Energy efficient windows' impact on indoor climate and building economy

Diana Avasoo, Pilkington Floatglas AB, Sweden

1. SYNOPSIS

The key to lower investment costs, improved comfort, healthier indoor air and a considerable reduction in CO2 emission is energy-efficient windows.

2. INTRODUCTION

Windows have traditionally been the weakest part of a building as far as energy loss is concerned. The introduction of low-emissivity coatings resulted in the production of multiple glazing units with very low U-values. However, the high performance of the glass area was spoiled by the fact that the units were installed in frames and casements having U-values that were twice as high. The window manufacturers had no incentive to develop windows with improved insulation performance, as the builders were concerned only with low purchase costs, and not with low life cycle costs. In 1991, as part of the Swedish Government's new five-year programme for more efficient use of energy, NUTEK1 started a technology procurement programme for energy-efficient windows. At that time, normal U-values of windows in the Nordic countries were in the range 3,0-2,0 W/m² K. The two winners, announced in January 1992, were a Norwegian company and a Swedish company, whose designs for wooden-framed windows with external aluminium cladding achieved U-values better than 0,9 W/m² K2.

3. THE RESEARCH APPROACH

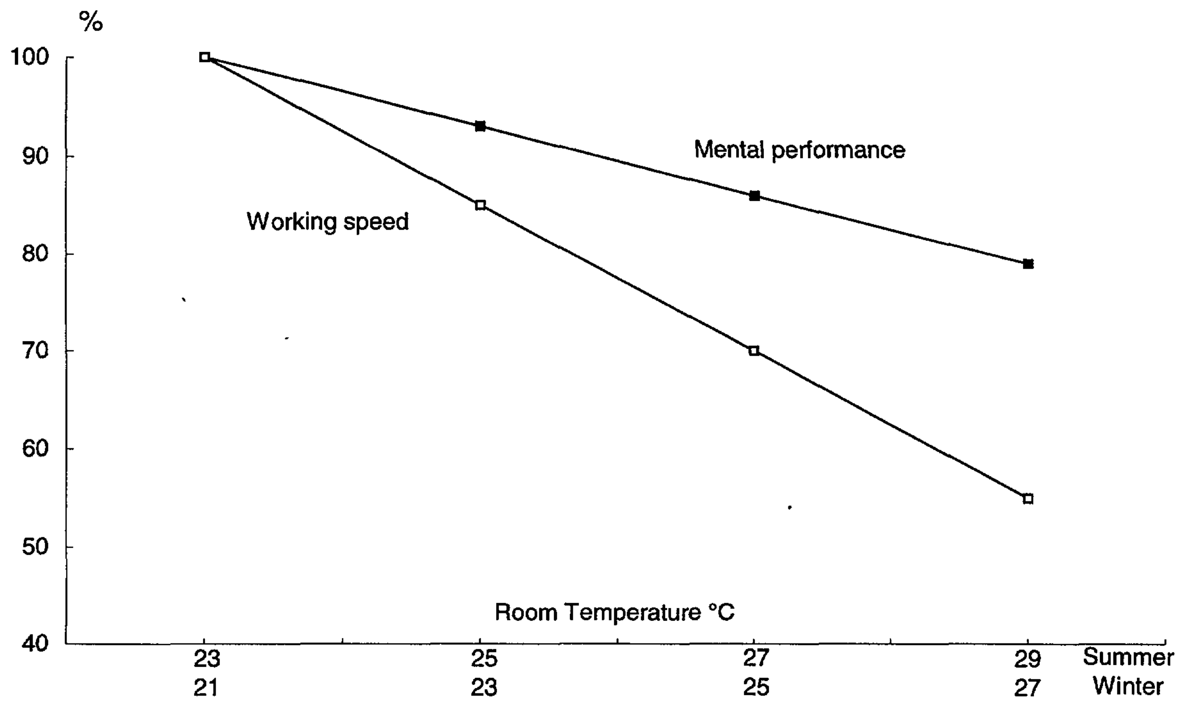
The winning windows cost about 25-30% more than traditional windows that met the requirements of the Swedish Building Regulations. At an average kWh-price of 0.05 ECU, energy prices in Sweden are among the lowest in Europe. Calculations showed that, as cold down-draughts from the new windows were reduced or entirely eliminated, major savings could be made in building heating systems. Total installation costs in new buildings for heating, ventilation and energy-efficient windows would be about 10% less than those for traditional heating systems and conventional triple-glazed windows.

3.1. Application to residential buildings

The very first large-scale installation of the winning windows was in 380 renovated apartments, built in the 1960s, in Västerås in Sweden. The flat roofs were leaking, energy consumption was high by Swedish standards and the whole area had a poor reputation. The project group, which consists of J&W Byggkonsult in Västerås, one of the largest building consultants in Sweden, AB Sunda Hus, installation consultants in Stockholm specialized in healthy buildings, ventilation and energy and architect Mr. Staffan Stenvall from VBB Arkitekter, had great ideas on solving the problems, but the missing link was a window with a very low U-value. The new energy-efficient windows provided the means for realization of a concept that creates an ideal indoor climate and good indoor air conditions all year round. After renovation, the flat roofs have been converted to pitched roofs, of sufficient height to accommodate a two metre high air supply duct. Inlet air flows through the duct at very low velocity, such that airborne particles fall out of suspension to the floor of the duct. Because of its size, the condition of the duct is easy to monitor, and the floor can be cleaned at intervals by an ordinary vacuum cleaner. The air heaters are washed with hot water, and no filters are installed. Air quality has been greatly improved, and the health of occupants previously suffering from allergies has improved. The previous heating system, with conventional water radiators beneath each window, has been replaced by one with one convector heater in the hall and one in the bathroom of each apartment. Ventilation air can be preheated when the indoor air temperature drops below the required set temperature. Balconies, which could previously be used for only a few months each year in Sweden's cold climate, were extended and triple-glazed, effectively providing another 8m² of living area. Specific annual energy consumption has been reduced from 200 kWh/m² to 81 kWh/m², of which 44 kWh/m² are for domestic hot water. Further, the monthly rent for an 85 m² apartment is now 53 ECU lower than that for a similar 85 m² apartment in the same area, renovated with a conventional heating system with radiators under each window and ordinary triple-glazed windows. 50% of the saving is due to lower heating costs, 30% due to lower investment costs and 20% due to lower maintenance costs.

3.2. Application to non-residential buildings

The major problem in non-residential buildings is excess temperatures. Excess temperatures in offices and working premises reduce concentration and general working performance and can even contribute to accidents.



Windows have a major effect on indoor climate and should be selected with care. Energy-efficient windows can be combined with solar control glass to optimise energy savings by reducing heating requirements in the winter and cooling requirements in the summer. Glasses and coatings are available today that enable one and the same window to combine a low U-value, low solar energy transmittance and high light transmittance as can be seen from Table 1. These high-performance glasses are available both as reflecting panes and as neutral panes. The neutral panes look very similar to ordinary window glass.

Glass combination in wooden frame	Daylight transmittance	Total solar heat transmittance	U-value W/m^2 K	
1. Double glazed	80%	76%	2,6	
2. Triple glazed	72%	67%	1,9	
3. Triple glazed energy efficient windows	65%	59%	1,0	
4. -"- with highe performance solar control glass	55%	40%	1,0	neutral, non reflective
5. -"-	38%	25%	1,0	silver reflective coating

3.2.1. Renovation of a school in Karlskrona, Sweden

This school suffered from uneven heating between the north and south sides, exacerbated by sick building symptoms that induced tiredness and dry mucous membranes in staff and pupils. One teacher suffered such severe allergic reactions that she applied for early retirement on health grounds. The windows in each classroom were many and large, resulting in cold downdraughts during the winter and excessive temperatures during the summer. Energy consumption was very high, and the boiler needed to be replaced. The lighting system was elderly, with high power consumption. Borrowing from experience of the renovation in Västerås, the project group replaced 280 m² of windows by energy-efficient windows with high-performance solar control glass, as shown by combination 5 in Table 1. Here, too, the flat roofs were converted to pitched roofs, again covering two metre high ventilation ducts. The entire radiator system was removed, which eliminated the need to replace the boiler. All of the building envelope was draughtproofed, and the lighting system replaced by energy-efficient lighting with occupation sensors. The total additional cost for energy-efficient windows was saved by not having to buy a new boiler. The ventilation installation contract was also cheaper, and the entire cost of the heating, ventilation and lighting systems was 50 000 ECU less than if renovation had been carried out in the traditional manner. In addition, annual cost savings for heating have amounted to 29 000 ECU, 60%, and those for lighting to 6300 ECU, 47%, almost three times greater than if the building had been conventionally renovated. And, as the most telling illustration of improvement of all, the teacher who had suffered from allergies has been able to return to work and has not needed to retire.

4. TECHNICAL IMPROVEMENTS

The energy-efficient windows that won NUTEK's competition in 1992 consisted of quadruple units in the form of a triple-glazed sealed unit on the inside with a single outer pane. Two of the panes had low-emissivity coatings, and the cavity of the sealed unit was filled with argon. The objective of these features was to achieve the specified performance requirements in terms of a low U-value and good technical performance. However, when the windows were presented, many architects felt that they were clumsy, while a number of purchasers thought that large quadruple-glazed windows were too heavy to handle. As a result, in order to get the production of energy-efficient windows started among several window manufacturers and to achieve more architectonically pleasing designs, NUTEK entered into an agreement with five Swedish window manufacturers, by which the manufacturers undertook to produce designs for triple-glazed windows with a maximum U-value of 1,0 W/m² K. To assist them in this, they were given access to a computer model program, tests by the Swedish National Testing and Research Institute (SP) and help with the design of the casements by some of Sweden's best architects. The new windows were presented at a seminar in Stockholm on 25th January 1995, and seem to win immediate wide acceptance by purchasers and architects. One window manufacturer had succeeded in reducing the U-value to 0,99 W/m² K, using a triple-glazed unit with two low-emissivity panes and a krypton filling. The use of an inert gas is necessary, as it is difficult to get down to such low U-values with narrow air-filled gaps. In future, it may be possible to achieve even lower U-values using insulated spacers, aerogels instead of gases and with even larger glass areas. The U-value of glass is still much lower than that of the frame materials in addition, glass admits free solar energy to the building that can be used for heating.

5. CONCLUSIONS

Do we use more energy than is necessary to heat or cool our buildings? New technology allows improved comfort at lower capital cost and with lower energy consumption. In fact, it is not totally new technology. It is sound, well-proven technology build a well-insulated shell and use the minimum of energy to heat and cool it. A well-insulated shell does not require the use of complicated equipment for climate control. The Danish Building Regulations, for example, restrict the use of cooling systems. Only if no other solution, such as the use of solar control glass in windows, external shading or energy-efficient equipment can bring the internal heat load down to an acceptable level may some artificial cooling system be permitted. Each project is considered on its merits, and must apply for dispensation from the requirements. In Germany, too, the new Building Regulations that came into force on 1st January 1995 contain restrictions on the amount of energy that can be used for artificial cooling. It requires about five times as much energy to reduce room temperature by one degree than it does to raise it by the same amount. It is therefore very cost-effective to choose windows with low solar heat transmission when excess indoor temperatures are a problem. Windows with low U-values are also recommended in non-residential buildings where excess temperatures occur during only part of the year and/or part of the day. When it is cold and dark outside, downdraughts and cold radiation problems can occur, which can be energy-efficiently and environmentally acceptably solved by using low-energy-loss windows.

6. ENDNOTES

1. NUTEK - the Swedish National Board for Industrial and Technical Development (Department of Energy Efficiency, DOEE)

2. The U-values are for the whole window including frame and casement. The tests have been carried out by the Swedish National Testing and Research Institute (SP) in a hot box in accordance with Swedish Standard SS 81 81 03.

7. REFERENCES

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