A BUILDING INTEGRATED SOLAR COLLECTOR DESIGNED TO PREHEAT FRESH AIR DURING THE HEATING SEASON

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1. ABSTRACT

A building integrated solar collector was designed to preheat the fresh air used to ventilate a commercial building in Norway. The solar collector is a 50 meters long air chamber that runs along the ridge of the sloped roof. There is a fresh air intake at each end of the collector. An air intake to the ventilation system at the center of the collector causes fresh air to flow through the collector.

The energy consumed for lighting, heating, ventilation, hot water, and plug loads has been monitored since Spring 1993. A more advanced monitoring system including an eight channel data logger has collected data since June 1994.

The paper describes the design of the solar collector and explains the naturally enforced mechanical ventilation system. The performance of the solar collector is evaluated based on the analysis of the data collected during the two stages of monitoring. The findings show that the solar collector contributes energy savings above 1000 kWh per week, which indicates that the actual annual savings could exceed the estimated 40,000 kWh. The solar collector would contribute additional energy savings if the surplus summer heat was used to produce hot water and to heat the floors of the locker rooms.

2. INTRODUCTION

A building integrated solar collector was designed to preheat fresh air that is used to ventilate a commercial building in Norway. The building serves as the headquarters for a local utility company, and the client asked for an energy efficient building.

A grant from the Norwegian Research Council helped funding a research project that was set up to monitor the performance of the collector over a period of one year.

3. THE BUILDING

3.1 Solar access

The building is located in Årdal at 61 ° Northern Latitude (figure 1). The building site runs along the river Utla that feeds into a lake East of the inner end of the Sognefjord, surrounded by steep mountains. Figure 2 explains how the solar access is limited by the surrounding mountains.

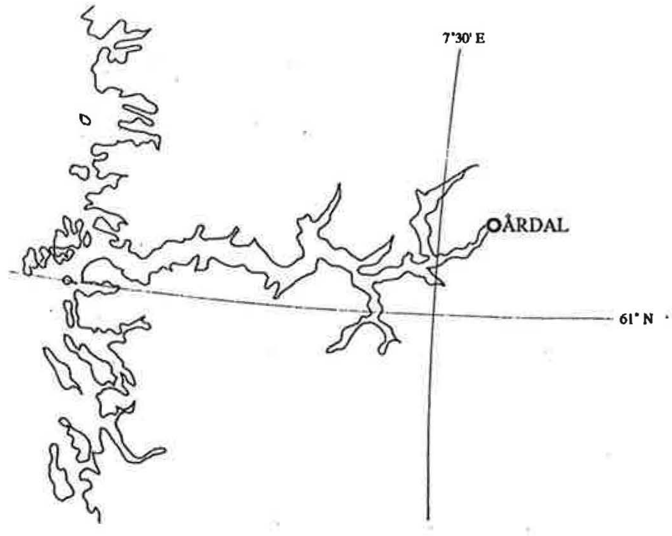

Figure 1: Map of Sognefjord, 1:25000000.

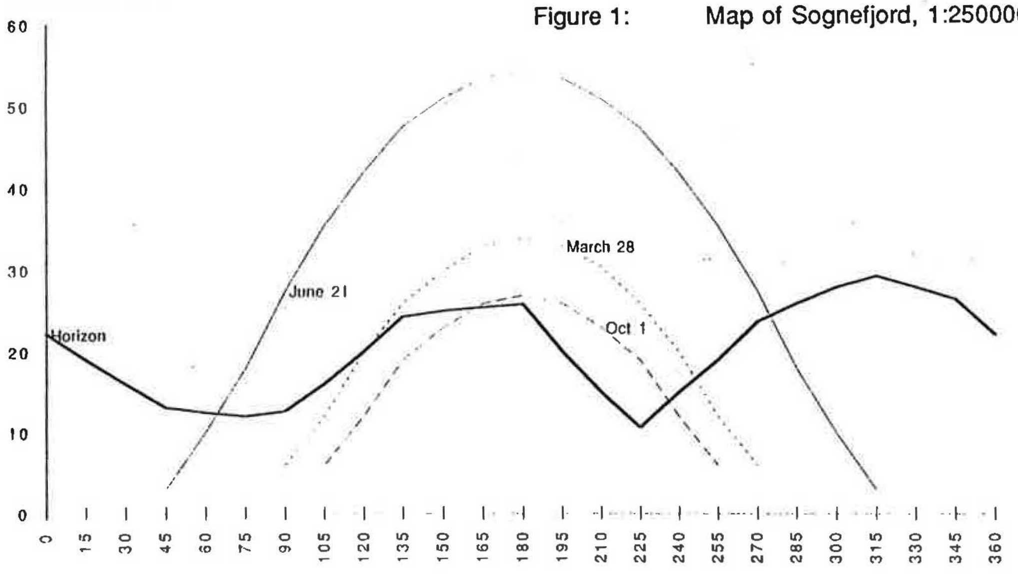

Figure 2: Solar access as seen from the site.

3.2 Passive solar design

The two story building has a total floor area of 1,300 m2, divided into three main functions; offices (620 m2), workshop and warehouse (250 m2), and cafeteria, locker rooms, and other common facilities (430 m2). The main entrance, the offices and the cafeteria are located along the curved facade facing South and South West. Rooms that require a few small windows or no windows at all are located on the North side. Exterior walls are well insulated. High thermal mass materials are used in the floor slabs (concrete), the exterior walls (brick), the interior walls (sheet rock), and on the roof (slate).

4. THE SOLAR COLLECTOR

4.1 Geometry

The solar collector is a 50 meters long air chamber that runs along the ridge of the sloped roof. The south-facing side of the collector consists of a 90 square meters glazing with a 60 degrees tilted double pane glass mounted in aluminum frames. The remaining exterior and interior walls of the solar collector are highly insulated. The ceiling is partly a conventional, highly insulated structure, and partly a transparent ceiling with a double pane, transparent insulation material mounted in aluminum frames to allow for daylighting of the interior.

4.2 Function

There is a fresh air intake at each end of the collector. An air intake to the ventilation system at the center of the collector causes fresh air to flow through the collector at a rate of 10,000 m3 per hour when the outdoor air temperature is below 19 °C. The air is preheated on its way through the collector. Outside the heating season an alternative air intake on the north side of the building allows fresh air to by-pass the collector and to flow directly into the ventilation system. A damper switches between the collector air intake and the north side exterior air intake. An exhaust fan extracts air from the collector at a rate of 2,000 m3 per hour to prevent overheating of the collector on clear summer days when preheating of fresh air is not asked for by the heating and ventilation plant.

5. HYPOTHESIS

5.1 Expected performance

Preliminary calculations based upon statistical climatic data indicated that the south facing glazing of the collector would receive a total of 45697 kWh of solar radiation per year. The heat gain from the building to the collector was estimated to 3673 kWh per year, and the heat loss to the ambient air and to the building was estimated to 10655 kWh per year. The estimated total annual heat gain from the collector was approximately 40,000 kWh.

5.2 Expected energy savings and pay back time

If the total net heat gain from the collector could be used to reduce the energy spent on preheating fresh air, the annual savings would be US $ 4,000 at an energy cost of US $ 0.10 per kWh. The cost of the solar collector was approximately US $ 30,000. The client received a US $ 15,000 research grant that paid for part of the construction cost, and for the monitoring project as well. Based upon a net cost of US $ 16,000 the expected pay back time was 5-7 years.

6. METHOD

6.1 Experimental construction and evaluation

The hypothesis is tested by evaluating the performance of the collector over a period of one year, and by comparing the collector performance to the total energy performance of the entire building.

6.2 Two stage monitoring

A two stage monitoring program was established. The total energy use of the building has been metered since April 1993. Meter readings from five separate categories of energy use is registered weekly. In Spring 1994 a data logger was set up to collect data on solar radiation, air temperatures, and fan operation. The 8-channel data logger collects data every 3 minutes, and data are averaged every 60 minutes. A final report on the collector performance will be presented by June 1995.

7. DATA COLLECTION

7.1 Meter readings

The energy used for heating/ventilation, auxiliary heating, lighting, hot water, and plug loads has been registered weekly over a year starting June 1, 1993. The total energy consumed by the building during the first year of operation was 286627 kWh or 220 kWh per m2.

7.2 Data from the 8-channel data logger

7.2.1 Climatic parameters

Solar radiation was measured by a SolData pyranometer type 80-HD mounted at a 60 degree angle on the outside of the collector. Outdoor air temperatures was measured by two Pt-100 temperature sensors mounted on the north side and south side of the building.

7.2.2 Collector performance

The temperature inside the collector was measured next to the HV-system air intake at floor level. The operation of the exhaust fan (on/off), and the damper (open/closed) was registered.

7.2.3 Human comfort

The indoor air temperature in two offices was measured, one at each floor of the building.

7.3 Validity of data

The client is in charge of the meter readings. Data is regarded as very reliable. The data logger produced reliable data since the last week of June 1994. Previous data are not reliable.

8. DATA ANALYSIS

8.1 Solease graphs

Data may be analyzed in "Solease", a computer program that produces charts of temperature variations, insolation, and fan and damper operation. The Solease graphs was used as introductory overviews of the performance of the building.

8.2 Excel calculations and graphs

Weekly summary tables for each data channel were analyzed in "Excel", a spreadsheet program for personal computers. Temperature variations and quantities of energy were calculated and presented in charts.

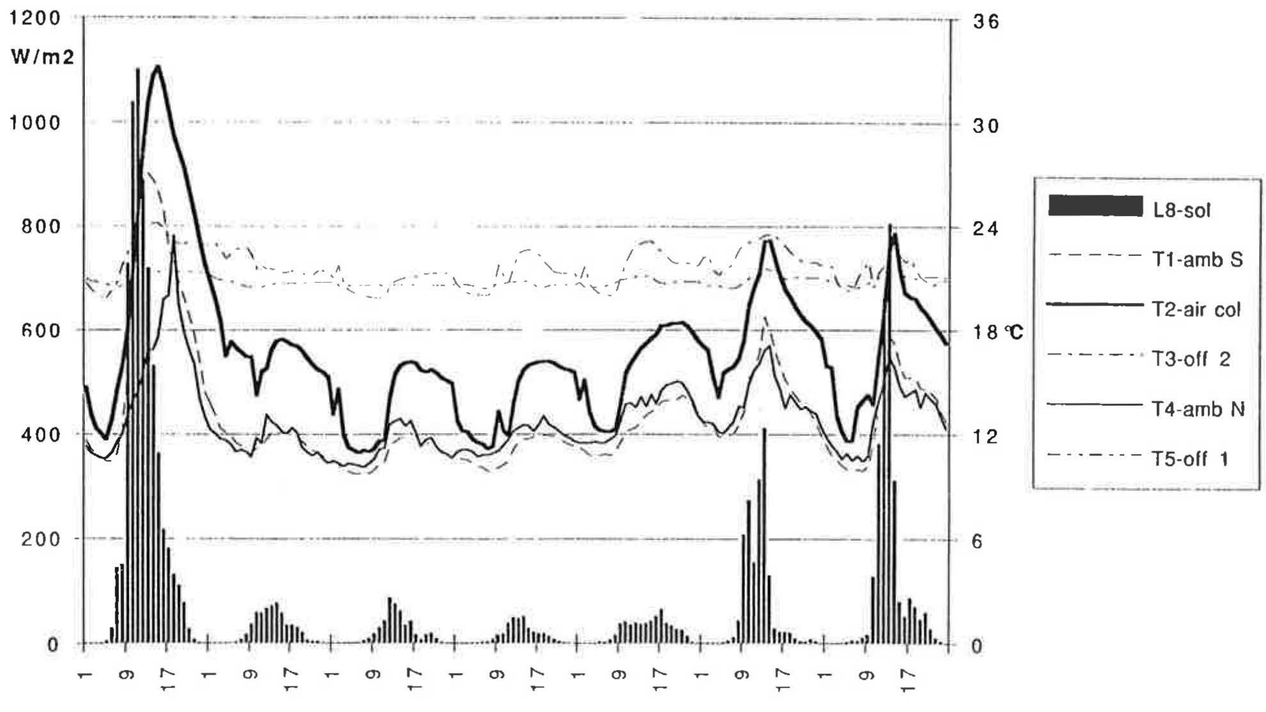

Figure 3: Solar radiation and temperatures; June 24 - 30, 1994.

9. FINDINGS

9.1 Energy savings during winter

Data are not available for a typical winter week, but the last week of June 1994 was cold with a total energy use equal to that of the first week of October the previous year. During operation hours, at a flow rate of 10,000 m3 per hour, the temperature increase varied from 0.4 °C to 15.8 °C. The energy saved by preheating fresh air in the collector this week was calculated to 1133 kWh. The energy represented by temperature increase of the air that passed through the collector when the exhaust fan was in operation (collector air temperature above 25 °C) was only 47 kWh.

9.2 Energy savings during summer

The first week of July 1994 was a warm summer week with several clear days. During operation hours the temperature increase through the collector varied from 0.3 °C to 19.0 °C. The energy saved by preheating fresh air in the collector this week was calculated to 1008 kWh. The energy represented by temperature elevation of the air that passed through the collector when the exhaust fan was in operation was calculated to 503 kWh.

9.3 Surplus energy during summer

The surplus energy produced by the solar collector when the outdoor air temperature is above 19 °C may be used to produce hot water, and to heat the floors of the locker rooms where most of the electricity for auxiliary heat is used today.

10. CONCLUSION

The monitored building performance shows that the solar collector contributes energy savings above 1000 kWh per week, which indicates that the actual annual savings could exceed the estimated 40,000 kWh. The solar collector would contribute additional energy savings if the surplus summer heat was used to produce hot water and to heat the floors of the locker rooms. The overall energy performance of the building could be improved by installing automatic light controls, and the indoor comfort could be improved by night flushing the building or by improved summer shading of the south-facing windows.