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# Buildings, health and energy

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# Buildings, health and energy

*A building must be capable of protecting us from cold, rain, wind, noise and air pollution. We should be able to stay in it and carry out various activities in it without suffering from ill-health or discomfort. The indoor climate should contribute to congeniality and wellbeing.*

*In point of fact, however, many people experience some form of ill-health - allergies, irritation of mucous membranes etc. - when spending time indoors. Some problems of this kind have been found to be attributable to the indoor climate of the buildings. In many cases the troubles are difficult to explain. It is problems of this kind that lie behind the concept of "sick buildings".*

*Shortcomings in the indoor climate thus constitute a problem in both dwellings and working premises. It is particularly disquieting to note that the problems are experienced mainly in environments in which we spend the major share of our lives: in dwellings, schools, day nurseries and care premises. In all probability, persons suffering from allergies or other types of hypersensitivity are affected to a greater extent than others by shortcomings in the indoor climate. The frequency of hypersensitivity is alarmingly high and seems to be rising, by no means least among children.*

This speech comprises a summary of two publications from the Swedish Council for Building Research (BFR); the knowledge survey "Buildings and Health" (BFR T4:90) and "Indoor climate and energy husbandry" (BFR G5:90).

One central conclusion presented in both these publications is that the hygienic and climatic requirements are frequently neglected and that they must reassume a central position in the building and building management process.

This means that the requirements must be stepped up so that greater demands are made on the quality of the materials, on responsibility and competence in the building process and on the overall strategy for energy conservation in conjunction with both new construction and modernization.

Unless such requirements can be satisfied in practical building, the price will have to be paid in the form of more energy.

# Climate and air quality

## Noise

Noise disturbances depend not only on the level and pitch of the sound but also on the activity which is disturbed and the attitudes of the individual to the sound and its source.

In order for sleep disturbances to be completely avoided the continuous sound level should not exceed 30-35 dBA. The maximum level for individual noise occurrences should not exceed 45 dBA. Most fan and ventilation noise has a frequency which is considered to be underestimated by the dBA unit.

The National Board of Health and Welfare proposes a 35 dBA daytime and 30 dBA night-time limit for sanitary inconvenience due to momentaneous sounds in rooms in dwellings. For noise with elements of very low-frequency sound, equivalent sound levels of 28 dBA daytime and 23 dBA night-time are proposed.

## Light and lighting

The amount of light must suffice for the activity engaged in and, moreover, the light must be correctly distributed in the room in the right direction. It is vital to avoid dazzling and unsuitable shadowing. Colours must be reproduced as naturally as possible.

Poor work lighting is hard on the eyes and often leads to unsuitable working postures and accident hazards. Most people do not need work lighting in excess of 300 lux. For precision work, several thousand lux may occasionally be desirable. Daylight and provisions for looking out should be provided in all rooms where people spend any appreciable length of time.

## Temperature

Chills and draughts can cause rheumatic troubles. Impaired muscular function, which is more common, can result in clumsiness, thus increasing the risk of accidents. Too high a temperature gives a feeling of dryness and a lower level of wakefulness. It is also believed to cause fatigue and headaches. Owing to individual differences it is impossible to specify a thermal surrounding that satisfies everybody at the same time, even if all the people are similarly dressed. As a rule, it is not possible to get further than to conditions in which 80 per cent of the individuals feel satisfied. Elderly persons and others who spend a great deal of their time sitting still or who suffer from circulation troubles need a higher temperature than younger and healthier individuals.

Draughts are experienced as more troublesome the higher the air velocity is and the colder the air is, but variations in air velocity also give rise to a greater feeling of draught. A certain amount of air motion is obviously necessary in order to produce the requisite air circulation in a room.

The National Board of Health and Welfare recommends the following values:

* The operating temperature in premises should be between 20 °C and 24 °C.

* The difference in air temperature at the head and feet of a seated individual (1.1-0.1 metres above the floor) should not exceed 3 °C.

* The radiation temperature asymmetry due to the influence of, for instance, a cold window or a cold wall, should not exceed 10 °C.

* The radiation temperature asymmetry due to the influence of ceiling heat should not exceed 5 °C at a height of 1.1 metres above the floor for standing persons and 0.6 metres for seated persons.

* The average air velocity at an operating temperature of 20-24 °C should not exceed 0.15 m/s. In this context, it should be noted that rapid variations in air velocity can lead to draughts, even if the average velocity is low.

# Air humidity

The ability of the human being to objectively assess relative humidity is relatively poorly developed. Air humidity is therefore primarily of indirect importance for the manner in which the climate is experienced. At low relative humidity, human beings and materials become statically charged and the generation of dust increases. High air humidity, in contrast, increases the risk of condensation on parts of the building and is conducive to the growth of mites and algae. The emission of gas from materials, fixtures and fittings is also facilitated at high humidity.

The water content in the room air in dwellings should be kept below 7 grammes of water per kg of dry air (corresponding to a relative humidity of 40 per cent at 20 °C) for at least 1-3 months of the year in order to prevent growth of dust mites. General humidification of the air is not to be recommended from the standpoint of hygiene, since the risks of side effects are considerable. Discomfort attributable to "dry air" can usually be remedied by lowering the air temperature one or a few degrees.

# Air quality

The air change in a room is not utilized only to ensure that the content of oxygen is sufficient and that the content of carbon dioxide is not too high. It is also utilized for cooling, to regulate the air humidity and to lead away different types of pollutants generated in the room. The most important sources of pollution are the following:

* Building and fitting materials, furniture.

* Radon from building materials and foundations.

* People and animals.

* Tobacco smoke.

* Microbiological growth (mould, mites, algae etc.).

* Cooking.

* Cleansers and pesticides.

* Cosmetics.

* Playing and hobby activities.

* Open combustion (e.g. gas stoves).

* Traffic exhaust (e.g. from garages).

* Refuse incineration and industrial plants in the surroundings.

## Building materials

Pollutants from building materials and from materials used in fixtures, fittings and furniture can -- either individually or in combination - cause discomfort of various kinds: irritation of the eyes, nose and throat, a feeling of dryness in mucous membranes and skin, skin rashes and unpleasant smells. The development of new materials has made the situation difficult to master, since on many occasions the exact composition of the materials is unknown when they are first introduced on the market, so that there is a lack of knowledge of the substances emitted by the materials and of how these substances behave.

One particular problem is that the ventilation ducts collect impurities that can emit harmful or troublesome substances.

Mineral fibres can accompany the air we breathe and coarse fibres, if touched, can cause skin and mucous membrane irritations. The mineral fibre that has attracted most attention is asbestos, the use of which has been prohibited in Sweden ever since 1976. This material is nevertheless present in built-in form in many different places and the risks thus remain. What is particularly problematical is the circumstance that so many ventilation ducts contain asbestos.

Fibres of mineral wool have been associated with irritation of the skin and of the mucous membranes.

Formaldehyde can give rise to discomfort. The World Health Organization (WHO) recommends a maximum guide value of 100 $\mu g/m^3$. The National Board of Health and Welfare has stipulated 250 $\mu g/m^3$ as a limit for sanitary inconvenience.

Some self-levelling screeds can give rise to hypersensitivity troubles and unpleasant smells.

## Radon

The risk of lung cancer being caused by radon is difficult to assess and estimates vary between 100 and 3,000 deaths per annum in Sweden. One of the factors influencing the assessment is the relationship between exposure to radon and smoking.

In the New Building Rules promulgated by the National Board of Housing it is prescribed that the annual mean value of the radon daughter content may not exceed 70 $Bq/m^3$ in rooms constantly occupied by persons. According to the rules laid down by the National Board of Health and Welfare the limit value for the radon daughter content in existing buildings is 200 $Bq/m^3$.

## Carbon dioxide and carbon monoxide

The content of carbon dioxide in the air exhaled by individuals is frequently used as an indicator of the pollution content from human beings. The outdoor air contains 300-400 ppm carbon dioxide. Inadequate ventilation in combination with a high person load can generate contents in excess of 1,000 ppm indoors.

The occupational hygiene limit value for carbon dioxide is 5,000 ppm, based on the inherent harmful effects of this substance. The National Board of Health and Welfare has proposed that the limit for sanitary inconvenience be set at a total of 1,000 ppm carbon dioxide.

The primary sources of carbon monoxide (CO) indoors are combustion gases from vehicles and tobacco smoke. Open fires indoors can generate high contents. Carbon monoxide is also spread from garages.

Normal, fresh outdoor air contains about 1 ppm of carbon monoxide. In busy streets the content is 10-20 ppm. Smoking in a room increases the content by 5-10 ppm. If the source is known, carbon monoxide can be used as an indicator of several pollutants in particulate and gaseous form from this source.

## Environmental tobacco smoke (passive smoking)

The most commonly occurring and rapidly experienced health effects of tobacco smoke are irritation in the mucous membranes of the eyes, nose and throat, and an unpleasant smell. Children of smokers suffer more often than others from diseases of the lower respiratory passages, bronchitis and asthma.

Tobacco smoke resulting in CO contents in excess of 2 ppm in the room air lead to severe irritation of the eyes or other discomfort among about 20 per cent of those exposed.

## Outdoor air

An air pollutant is seldom present in outdoor air on its own and normally the air contains a mixture of several pollutants. The composition varies according to the prerequisites. It has not yet been determined how the various substances affect human beings when they interact. The effects of air pollutants also depend on factors such as temperature and humidity and probably also on the presence of pollen and mould, etc. This means that limit values for individual substances are relatively inadequate means.

Guide values have been stipulated for the maximum concentrations of certain substances in the outdoor air:

| Substance | $\mu g/m^3$ | source |
|---|---|---|
| Sulphur dioxide, diurnal mean value | 100 | SNV |
| Sulphur dioxide, hourly value | 200 | SNV |
| | 350 | WHO |
| Sulphur dioxide, 10-minute value | 500 | WHO |
| Particle concentration, annual mean value | 75 | SNV |
| | 50 | WHO |
| Particle concentration, diurnal mean value | 260 | SNV |
| | 125 | WHO |
| Nitrogen dioxide, diurnal mean value | 75 | SNV |
| | 150 | WHO |
| Nitrogen dioxide, hourly value | 110 | SNV |
| | 400 | WHO |
| Ozone, hourly value | 150-200 | WHO |
| Ozone, 8-hour value | 100-120 | WHO |

SNV = National Environment Protection Board
WHO = World Health Organization

# Hypersensitivity

The number of hypersensitive or allergic individuals appears to have increased substantially in recent years. The substances which are the prime causers of allergies are pollen, animal hair, dust mites and mould.

Dust mites are tiny spiderlike animals only about one-tenth of a millimetre in size. They need both heat and high air humidity in order to propagate. Growth of mites is prevented if the air humidity is kept at a low level for a few months of the year.

As a rule, the mould contents in buildings are not so high that they constitute a risk of allergy among normally healthy individuals. In persons who are already allergic to mould, the contents in a dwelling with a "normal" content of mould can nevertheless suffice to trigger symptoms such as asthma, hay fever, hives or eczema.

The most common problem is that the mould fungi are capable of forming substances emitting a powerful odour of long duration. Sensitive individuals are also likely to suffer from irritation of the respiratory passages, skin and eyes.

Mould fungi thrive on surfaces on which there is nourishment and a suitable humidity, for instance damp water pipes, windows and walls in kitchens and bathrooms or inside damp structures. Mould is also counteracted by low humidity.

# Building design and construction

*The orientation of buildings and their locations in relation to one another influence the outdoor climate in the immediate surroundings. The outdoor climate, in turn, is one of the prerequisites for the indoor climate. Those parts of the architectonic configuration that probably have the greatest influence are the manner in which light and solar radiation are exploited and how wind protection and local environment are created.*

## Location of the building

The very location of a building can cause problems with the indoor climate. Waterlogged land or land with difficult runoff conditions should not be built on without a special foundation. Land with a high content of radon also imposes exacting demands in this respect.

Cold spots and areas in which streaks of fog are common should be avoided, as should locations exposed to keen winds. The relative locations of buildings can have a considerable influence on local wind conditions. Other external circumstances that can give rise to problems are noise, smell, smoke, vehicle exhaust and other pollutants.

Sunlight is of major importance for congeniality and comfort. Properly utilized, solar irradiation can also afford a substantial contribution to the heating of buildings. Allowance must nevertheless be made for the risk of uncomfortably high indoor temperatures during the summer months. Large window areas increase the risk of radiation draughts during the winter.

## Shape and configuration

Both the configuration of the building and the shape of the rooms and their locations in the building influence air circulation and ventilation requirements. The layout can also be used as an active means of providing protection against noise, good lighting conditions etc. The interplay between form, light and colour is also of considerable importance for climatic experience and wellbeing.

Another important aspect of the layout is the need for sufficient and readily accessible spaces for building services, care and maintenance.

## Materials and structures

The choice of the right materials in the building structures, fixtures and fittings may be of decisive importance for how healthy the building will be.

Structures should be consistently tested from the standpoint of building physics (e.g. moisture dimensioning) and with due regard to the long-term permanence. It is also important for the structures to be understandable enough to be executable in practice on the building site.

The rapid development in the area of materials renders the task of both planners and designers more difficult. Mandatory testing and a mandatory statement of the contents of materials are therefore desirable and should also cover furniture, fixtures, fittings and machinery. Many problems can nevertheless be avoided with relatively simple means:

* Use only materials with a statement of contents and which are low-emitting.
* Never use materials with a known or suspected toxic effect on human beings.
* Find out what climate the material will be exposed to in the built-in condition, and never build in a material that perhaps cannot withstand this climate.
* Check the long-term durability of the material and insist upon test certificate of this.
* Make sure that understandable care and maintenance instructions are provided.

# Moisture protection

Moisture is one of the most severe stresses to which our buildings are exposed. Rain, snow and ground moisture give water which may have negative effects both on the building (mould, rot and corrosion) and on the indoor climate (growth of fungi and mites). The energy balance also deteriorates, since heat is used when water evaporates.

The following points should be observed in conjunction with the structural work:

* Prevent moisture from reaching sensitive materials in the various parts of the building.
* Locate moisture-sensitive structural parts as warm as possible.
* Make provisions for ventilation of structural parts which are liable to get damp despite everything.
* Elaborate the design so that unwanted water is easily detected.
* Specify how much drying out of different parts of the building is required.

When working on the construction site, good moisture conditions are created, for instance by

* Using prescribed materials.
* Protecting materials against moisture and not building in damp materials.
* Complying with the drawings as regards the location of damp-proof courses, thickness and application method.
* Preventing mechanical damage in damp-proof courses.
* Clearing rubbish and residual materials from all spaces.
* Providing time for drying out.

During the user phase, moisture problems are avoided by:

* Limiting the amount of water vapour generated by showers and laundering.

* Making sure that the air passages in wet spaces are not blocked.

# Building ventilation

*The task of the ventilation is to supply air of good quality and to contribute to a sound room climate. The ventilation requirements are dimensioned by numerous factors: the balance between oxygen and carbon dioxide in the air, smell, temperature, moisture and the occurrence of unwanted substances. Over and above a certain basic level, emissions from materials, tobacco smoking and the presence of moisture are normally the factors that decide the need of ventilation.*

## Air change requirements

In the New Building Rules promulgated by the National Board of Housing it is specified that the flow of outdoor air to rooms with a normal room height occupied by human beings more than temporarily shall be at least 0.35 l/s per square metre of floor area. In bedrooms, however, the air change rate must be at least 4 l/s per sleeping place. In offices the minimum requirement is 5-7 l/s and person. From kitchens, bathrooms and toilets in dwellings at least 10 l/s must be extracted, which will be the dimensioning figure in small apartments.

This air change rate is the result of numerous considerations: an acceptable indoor climate, good energy husbandry, no moisture damage to the building structure and so on.

The requirements are valid provided that the strains on the air quality are moderate. In offices where smoking is permitted the outdoor air flow rate must be at least 10 l/s per person.

## Design of ventilation systems

A well-designed ventilation system must be easy to install, easy to adjust and easy to look after.

The work on the construction site is facilitated if the various tasks to be performed are uncomplicated and safe. Joints and couplings that are simple to apply should be chosen. Adjustment of the system, which is very important indeed, requires sufficient dampers and measuring devices of good quality.

The operation and maintenance of the building services and systems must be at the focal point of the planning work. The alternatives are sufficient simplicity for practical care or sufficient complexity to eliminate the need of care. Simple and logically arranged systems, by all means divided into smaller units, simplifies operation and increases the possibilities of individual adjustment of the air flow rates.

From the standpoint of operation, apparatus should be placed where it is easy to reach and so that it is easy to carry out service on or replace components. Ducting shall be arranged so that it is easy to clean. Only components with good performance and long service life should be selected.

# Effective ventilation

It is of very great importance from both economic and comfort standpoints that air distribution and air flows in the rooms are as effective as possible. This effectiveness is nevertheless fundamentally dependent on limitation of the pollutants and their dispersion.

The ventilation, moreover, must retain its function with the passage of time. Measurements in buildings have proved that the factual outdoor flow is often far below that specified in regulations and procurement documents.

# Return air recycling

The New Building Rules promulgated by the National Board of Housing accept ventilation systems with return air under certain conditions. Problems with spreading of tobacco smoke and other pollutants, however, indicate that return air recycling should be avoided. When such systems are required, special requirements must be imposed on fine adjustment, regular functional checking and cleaning of ducting systems and filters.

# Responsibility and co-operation

*The elaboration of the building process and the conditions under which it is performed afford a necessary background to any and every discussion of the final products of building. Studies of "sick buildings", by no means least, have focussed on the overall building and management process, since the causes of the problems cannot be attributed to any specific phase but appear as an interactive effect of planning, designing, construction, fine adjustment, handing over, operation and maintenance.*

*Cost rises and obvious shortcomings have rekindled the discussion of quality assurance of building in recent years. Among the obvious problems in this respect are the numerous decisions and deliberations between various interests and areas of competence embraced by building.*

*Formulating the quality requirements is in itself a difficult task. Following them up and evaluating them is even more complicated. The building process is largely unidirectional, in that earlier stages give instructions, rules and restrictions governing how subsequent stages are to handle the technique. The space available for complete quality loops (planning - execution - follow-up) is extremely limited.*

## Co-operation in the building process

The programme work is the task during which the fundamental requirements are to be formulated. The forms for this important task are still inadequately developed. This is particularly true of knowledge of how to express demands on the indoor climate.

The ability of the client to place the order is highly decisive for the results. In the dialogue with the designer it is a matter of translating general wishes into quantitative data. The knowledge necessary for this dialogue is frequently lacking. Relatively few clients, moreover, have a really clear idea of the importance of qualified planning and designing. The result may easily be that certain qualities are overemphasized at the expense of others and that cuts are made at the expense of quality and longtermness.

Co-operation problems are also encountered between the different designers. The building services, for example, are not designed sufficient co-ordinated with the design of the building.

One particularly critical point is when the building passes from production to management. Handing over to the management seldom takes place in a systematic manner and with the requisite documentation for operation and maintenance.

# Building documentation

The building documents of today are marred by considerable deficiencies. They serve mainly as documentation of the designing and as directions about what is to be done. More seldom do they specify how this is to be done and virtually never why. Consequently, risks are incurred for faulty execution and faulty handling.

Instructions for operation and maintenance are essential with the complicated buildings of today. To the extent that such instructions are provided they are frequently inadequate. A minimum requirement is for the instructions to describe the stipulated functional requirements and how they are satisfied, to give a correct description of the final execution of the building and of how care and maintenance are to be performed.

# Division of responsibilities

Purposeful quality work presupposes as a rule that those involved have tangible incentives. The relationship between producer and consumer in the building sector is, however, far too unclear on account of the numerous parties involved.

The system of responsibility must become clearer, for instance in that the client and the manager are given direct responsibility for observance of the demands made by the users on a healthy building. Similarly it is essential for feedback of experience to be improved so that unsuitable technique can quickly be eliminated.

Healthy buildings require a combination of proven experience and scientifically founded knowledge. It is therefore a matter of responsibility that all parties must endeavour to keep themselves informed of and to apply both known and new knowledge.

# Operation and maintenance of the building

*To the same extent as other technical products, the building and its building services require skilled care and continuous maintenance. Deficiencies in care and maintenance of the building services systems are, however, by no means uncommon. Obviously these deficiencies and shortcomings have an adverse effect on the quality of the air.*

## Systematic care and maintenance

Experience indicates that not even large facilities, where the manager normally has professional personnel at his disposal, are looked after satisfactorily in practice. Operating personnel often lack the necessary knowledge and the climatic issues are neglected by comparison with energy conservation and structural engineering measures.

For many of the technical subsystems in the building there are clear signals of functional shortcomings. This, however, does not apply to air treatment. The air pollutants are not easy to detect and the costs often decrease with poor function. The conclusion must be that the ventilation requires systematic control and attendance in order to be kept in good condition. Regular functional checks must be combined with cleaning and filter changes at regular intervals.

In order to save energy, air flow rates in working premises are often set at a lower level during nights and weekends. The result is likely to be that the ventilation does not suffice to remove pollutants from building materials, fixtures and fittings. This is particularly unfortunate in new buildings.

Expedient management includes regular and frequent tidying and cleaning -- by no means least of the ventilation ducts. It is nevertheless important for the tidying and cleaning to be done with cleansing agents which in themselves do not cause negative effects on health.

## Increased managerial responsibility

Increasingly exacting demands on competent property management are imposed in pace with the increasing complexity of the building services. Obviously, the technique must be chosen in view of the level of knowledge within the management organization, but knowledge within the management must nevertheless be maintained in respect of the selected equipment.
The rules and regulations concerning building impose all too limited demands on function in the operating stage and on the responsibility of the management for healthy conditions.

# Energy conservation in buildings

*Energy conservation is one of the prerequisites for a good indoor climate in that most forms of energy production and use have negative effects on the outdoor air supplied to the building. Moreover, in our climate a well insulated building that is free of draughts comprises the building engineering base for a sound indoor climate. The thermal comfort will be good in that radiation draughts towards cold surfaces, draughts on account of leaks in the climate screen, etc., are reduced.*

## Thermal insulation

In the same way as in new buildings, improved thermal insulation normally contributes to a better thermal indoor climate, particularly in the parts situated close to exterior walls and windows. During the spring and autumn, in certain cases, there is a risk of uncomfortably high indoor temperatures in buildings with large window areas facing south and with effective thermal insulation.

Since the amount of heating needed by the building will change in conjunction with supplementary insulation, it is important for the heating system to be readjusted after the measure.

## Tightness

Properly functioning and controlled air change in a building presupposes that the building is airtight. On the other hand, an airtight building requires a properly functioning ventilation system with correctly located supply air registers.

Tightening old buildings with the aim of saving energy must be done with great care. As a rule, it will be necessary to make new openings for controlled outdoor air supply.

## Air change and energy

Practical experience shows that problems with the indoor climate often arise in the intersection between energy husbandry and changes in materials or technique. This does not mean that indoor climate and energy conservation are in a state of opposition, but increased air change rates inevitably mean that larger volumes of air have to be heated up.

To keep the necessary outdoor air flow down every effort should be made in the first instance to reduce pollution. In those cases when problems with air quality or thermal comfort cannot be remedied except with increased air flow rates or higher air temperatures this is justified despite the fact that the use of energy can increase. The costs for investments in energy conservation or higher use of energy should be considered in relation to the costs incurred by society for production losses, care of the sick and wear on the environ etc.

All outdoor air supply to a building must normally be heated for reasons of comfort. If the air flow rates are increased, more energy is required. The difference may be considerable. The following table gives a summary of ventilation levels for a room with a floor area of 12 $m^2$ per person.

Ventilation levels described in different ways for a room with a floor area of 12 $m^2$ per person. The originally used measure is shown in bold type.

| | l/s and person | air changes/h | l/s and $m^2$ floor area | energy kWh/year | cost, SEK/year |
|---|---|---|---|---|---|
| New Building Rules (dwellings, general) | 4.2 | 0.53 | **0.35** | 554 | 222 |
| New Building Rules (bedroom for two persons) and ASHRAE Ventilation Rate Procedure, base level | **4** | 1 | 0.67 | 1,045 | 418 |
| New Building Rules (offices) | **5** | 0.63 | 0.42 | 657 | 264 |
| Buildings and Health, functional margin | **7** | 0.88 | 0.58 | 920 | 368 |
| Buildings and Health, high emission | **20** | 2.5 | 1.67 | 2614 | 1046 |
| Allergy Commission, low emissions and the NKB proposal | **10** | 1,25 | 0.83 | 1,307 | 523 |
| Allergy Commission, safety level | **15** | 1,88 | 1,25 | 1,965 | 780 |
| Allergy Commission, high emissions | **30** | 3,75 | 2,5 | 3,920 | 1,568 |

For a detached house with an area of 144 $m^2$, occupied by six persons, the annual energy requirement to heat the ventilation air may vary between about 6,600 kWh (general requirement of the New Building Rules) and 23,500 kWh (requirement of the Allergy Commission at high emission levels).

Systems for heat recovery are, however, becoming increasingly common. As a rule, up to a good 50 per cent of the heat in the ventilation air can be recovered. With a heat pump which collects the heat in the exhaust air through a heating battery the recovery factor is normally even higher.

The requirements imposed in the New Building Rules for dwellings give a significant safety margin for households that are now overcrowded. (This is particularly true of single-family detached houses.) The true air flows, however, are often smaller than those specified in the norm, and consequently a satisfactory ventilation standard requires some increase in energy use.

## Strategy for energy conservation

Buildings and the built environment account for more than one-third of the total amount of energy used in Sweden. Bearing this in mind, the technique used for heating buildings and hot water is of central importance for the change-over of the energy system necessitated by the phasing-out of nuclear power.

Since the first energy conservation plan of 1978 the building stock in existence at that time has reduced its energy use for heating and hot water by about 25 per cent, from 120 to 90 TWh. The phasing-out of nuclear power is now displacing interest towards more efficient use of electricity and against energy and power husbandry that can limit such electricity use as cannot be avoided.

The possibilities of conserving even more energy are good partly with more efficient insulation, heat recovery, increased quality control and meticulous fine tuning, and partly with developed techniques such as solar heating, heat storage and heat pumps.

The aspiration must be to reduce energy use in buildings in the long term by exploiting the potential offered by modern building and climate techniques. It is important to carry out energy conservation measures in conjunction with modernization and refurbishing of existing buildings in appropriately composed action packages. In existing buildings, this also normally results in improved climatic and functional quality.

The indoor climate must nevertheless be the guiding factor for energy conservation. This implies stricter demands on the quality of the materials, on responsibility and competence in the building process and on the entire strategy for the energy conservation work. Over and above energy-efficient properties, materials, constructions and components must obviously have long durability and give low operating and maintenance costs, both when constructing new buildings and when improving old ones.

A broader view of resource husbandry calls for more than the best possible use of energy in view of kind of energy, time distribution and application areas. In building, also, the approach must be extended to an overall husbandry with resources, involving balances between, for instance, public health, dwelling standard, energy use and nature conservation. Unless such requirements can be satisfied, the aspirations with regard to energy conservation will have to be lowered.

Each individual building is a part of a local/regional ecological system and of several energy systems with a local, regional or national span. There are enormous differences between southern and northern Sweden, between the major conurbations, medium-sized towns, semi-large or small population centres and purely rural areas. Consequently, it cannot be taken for granted that a national uniform view of the configuration of the built environment as a climate system will result in the most efficient husbandry.

Important new components such as natural gas and wind power will be able to be established only in limited parts of the country. Some types of places will have ample access to waste heat from the production of electricity in combined power and heating systems. Other places have biofuels within easy reach and a sparseness in the built environment that facilitates the use of bulky fuels, establishment of compost/digestion gas production etc. In the built environment that is not heated with power or waste heat, solar heating in combination with other environment-friendly energy systems appears to be interesting.

In this perspective, more stringent demands are imposed on municipal and regional planning with accompanying supply and use of energy. At the same time a prerequisite for successful energy husbandry is for there to be a long-term national strategy with clear goals for the environment and energy policy.