# Utilization of Solar Energy Systems for Retrofit Design of School Buildings and an Example Application

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## ABSTRACT

As a large part of the education year occurs during the cold weather season, the proportionally large glass areas permit excessive heat loss in the classrooms. The problem with large glass areas arises from the lack of control of mechanically generated heating systems. A solution for the improvement of these classrooms, is to use solar energy in the design, which is economical and practical. In this study, a school in İstanbul, which has existing large classroom windows and has a solar energy collector behind the south classroom window is introduced and measurements are evaluated.

## KEYWORDS

Solar energy, Solar heating, Solar collector, School buildings, Retrofit design.

## 1. INTRODUCTION

In the design of old school buildings and classrooms it is seen that they have a very large proportion of glass area to wall area in the external shell of the building. As a large part of the education year occurs during the cold weather season, the proportionally large glass areas allow excessive heat loss. The problem with large glass areas arises from the lack of control of mechanically generated heating systems and direct sun light admitted in to the room through the large window areas. (Olson, 1982) To overcome this problem some of these schools are being retrofitted with double glazed windows. Economically, fitting double glazing is expensive and it only stops some of the heat loss occuring and alone it is not sufficient for the solution of the problems. There is an alternate solution to the improvement of these classrooms, using solar energy in the design, which is more economical and practical. (Zorer, 1993 - 1995) It reduces mechanical heating cost and the pollution of the environment and provides a more comfortable thermal environment. (Gedik, Zorer 2000)

A research project supported by TUBITAK (The Scientific And Technical Research Council Of Türkiye) is designed to improve the thermal efficiency of classroom design through the use of solar energy . This paper presents a part of the results of the project. In this study, a school in İstanbul, which has existing large classroom windows has a solar energy collector behind the south classroom window is introduced and measurements are evaluated. This suggested system has the advantage of not requiring any modification to the existing heating system or occupying any interior space. The solar energy collectors are easy to both install and remove as required and also reduce glare problems caused by direct sunlight passing through the windows. The insulated collector, allows hot air to enter the classroom while significantly reducing heat loss out the window area. (Gedik Zorer 2002)

## 2. COLLECTOR SYSTEM DESIGN

The main components of the solar air collector are the glazing, the air space between the glazing and the collector plate, the aluminum collector profiles with air chambers and the insulated backing of the collector. (Figures 1 and 2)

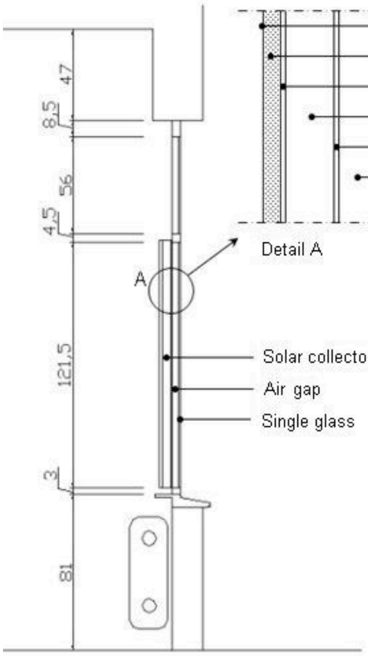


Figure 1. The detail of solar collector

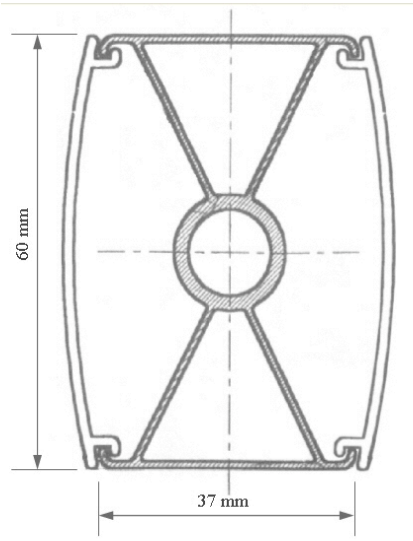


Figure 2. The profile of solar collector

The function of the glazing is to admit as much solar radiation as possible and to restrict the transmission of heat radiation back through the glazing so that the optimum greenhouse effect results. Hence, the existing single glazed in front of the collector in the classrom when changed with the special glazing has ninety-two percent transmittance of light.

The aluminum collector profile with air chambers is shown in Figure 2. The wavelength selective coating is applied to the front face of the collector profiles that have a low emmisivity of energy in the infrared wavelengths. Since infrared energy flow makes up a large part of the total energy loss of the system through the glazing, selective surfaces are quite effective in improving performance. (Meltzer 1985)

Control of air flow through the air chambers is critical for optimum thermal performance. Convection is a sensitive dynamic process. Any buffling or bends in the air chambers reduce air flow rates and reduce efficiency. Therefore the collector is tested using infrared radiation lamps in the laboratory. The collector reaction to change in the value of heat transfer is measured. Air temperatures and velocities are measured at the bottom (air entry) and top (air exit) of the collector. Moreover, performance of the collector geometry is analyzed using Computing Fluid Dynamics (CFD). The results of the measurements and theoretical analysis are compared. (Gedik Zorer etc, 2004) The back face of the collector is insulated to generate effective convective air flow on the basis of the test results. The insulated backing of the solar collector serves the dual function of blocking heat transfer between the classroom and the back of the profiles (and air chambers) and insulating the window area to reduce heat transfer from the classroom to the outdoors.

Figure 3. View of top-bottom of the collector

Figure 4. Front view of the collector

## 3. MEASUREMENTS

A computer system with appropriate software was used to obtain air temperatures, velocities and solar radiation data in the classroom. Seven temperature readings were recorded. First, top vent and second bottom vent collector air temperatures were recorded. (Figure 3). Two temperature sensors were attached to the collector at the top and bottom vents. These sensors indicated the temperatures for air entering and exiting the collector. Thirdly, temperature of the collector's surface facing the glazing and fourth, inner surface temperature of the glazing were recorded. (Figures 4 and 6). Fifth, indoor temperature of the classroom and sixth, indoor temperature of the adjacent classroom without a collector but having the same window size and orientation were recorded. Seventh, outside temperature readings were recorded. Eighth and ninth data recordings were for solar radiation and air velocity. (Figure 5) A hotwire thermo-anemometer was attached to the top of the collector to measure air velocity exiting the collector.

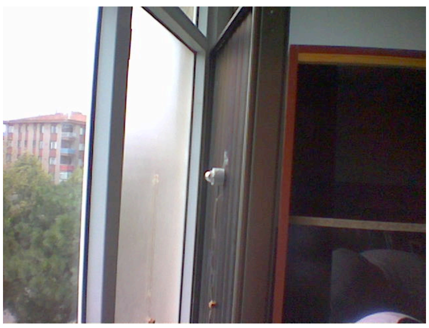

Figure 5. Pyranometer on the collector

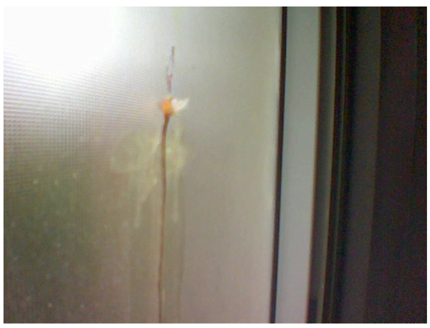

Figure 6. Temperature sensor on the glazing.

## 4. EVALUATION OF THE MEASUREMENTS

Figure 7 shows temperature readings for inside the classroom and air entering – exiting the collector. The top vent air (air exit) temperature of the collector increases when the sun shines. The difference between the top vent and bottom vent air temperatures is a maximum at peak solar collection time on the south (between 12.00-15.00 hrs). On clear days the temperature difference is about 25-28 ºC. Moreover, air temperature exiting the collector is about 25-27 ºC higher than the inside temperature of the classroom. As seen in Figure 8, the top vent air velocity is about 0.5-0.6 m/sec in the same period.

The difference between the top vent and bottom vent air temperatures is about 2 ºC during the evening and night hours. During the daytime hours, the bottom vent air temperature is about 1ºC higher than the inside temperature of the classroom. During the evening and night hours the inside temperature of the classroom is about 4 ºC higher than the bottom vent air temperature.

Figure 9 shows measured solar radiation ($w/m^2$) data. In sunny hours, solar radiation reaching the collector surface is about 666 $w/m^2$. Figure 10 shows the temperature of the collector's surface facing the glazing is about 20 ºC higher than inner surface temperature of the glazing during sunny hours. This difference reduces to 5 ºC during the evening and night hours. Figures 7 - 10 show the same trend throughout the cycle.

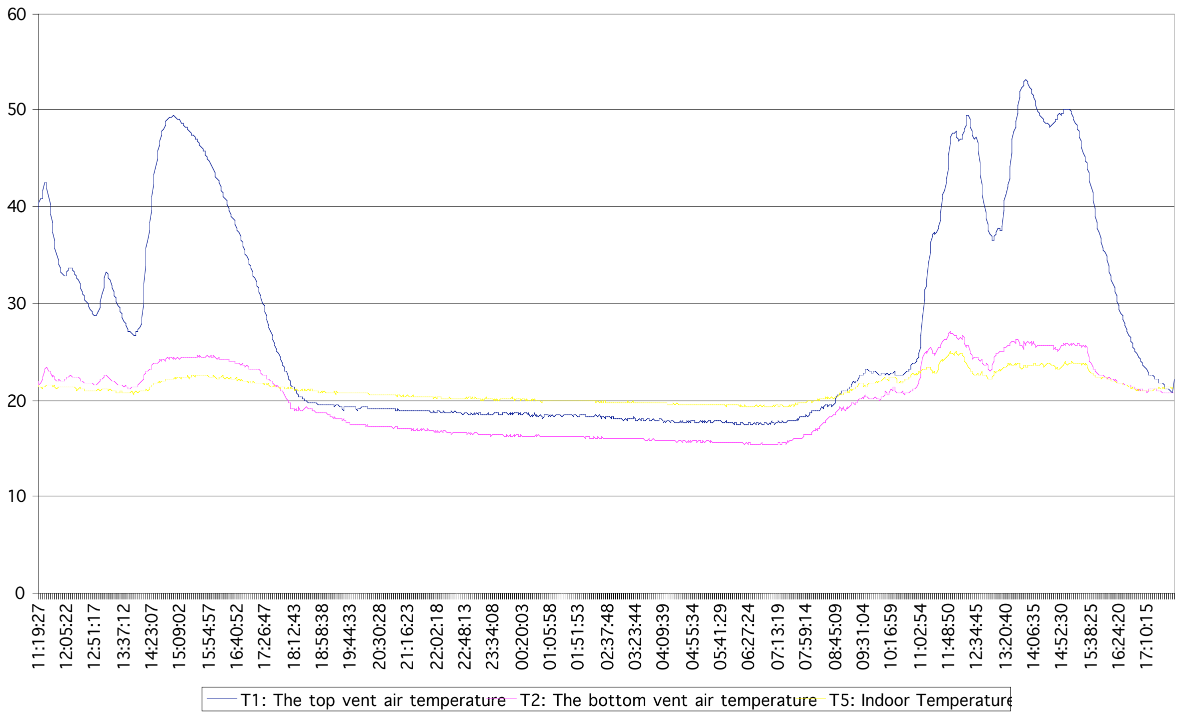


Figure 7. The temperature readings for inside the classroom and air entering-exiting the collector. (20-21 February 2005)

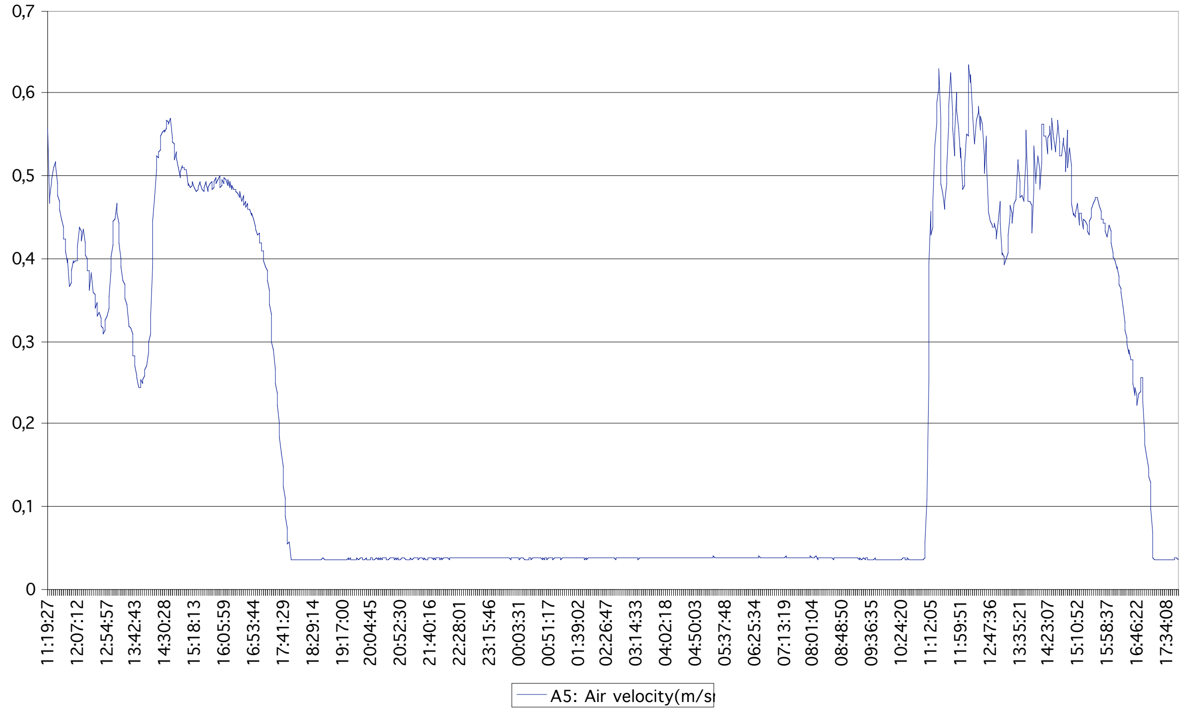


Figure 8. Hourly the top vent air velocity readings. (20-21 February 2005)

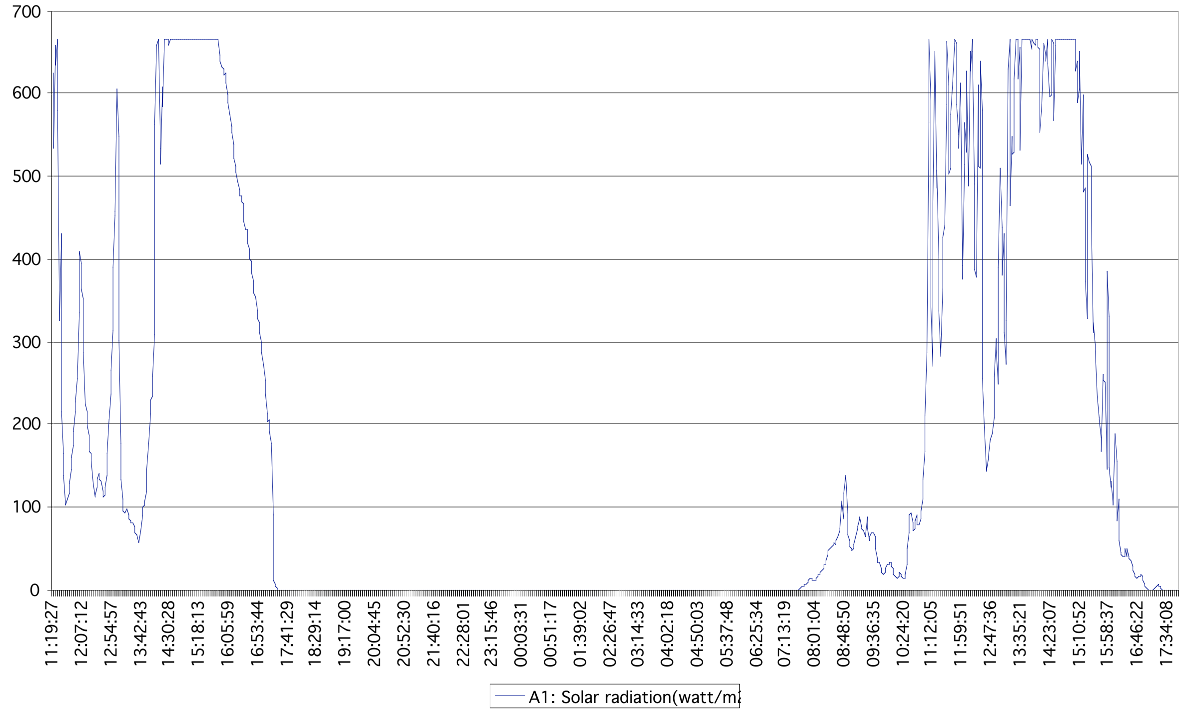


Figure 9. Hourly solar radiation data (20-21 February 2005).

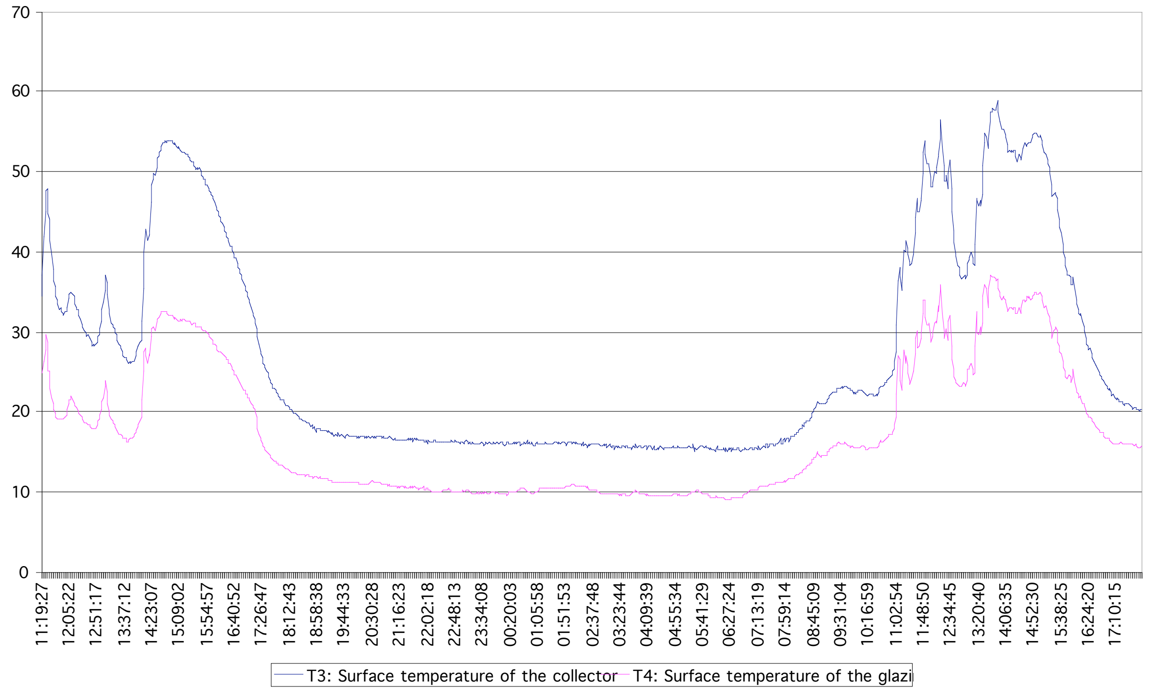


Figure 10. The temperature of the collector's surface facing the glazing and inner surface temperature of the glazing. (20-21 February 2005).

## CONCLUSION

In winter the solar window collector provides significant heat gain by convection during sunny hours. During overcast hours, the insulated backing of the collector insulates the window area to reduce heat transfer from the classroom to the outdoors.This suggested system has the advantage of not requiring any modification to the existing heating system or occupying any interior space. Moreover the solar energy collector in the classroom also reduces glare problems caused by direct sunlight passing through the windows.

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