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**Programme for Energy-Efficient and Healthy Apartment
Buildings in Stockholm**

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1. SUMMARY

In order to speed up the development of healthy, energy-efficient buildings, the City of Stockholm has formulated a programme for the building of apartment houses. The programme describes the characteristics the buildings should possess in order to achieve the political objectives of energy efficiency, health safety and reduced impact on the environment. These characteristics are described in the form of general functional requirements which provide a good deal of freedom in the choice of technical solutions. Once the buildings have been built, the internal climate and use of energy is followed up. This follow-up provides a unique feedback of experience, both for the City and for the builder, as to how effective the various technical solutions are.

2. OBJECTIVES FOR IMPROVING SWEDISH ENERGY EFFICIENCY

According to the Swedish Planning and Building Act, buildings shall enable efficient use of energy. They shall be suitable for their purpose and provide room for comfort, good hygiene and a satisfactory indoor climate. They shall also be designed so as to enable operating costs to be kept down. In the government directive of 1991 it is stated particularly that more efficient use of energy must be stimulated so that important energy and environmental policy objectives can be achieved, and so that it is possible to utilise the potential for improving efficiency in the use of electricity which will exist economically and technically throughout the nineties.

In accordance with the process of harmonisation with the EC which is taking place in Sweden, the Swedish building regulations are being revised according to a directive stating that detailed regulations on design shall be removed and replaced by functional requirements – in other words, demands concerning the characteristics a building should have.

According to the national objectives, buildings shall be energy-efficient, provide safety in terms of health, and provide a good indoor climate. Building regulations should be formulated as general functional requirements.

3. REALITY IN STOCKHOLM

Indoor climate

A survey into how the indoor climate in the Stockholm housing stock is experienced, which was made with questionnaires among 10,000 households in the winter of 1991/92. It showed that in housing constructed after 1961 problems of health associated with dwellings, such as irritation in the eyes, nose and throat, are about twice as common as in buildings constructed before 1961. One third of the residents are troubled by “dry air” and “close, poor quality air”. Half of the residents complain of drafts and too low an indoor temperature in the winter.

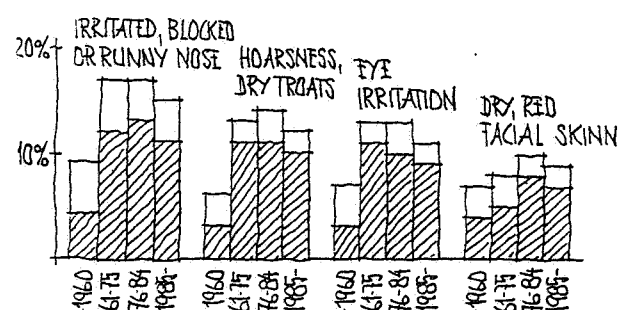


Figure 1: Percentage of residents in apartment houses in the City of Stockholm who often (every week) are troubled by irritation of the mucus membrane. The largest proportion of those who are disturbed who trace their complaints to their dwelling environment (the columns striped diagonally) live in homes that were built between 1976 and 1984.

Of the apartment buildings constructed before 1961, 13 per cent are classified as problem buildings, or what in Sweden is commonly called "sick buildings". For houses built in 1961-75 the corresponding figure is 15 per cent, and for houses constructed 1976 or later the figure is 20 per cent. The increase in the number of problem buildings, and the experience of the residents of the indoor climate, is alarming.

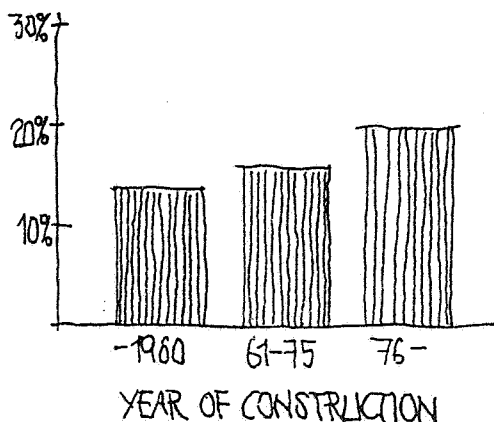


Figure 2: Proportion of "sick buildings" in Stockholm. The classification is based on what is known as the SBS 3 index >5% applied by the Occupational Health Board in Örebro. This means that if more than five per cent of those who live in an apartment block have answered that they are often troubled by at least one skin symptom, one mucus membrane symptom and a general symptom the building is classified as sick.

Energy efficiency

According to statistics for apartment houses in Stockholm, the use of energy (net) for heating and hot water has been reduced from 230 to 185 kWh/m² between 1977 and 1985. Since then the use of energy has remained at about the same level, even though the price of oil at fixed prices is almost twice as high today as it was in 1977, when the major energy saving campaign in Sweden started. The ambition to pursue this still very profitable improvement of energy efficiency by means of concrete action has thus decreased dramatically in the last few years.

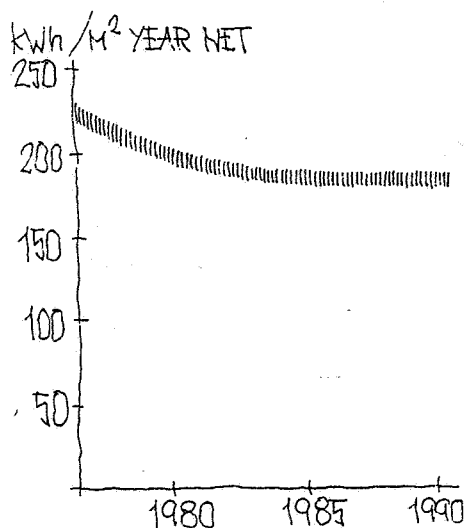


Figure 3: Energy requirement for heating apartment blocks in the City of Stockholm, grouped by year of construction.

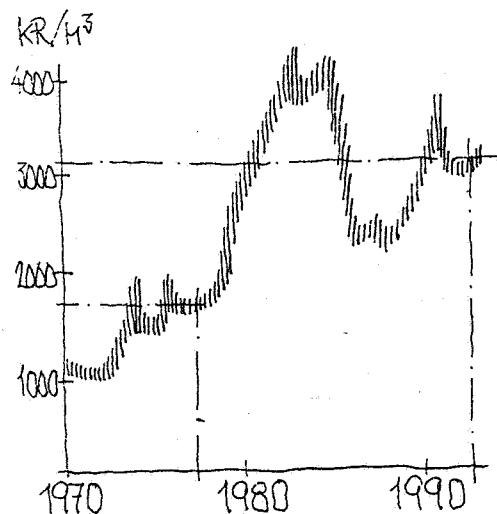


Figure 4: Changes in the price of heating oil (Eo1) in Sweden, at 1992 money value.

Electricity consumption has increased dramatically during the past ten years. While electricity consumption in households has remained fairly constant, electricity consumption for premises in general has increased. This is mainly electricity for operating mechanical ventilating equipment and heat recovery systems.

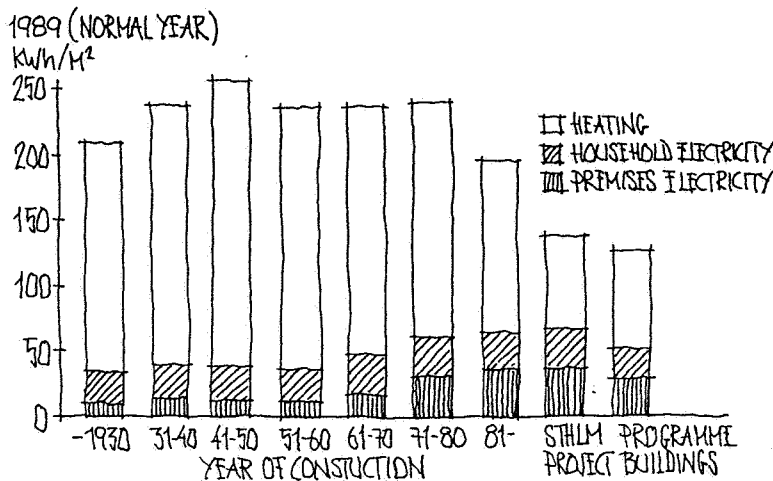


Figure 5: Energy consumption in apartment blocks in Stockholm, specified as energy for heating, household consumption and premises consumption. The second to last column shows the average consumption of energy as measured in the six buildings included in the Stockholm project (see below), which were constructed at the beginning of the eighties. The last column shows the target expressed in the Stockholm programme which was recently adopted for energy efficient and healthy buildings.

4. GENERAL FUNCTIONAL REQUIREMENTS

The reason for abandoning the detailed technical requirements in the building regulations is that they must relate to existing technology and are impossible to apply to new, creative and innovative solutions. Nor is it possible to adjust them according to changed real circumstances. The conversion to verifiable functional requirements is intended to stimulate builders to develop and to increase the potential to produce cheaper, but nonetheless suitable, dwellings.

5. EXPERIENCE FROM THE STOCKHOLM PROJECT

Since the beginning of the eighties, the City of Stockholm has been engaged in a number of energy-efficient building projects, including the Stockholm Project. Six apartment houses were constructed with different concepts for reducing the need to purchase energy for heating and hot water. The project was carried out as a joint project between the City of Stockholm, the Building Research Council, the builders and the Stockholm Institute of Technology. The very extensive evaluation has been published in several building research reports. Some of the lessons were:

- It is possible to construct buildings which require considerably less bought-in energy for heating and hot water than is required in the average newly constructed buildings.
- Apartment blocks can be made more energy-efficient. Measures to improve the efficient use of electricity in the premises are often totally non-existent. At the same time, it is relatively simple to reduce electrical energy consumption in, for example, ventilation installations and apartment house laundrettes and for lighting.

- Low energy consumption can be combined with a sound indoor climate if this is given greater emphasis in connection with planning, building and management.
- If a finished building is to satisfy functional and quality requirements, awareness must be increased, and quality control improved, throughout the entire building process and in the management phase.
- Details are important – thermal bridges, poor input air ducts, etc., can spoil energy efficiency in what is otherwise a sound building.
- The existing forms for the handing over, responsibility and commissioning do not guarantee efficient operating.

6. STOCKHOLM PROGRAMME FOR HEALTHY ENERGY EFFICIENT BUILDINGS

In the City of Stockholm's energy plan a spontaneous development of the use of energy is compared with a development where economically motivated measures are taken to improve efficiency. The analysis shows that considerable benefits are achieved with measures to improve the use of energy. Environmental disturbances from energy production installations can be halved, energy costs lowered, and the need for new energy production installations reduced. Stockholm's environmental plan emphasises the importance of concentrating on sound indoor environment, particularly against the background of the problems associated with the concept of "sick buildings".

The "Programme for energy-efficient and healthy apartment buildings – new buildings" is one stage in the project of implementing the intentions of the energy and environmental plans. These will be followed by programmes for other premises and for re-building activities.

Functional requirements for indoor climate

The objects of the programme regarding the indoor climate is that **dwelling shall be healthy, have a high quality of air and satisfactory heating comforts**. The functional requirements are:

- **Health complaints** stated by the residents in a survey with questionnaire should not exceed the reference values for Stockholm.
- **The air quality** shall be evaluated as good or acceptable by at least 80 per cent of the residents.
- **Heating comfort** shall be regarded as good or acceptable by at least 80 per cent of the residents.
- **The radon compound content** in completed apartments shall not exceed 70 Bq/m³ in inspection measurements.

As a result of the above mentioned survey of 10,000 households in Stockholm a large body of reference material has been built up. This, together with other material, provides the basis

for creating those references which are needed in order to assess the normal quota of health complaints in apartment blocks. It also supports the assumption that the target – that at least 80 per cent of the residents should consider the indoor climate to be good or acceptable – is set at a reasonable level.

Functional requirements for energy efficiency

The functional requirements for energy efficiency are:

- **The total use of energy in the building in question shall not be higher than the estimated use of energy for a corresponding programme building.**

A programme building is a fictitious building which is based on the conditions of the building in question. It is thus exactly the same as the building which is to be constructed, but based on the reference building for in the new building regulations in terms of energy for heating. The production cost, therefore, is not affected in relation to the new building regulations in this respect.

The electricity efficiency of the programme building represents a considerable improvement compared with standards of the eighties. It is already profitable to further improve electricity efficiency in ventilation installations. The assumed electricity efficiency for ventilation installations involves a higher investment in the building phase but provides sound economy in the operating phase. Pay-off time is 3-5 years.

Weighting up of electrical energy

In calculating the total use of energy, the use of electricity shall be weighted up by a factor of 2.4. This means that the importance of effective use of electricity will increase. Exhaust air system buildings without heat recovery can thus satisfy the requirements for a building permission from the energy point of view, provided that the building as a whole is designed for efficient use of electricity and with a good climatic shell. The factor 2.4, which has been arrived at in co-operation with Stockholm Energy, is based partly on an appraisal of future changes in electricity prices compared with other energy carriers, and partly on the actual sacrifice of energy raw-materials and the environment which production of electricity gives rise to.

Upper level for total use of energy

The method of establishing a total level for the use of energy with the aid of a programme building gives the builder freedom to decide what building or installation technique s/he will use, in the way s/he considers best suits the individual case. The demand for a total level for energy use also means that the builder can rank a variety of measures to improve energy efficiency within the various areas of use – heating, hot water, premises electricity and household electricity.

The more effective use of energy leads to lower costs for the residents. Compared with a normal building from the eighties with 100 apartments, the cost of energy would be reduced by 320,000 kronor per year if the programme targets were satisfied.

Well functioning operations

The programme's targets for a well functioning operation are:

- **Functional requirements for indoor climate and energy efficiency shall be maintained in the operating phase.**

The builder shall demonstrate, in a quality plan, how the functional requirements are taken into account during planning and building, and how they are to be maintained in the operating phase.

Reporting in connection with building permission

The formulation of the energy programme, with functional requirements and follow-up of the completed building, are intended in the long run to generate a situation where the City's scrutiny can be limited to a follow-up to ensure that the characteristics have been achieved in the completed building. Initially, however, it is proposed that the builder should demonstrate in a **report in connection with application for building permission** how the energy programme had been achieved. This will enable a dialogue between the City and the builder as to how the functional requirements in the programme can be achieved. The reporting requirements in connection with building permission applications include:

- Quality plan;
- General system sketches for building method, heating and ventilation systems, air flows and air ducts, as well as total area specification;
- Calculation of the use of energy.

In the report the builder shall demonstrate that it is likely that the building in question can achieve the targets of the programme. The system sketches shall indicate in a general way the principles of the selected technical solutions for heating and ventilation systems – selections which can sometimes directly influence the part of the building design which is determined in connection with the building permission. The selection of the ventilation installation, for example, will influence the design of the building and must reasonably be used as a basis for the building design which is selected and established in the building permission.

The calculation of energy consumption is based either on the established design or on functional requirements for the continued planning and for implementation. The reporting requirements mean that the builder will have to make a choice as to what standard he is aiming for as regards indoor climate and energy efficiency. Thus, detailed planning is not required to satisfy the reporting requirements. The work input for calculation and system sketches is estimated to correspond to two working days.

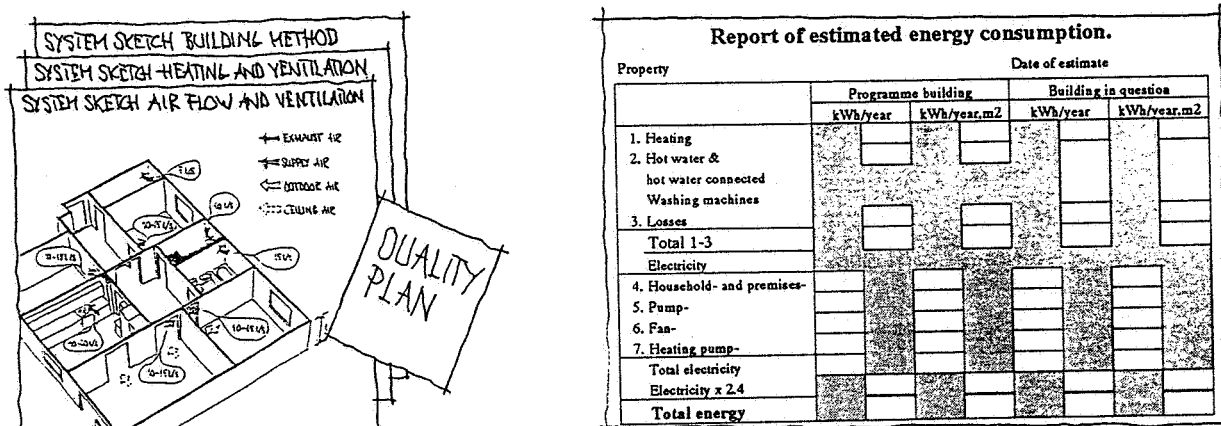


Figure 6: Three systems sketches, a total estimate of energy consumption and a programme for quality assurance are submitted in connection with the application for building permission.

Follow-up of completed building

After the second heating season the builder should follow up the use of energy and the indoor climate in order to check that programme targets are satisfied in the finished building. The use of energy for heating, electricity for the premises and household electricity are measured and compared against the estimate of the energy requirements stated in the building permission application. The experience of the indoor climate and health is checked by a questionnaire to the residents. After a time the overall facts about the indoor climate, energy consumption and the various technical solutions which are described in the form of systems sketches will provide a unique and valuable base of information for selecting and developing new technical solutions.

Incentives

In order to promote the programme's intentions a sum of 250,000 kronor (10,000 kronor per apartment) will be awarded during the first three years to builders which best satisfied the functional requirements in the programme. The award is financed by NUTEK (Swedish Business and Technical Development Agency).

7. EVALUATION AFTER TWO YEARS

Compared with new buildings in the eighties, the programme represents a reduction in the consumption of energy of some 35 per cent and thus a corresponding reduction in environmentally hazardous effluent.

The overall functional requirements for health, air quality and heating comfort, focusing on the experiences of the residents, probably means that the trend of an increasing number of sick buildings can be turned. Where they occur they should be discovered in connection with a follow-up and can thus be remedied at an early stage. However, if we can substantially reduce the cost of remedying some 20 per cent of new buildings which are today classified as problem buildings, a good deal has already been won.

The programme has been adopted by the Stockholm Property Board and Building Board. It

will be applied immediately and will be appraised after two years. The appraisal will be made in co-operation with the National Board of Housing, Building and Planning (Boverket), NUTEK and the Building Research Council, with a view to reporting experiences prior to future reviews of the building regulations.

Targets and requirements	Reporting requirements	Follow-up
<p>1. Indoor climate and comfort</p> <p>1.1 Dwellings shall be healthy, reference values in Stockholm survey should not be exceeded. The radon compound content should not exceed 70Bq/m³ air.</p> <p>1.2 Houses shall have a good quality of air, at least 80 per cent of the residents should consider that the air is good or acceptable.</p> <p>1.3 Dwellings shall have a good heating comfort, at least 80 per cent of the residents should consider that they can achieve good or acceptable heating comfort.</p>	<p>System sketches of building method, air flow, air diffusion and heat and ventilation systems. Investigation of ground radon content.</p> <p>System sketches, see above</p> <p>System sketches, see above</p>	<p>Questionnaires to the residents. The builder is responsible for conducting surveys and for measuring the radon content in a sample of apartments.</p> <p>Questionnaires to residents, see above</p> <p>Questionnaires to residents, see above</p>
<p>2. Low need for purchased energy and electricity-efficient solutions.</p> <p>2.1 The total use of energy for the building in question shall be lower than for the corresponding programme building. In calculations all use of electricity is weighted up by a factor of 2.4. In the case of heating and hot tap water the programme building corresponds to NR's reference building. Electricity consumption is calculated on the basis on an electricity efficient FTX system.</p>	<p>An estimate of energy consumption for the building in question and the corresponding programme building shall be stated. The energy requirement for heating and hot water is calculated on the basis of Nya Enorm or the equivalent. Electricity consumption is calculated separately in accordance with the model in the energy programme.</p>	<p>The builder is responsible for ensuring that the energy consumption for the whole of the year covering the second heating season is measured and reported to the City. The measurements shall include the following items: bought-in energy for heating, hot tap water, premises electricity, household electricity and electricity for common rooms, if any.</p>
<p>3. Well functioning operations</p> <p>3.1 Functional requirements as regards indoor climate, comfort and heating needs and electricity comfort shall be maintained in the operating phase.</p>	<p>State in the quality plan measures for commissioning and operating, in order to maintain the programme requirements at the operating stage.</p>	<p>Follow-up of programme requirements after the second heating season.</p>

Figure 7: Summary of programme requirements.