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Lund Institute of Technology
Department of Building Science
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Solar-Protective Glazing for Cold Climates

A Parametric Study of Energy Use in Offices

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Building Science

Lund University

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Department of Building Science

The Department of Building Science is part of the School of Architecture within the Faculty of Technology. The Department has two professorial chairs, Building Science and Building Services. Research at the Department is concentrated on energy management, climatic control and moisture problems. The main areas of research are:

- design and preformance of new low-energy buildings
- energy conservation in existing buildings
- utilization of solar heat
- climatic control
- climatic control in foreign climates
- moisture research

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Solar-protective glazing; energy use; reflective; heat-absorbing; tinted glass; offices; cold climates; heating; cooling; peak loads; indoor temperature.

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Abstract

Annual energy use for heating and cooling an office room equipped with various types of solar-protective glazings was studied with the aim of identifying the glazing optical properties that yield low energy use in cold climates. The room's orientation, the glazing-to-wall area ratio (*GWAR*) and the climate were alternately varied and the impact of these parameters on annual energy use, peak demand and indoor temperature was analysed. The study was carried out through computer simulations of energy use with the program *DEROB-LTH*, which uses angular-dependent calculation algorithms for windows. Specific heat losses, internal loads, ventilation, infiltration rates and temperature set points were kept constant for all cases and heating and cooling loads were added in a 1:1 ratio throughout the study. Results indicate that, in heating-dominated climates, solar-protective glazings reduce cooling loads significantly but increase the heating demand thus increasing annual energy use in most cases. On south and north facades, high solar transmittance glazing ($SC > 0.6$) yielded lower annual energy use than average transmittance glazing with 30% *GWAR* because cooling loads were easily offset by large reductions in heating. On east and west facades, however, average transmittance glazing ($0.4 < SC < 0.6$) performed better than high transmittance glazing. A low-emissivity coated glazing ($SC = 0.6$) appeared to be a good solution for all orientations while extremely low solar transmittance glazing ($SC = 0.16$) was always a poor solution. South and north orientations had a lower annual energy use with a larger solar aperture than east and west facades indicating that larger glazing areas or a higher shading coefficient should be selected on south and north facades. A higher solar transmittance or larger glazing areas were also more energy-efficient in Montreal and Luleå than in Lund, Stockholm and Oslo because there is a larger potential for passive solar utilisation in the winter in those cities. In general, it was found that the orientation and glazing solar transmittance affected heating loads in the same way while the effect of glazing transmittance on cooling loads was more significant than that of orientation. The study generally indicates that solar-protective

glazing with an average *SC* can be energy-efficient in cold climates provided that an appropriate glazing area is selected and that the orientation and climate are taken into consideration in the design.

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6 Summary

Annual energy use for heating and cooling a standard, rectangular office room equipped with various types of solar-protective glazings was studied with the aim of identifying the glazing optical properties that yield low energy use in cold climates. The office room was alternately equipped with reflective, heat-absorbing (tinted), low-emissivity and clear glazing with shading coefficients varying between 0.16-0.86. The orientation was varied by 45° increments and glazing-to-wall area ratios (*GWAR*) of 0-, 10-, 20-, 30-, 50-, and 70% were tested in various climates: Lund, Stockholm and Luleå (Sweden), Oslo (Norway) and Montreal (Canada). Peak loads and indoor temperatures in the centre of the room were also studied for Lund and Montreal, with 30% *GWAR* and the south orientation.

The study was carried out through computer simulations with the program *DEROB-LTH*, recently supplemented with an improved angular-dependent algorithm for windows. The program *WINDOW-4.1* was also used to calculate the angular-dependent optical and thermal properties of the glazings on the basis of manufacturers' data for normal incidence. The room's geometry, thermal losses, internal loads, ventilation and infiltration rates and heating and cooling temperature set points were kept constant throughout the study. Thermal losses were controlled by varying the insulation thickness in the opaque wall around the window as a function of each window's U-value. This method allowed the inclusion of windows with a wide range of U-values in the study.

An analysis of hourly load fluctuations showed that heating peak loads occurred during the weekends when only one heating temperature schedule was used for all days of the week. The study thus suggests that a different heating schedule should be used for weekends and that simulation programs should allow the modelling of a flexible heating temperature schedule. Otherwise, weekend loads determine the size of the heating equipment. It was estimated that allowing temperatures to drop to 18°C during the weekends could save about 4% of the annual energy demand.

The study generally showed that solar-protective glazings reduce cooling loads significantly but yield higher heating loads thus resulting in a higher annual energy demand in most cases. Results also indicated that the impact of a change in glazing transmittance and orientation on heating loads (and annual energy use) was of the same magnitude while the glazing type affected cooling loads more significantly (about twice as much) than the orientation. Another important finding was that the low-emissivity coated glazing (*SC* = 0.68) appeared to be an energy-efficient solution for all orientations and climates while extremely low solar transmittance bronze reflective glazing (*SC*=0.16) was always a poor solution.

An analysis of annual energy use for heating and cooling showed that the optimum glazing choice was orientation-dependent. Generally, the glazing type had the most significant impact on annual energy use on the south facade. Also, with 30% *GWAR*, north and south orientated rooms had lower annual energy use with high solar transmittance glazing like clear and low-e coated glass (*SC* > 0.6) while on east and west facades, average transmittance glazing (0.4 < *SC* < 0.6) performed better. On the south facade, there is a larger potential for passive solar utilisation in the winter. Thus, increases in cooling resulting from high transmittance glazing were easily offset by large reductions in heating. On east and west facades, the increases in cooling resulting from high transmittance glazing were not offset by the reductions in heating. On the north facade, the small increases in cooling due to high transmittance glazing were easily offset by small reductions in heating loads. This facade receives practically no direct solar radiation in the winter indicating that the reductions in heating loads were mostly generated by diffuse solar radiation.

The results also indicated that larger glazing areas performed better for south and north orientated rooms than for east (and west) orientations because of a larger potential for solar utilisation in the winter on the south facade and relatively low cooling demand on the north facade. When heating and cooling loads were added in a 1:1 ratio in Lund, the annual energy use was minimal at solar apertures (product of the *SC* and *GWAR*) around 0.2 on the south facade, around 0.12 on the east facade, and between 0.2-0.3 on the north facade. Thus, the optimum *GWAR* for south-orientated office rooms was 22% for clear glass, 30% for low-e coated glass (*SC*=0.68) and over 40% for average transmittance reflective and absorbing glass (*SC*=0.44-0.48), etc. For east-orientated (and west-orientated) rooms, the optimum *GWAR* was 14% for clear glass, 19% for the low-e coated glazing and around 25% for average transmittance glazing. On the north facade, the optimum *GWAR* was 23-34% for clear glass, 32-48% for low-e coated glass and 42-68% for average transmittance solar-protective glazing. Thus, the study also indicated that average transmittance solar-protective glazing should only be used with large *GWAR* (> 40%) on south and north facades but can be energy-efficient with *GWAR* around 25% on east (and west) facades.

A comparison of energy use between 5 cold climate cities indicated that Luleå had the highest annual energy use. Montreal was second mainly due to high cooling loads. Stockholm and Oslo came third with very similar energy trends and Lund had the lowest annual energy use. Results indicated that the optimum glazing strategy is also climate-dependent. In general, Montreal's annual energy use was affected more by a change in glazing or orientation than all other cities because this city receives more insolation throughout the year. The smallest relative impact of orientation and glazing type on annual energy use was in Luleå. In colder cities like Montreal and Luleå, an increase in *GWAR* (from 20 to 50%) resulted in reductions in annual energy use, especially on the south facade. In Lund, Stockholm and Oslo, increasing the *GWAR* generally yielded higher annual energy use, especially on the east facade since large glazing areas generated large cooling loads hardly offset by reductions in heating. With 50% *GWAR*, average to high transmittance glazing performed approximately in the same way in Montreal and Luleå while average transmittance glazing generally performed better in Lund, Stockholm and Oslo. The study thus suggests that higher transmittance glazing or larger *GWAR* should be used in sunny, cold cities like Montreal and Luleå where there is some potential for solar utilisation in the winter and/or where heating loads are substantial.

An analysis of peak loads for south-orientated rooms and 30% *GWAR*, showed that peaks occurred around the same time regardless of the orientation, glazing type and climate for all cases but one (east orientation, clear glass). Heating peaks occurred around 07.00 hours in the morning while peak cooling loads were in the afternoon between 13.00-16.00 hours, both in Lund and Montreal. In contrast, the lowest heating load was in the afternoon while the lowest cooling load was around 07.00 hours in the morning. Annual heating peaks were about twice as large in Montreal as in Lund but the peaks were not affected by the glazing transmittance. This is easily explained by the fact that there is little solar radiation incident on the building at 07.00 hours. In contrast, the cooling peak was dependent on the glazing transmittance, especially in Lund where a change in glazing type reduced peak loads by up to 61%. The impact of glazing type on the peak cooling was smaller in Montreal (at most 32%).

A brief analysis of indoor temperatures at the centre of the room for south orientation and 30% *GWAR* indicated that the low solar-transmittance reflective glazing (*SC*=0.16) eliminated the need for a cooling system in Lund. In Montreal, however, even with extremely low transmittance glazing, much of the summer “working” time (2 months) had temperatures well above the comfort zone limit (> 28°C).

The study thus generally indicates that solar-protective glazing can be energy-efficient in cold climates provided that an appropriate glazing area is selected and that the orientation and climate are taken into consideration during the design. For example, in Lund, average transmittance solar-protective glazing ($0.4 < SC < 0.6$) was energy-efficient, with large *GWAR* (>40%) on south and north facades or with smaller *GWAR* (25%) on east and west facades. Very low solar transmittance glazing should, however, be avoided except for offices that do not have artificial cooling. However, the study showed that a reduction in beneficial solar gains in the winter always resulted in a higher heating demand. Since the heating demand was many times larger than the cooling demand for all cities included in the study, the use of solar-protective glazing often resulted in higher annual energy use. This study thus suggests that more flexible solutions such as seasonal or dynamic shading or switchable (smart) glazing should be researched as they offer the potential to reduce solar gains when they are a nuisance while allowing a passive utilisation of solar radiation during the winter. Even a small amount of diffuse radiation on the north facade reduced heating loads. It should also be remembered that the potential for reducing overall energy use may be much greater with clear glazing in buildings where artificial lighting is dimmed as a function of daylighting. This latter possibility, along with shading, needs further investigation. Thermal and visual comfort should also be studied more thoroughly.

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