment buildings. Most of the family houses are ventilated by opening windows. Mechanical exhaust is required in bathrooms that do not have operable windows (cannot be naturally "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 buildings is increasing in the Czech Republic. On the other hand, not many people build for themselves low-energy homes fitted with mechanical ventilation systems with heat recovery.

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

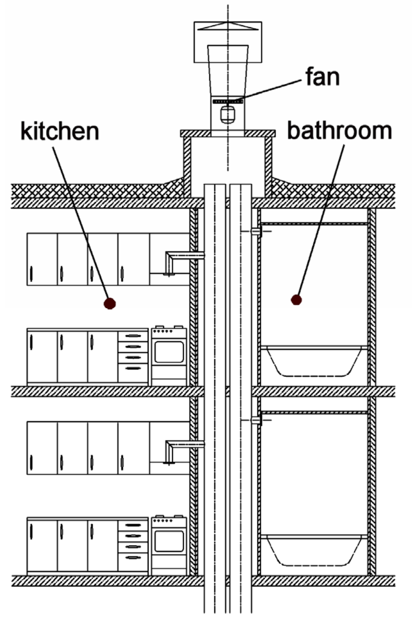

Figure 3: Ventilation system in a prefabricated reinforced-concrete building

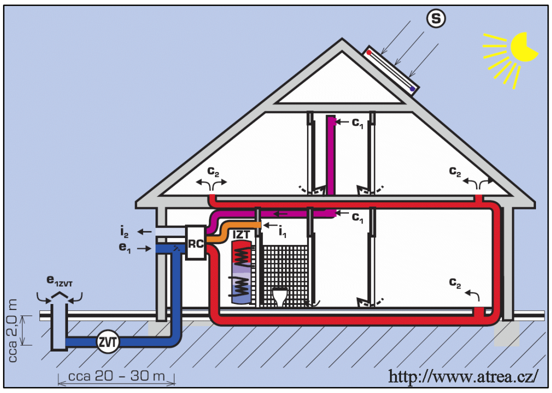

Figure 4: Mechanical ventilation with heat recovery used for warm air heating

systems with water circulation that are commonly used in detached dwelling are not necessary when MVHR is used for warm air heating. An example of MVHR used for warm air heating (in combination with a ground heat exchanger and solar collectors) can be seen in Fig. 4.

3.3 Schools

Almost all classrooms in Czech schools are naturally ventilated by opening windows. The school buildings are usually quite old because the Czech population is stagnating and the demand for new school buildings is very low. The requirements on microclimate in schools are set in the regulation 410/2005 *Hygienic requirements on the educational facilities for children and adolescents.* The required air flow rates for various rooms in schools are in Table 5.

Table 5: 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

3.4 Swimming pools

The requirements on microclimate in swimming pools 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 must be sufficient to maintain relative humidity under the limit values. The limit value of relative humidity in the swimming pool is RH ≤ 65 %, in the showers RH ≤ 85 % and in other spaces RH ≤ 50 %.

4 Summary and a look ahead

The current Czech legislation is not really a driver for change in residential ventilation since it still considers natural ventilation by opening windows satisfactory in many situations. Actually, the only legislative driver in ventilation of residential buildings is a set of binding requirements of fire regulations on ventilation of escape routes.

Mechanical exhausts installed in residential buildings are not intended as 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 fans 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 exhaust 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. Mechanical exhaust systems with a central fan can relatively easily be modified to a multi-fan arrangement. The main problem of mechanical exhaust ventilation in buildings is the lack of purpose provided controllable air supply openings. Exhaust ventilation relies on air leakage of the building envelope which varies from building to building. Almost all new operable windows are equipped with circumferential hardware that allows so called micro-ventilation. The window is not tightly closed in a 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. Use of mechanical ventilation with heat recovery in apartment buildings is quite exceptional.
The main barriers to 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. However, the balanced mechanical ventilation systems with heat recovery become more competitive when they are also used for space heating (warm air heating).

It is almost certain that commercial buildings (shopping malls, banks, restaurants, etc.) will remain the biggest market for the balanced mechanical ventilation systems with heat recovery in near future. Balanced mechanical ventilation with heat recovery will more often be used in some parts of naturally ventilated buildings in order to meet ventilation requirements in an energy efficient way (e.g. ventilation of kitchens, cafeterias, lecture halls, auditoriums, 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 (such as university campuses).

Building Management Systems (BMS) are not yet commonly used in buildings but their application seems unavoidable in future as the building technologies become more and more sophisticated.

5 References

[1] Decree 361/2007 Occupational Health

[2] Decree 410/2005 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 12831:2003 Heating systems in buildings - Method for calculation of the design heat load

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

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

[11] Czech Republic: www.czech.cz

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

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

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

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

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