EXPERIENCE WITH PASSIVE SOLAR HOUSES IN SWITZERLAND

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1. Introduction

Nine single family dwellings were instrumented, and measuring campaigns were carried out between the years 1979 and 1983, supported by the Swiss National Energy Research Fund (NEFF). In (1) the authors have presented a comprehensive evaluation of the measurement results drawn from (2, 3, 4, 5). Table 1 shows the passive solar systems of the measured houses. Comparisons are made throughout the report (1) to a well insulated, non-solar dwelling having a legal minimum window area (6) as well as to a statistically average Swiss single-family dwelling (7).

2. Climate

It is important to keep in mind that the climate in the densely populated parts of Switzerland is characterized by moderate winters. From December through February there occur frequent **periods without any direct sunshine of up to several weeks** due to fog stratus. The horizontal global irradiation is 1100...1300 kWh/m2 year, the annual heating degree days are 3300...4000 Kd (20/12°C base).

3. Building Envelopes

The following paragraphs indicate to what extent the examined houses differ from "average" dwellings or from the SIA (Swiss Society of Engineers and Architects) Standards.

The **window glazing area** (as seen from inside) varies around the statistical average of 15...20 percent of the gross heated floor area. The four houses equipped with convective air systems (wall or window collectors and heat storage with closed loop) have even smaller window areas. However, the **total glazing area** including the air collectors exceeds the average window glazing area by 30...150%.

The percentage of south glazing including collector glazing does not exceed 80 percent of the south wall area due to the frame area. For the

	System		Location	Heated floor area (m2)	Ref.
INSTRUMENTED PASSIVE SOLAR HOUSES	Direct gain		Begnins	240	(2)
	Direct gain		Binz	195	(3)
	Convective (air)		Gonten	220	(3)
	Convective (air)		Oberglatt	160	(3)
	Convective (air)		Rothenfluh	152	(3)
	Convective (air)		Widen	197	(4)
	Greenhouse		Cologny *)		(5)
	Greenhouse		Les Geneveys	150	(2)
	Trombe wall		Renens *)	189	(2)
FOR COMPARISON	Minimum window		Cham	200	(6)

*) No energy balance available

Table 1. Passive solar systems of the examined houses

three houses with direct gain or with greenhouse the glazing percentage is not more than 20...40 percent, the lower value belonging to the "Binz" house, which in fact has no passive solar attributes.

The **heat loss coefficient** of the envelope is 180...477 W/K. When these values are normalized to the gross heated floor area for the purpose of comparison (see Fig. 1), three groupings appear clearly. The minimum window house "Cham" represents the lowest grouping of about 0,8 W/K,m2. This low value is explained not only by the small glazing area but also by the good insulation and the carefully avoided thermal bridges. The passive solar houses constructed after 1980 form the middle grouping. Finally, those built before 1980 comprise the upper grouping.

Three houses have **night insulation** of windows. Two of these houses are equipped with internal shutters mounted on the casement. The third has movable mylar foils with selective coatings.

It should be pointed out that the **construction** of the houses is a traditional mixture of masonry, wood and concrete with the exception of "Widen", which has a wooden frame construction on the upper floor. U-values of walls and roofs are 0,2...0,35 W/m2K.

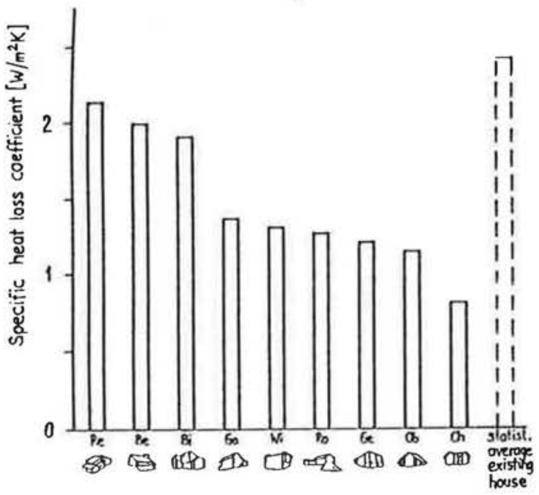

Fig. 1. Specific heat loss coefficient of the measured houses and of the statistical average single-family dwelling.

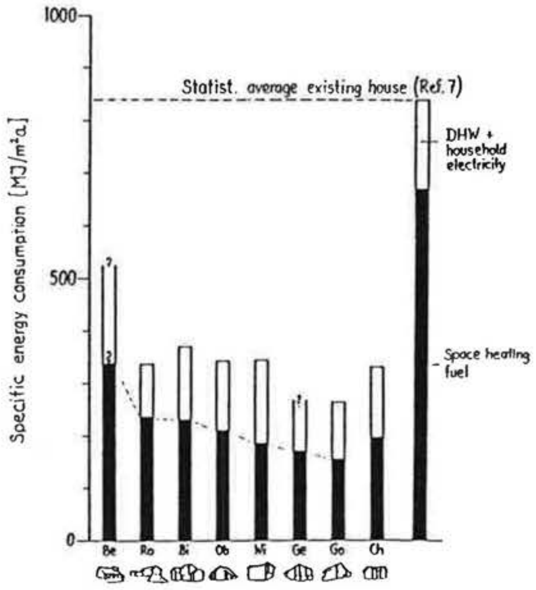

Fig. 2. Specific energy consumption for room heating and domestic hot water + household electricity.

4. Heating Systems and Energy Consumption

It is interesting to know that all houses of Table 1 with only one exception are heated with wood, although wood heating represents only a few percent of the Swiss space heating demand. This has to be taken into account considering Fig. 2. The **specific energy consumption** for space heating as shown (black bars) is influenced also by the occupants behaviour. The slow temperature decline in the well insulated houses makes it possible for the occupants to await the day's weather forecast before deciding whether to fire the wood stove. Such occupant behavior results in a heating strategy which anticipates the heating demand to come. This is more fuel conserving than would be the case with automatically controlled heating responding to momentary temperatures. For this reason it is difficult to make a direct comparison between occupant controlled wood heating and automatically controlled conventional gas or oil heating. It is safe to assume, however, that the latter is less fuel efficient.

Fig. 3 shows that the measured **specific net heat demand** is well below the threshold or target values as stated by the Recommendation SIA 380/1, which corresponds approximately to the legal construction standards in some Swiss districts. It represents only one third of the specific net heat demand of the average existing dwellings in Switzerland. When comparing to the heat loss coefficient shown in Fig. 1 one must remember that the specific net heat demand is also a result of the average room temperature, which differs from house to house.

The observed specific net heat demand has no correlation to the total glazing area, as can be seen in Fig. 3, if only the houses with a value below 200 MJ/m2a are considered.

5. Solar Contribution

The energy balances in Fig. 4 show that one third to about one half of the heat losses (gross heat demand) is covered by the sun in the passive solar houses. Note that the minimum window house "Cham" has a considerably smaller solar contribution, but a comparable net heat demand due to the better insulation (see Fig. 1). It may be concluded that better insulation of the measured passive solar houses would result in a higher solar fraction, as long as no serious overheating were to occur.

Moreover, the solar fraction could be increased by increasing the glazing area, but, again in order to prevent overheating, only in the form of air collectors. Fig. 5 shows the south wall of the four measured houses equipped with closed-loop convective systems. **Window collectors** produce higher transmission losses than **wall collectors**, but they also can provide direct gain even below an incident irradiation of about 400 W/m2. At these solar intensities, wall collectors are likely to be ineffective since the collector output temperature will often be below the storage temperature.

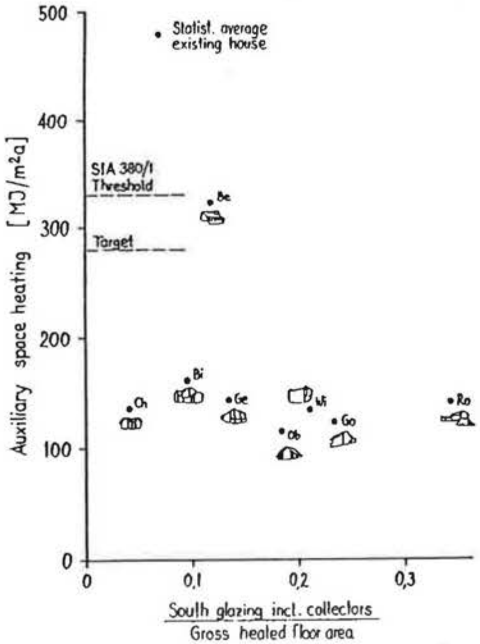

Fig. 3. Specific net heat demand vs. specific total glazing area (windows + collectors).

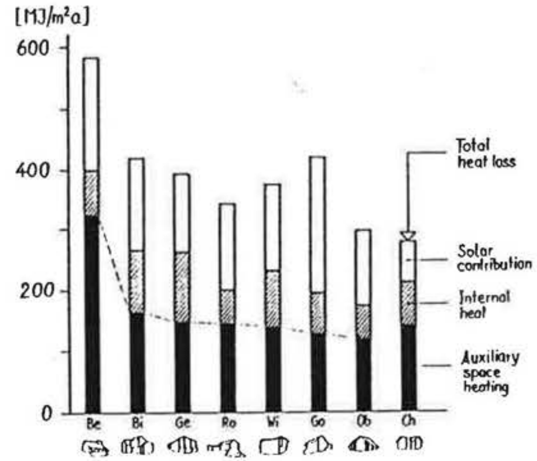

Fig. 4. Energy balance during heating season Oct.-May.

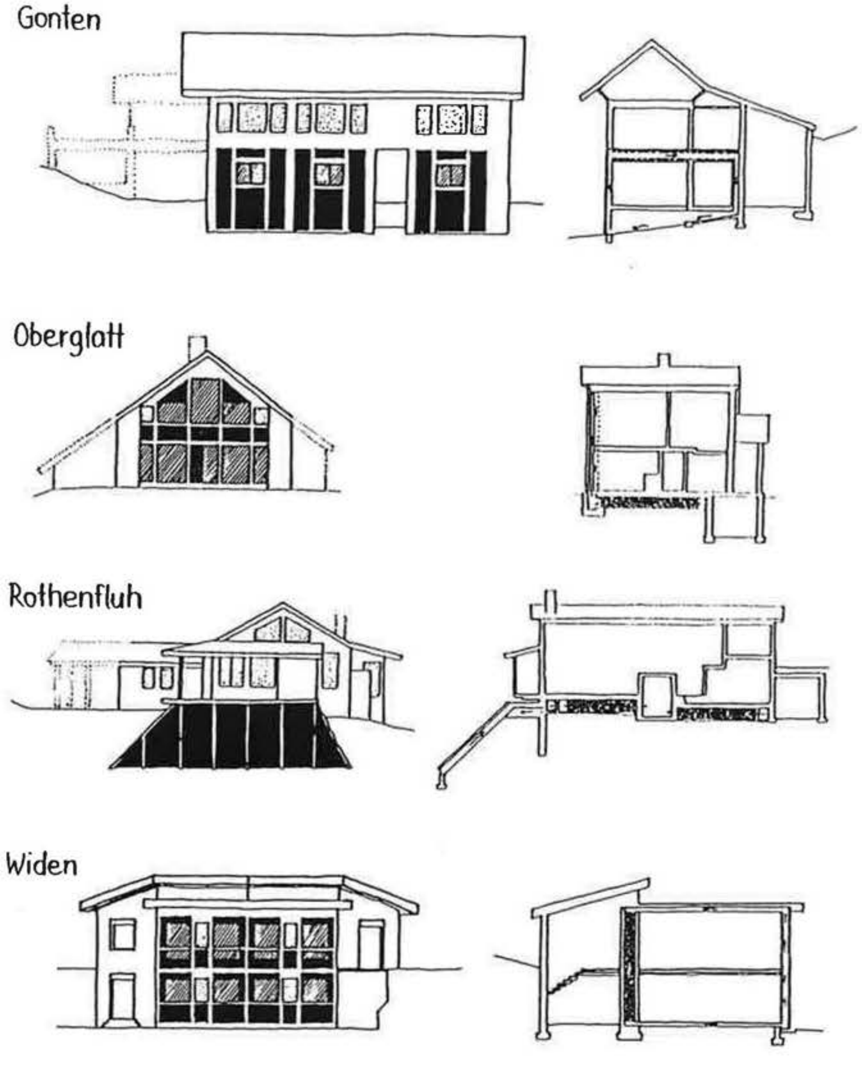

Fig. 5. South walls and cross sections with heat storage position of the four houses equipped with convective air systems (closed loop).

Wall collector (back side opaque)

Window collector (2 x double glazing with intermediate movable heat absorbing blind)

Window

A mixture of 1/3 window collecor area and 2/3 wall collector area has yielded good results. The rockbed or concrete heat storage acts as base load heating. High storage temperatures preclude the need for auxiliary heating when ambient temperatures are as low as -2°...-6°C on clear days and +3°...+1°C during overcast weather. This results in a shortened heating season of 3 1/2...4 months compared to the usual 7...8 months. However, note that the minimum window house "Cham" experiences the same shortened heating season of only 4 months!

The energy saving effect of a single and of a double glazed **greenhouse** with volumes of 33 and 80 m3 was computed to be roughly 5...10 percent relative to the energy consumption of the same house without greenhouse. Many recent computer simulations have led to similar conclusions. It is generally accepted that an attached greenhouse is an attractive element of living culture, but not necessarily a "cost-effective" means for saving energy. Misusage may even lead to energy waste.

6. Comfort

The average air temperature in most of the observed houses is between 18° and 19°C. Only two houses do not fit this pattern: "Widen" (see Table 1) with 20°C and some temporary overheating on the first floor and "Binz" with 15,5°C depending on the occupant's behavior.

Indoor comfort is reportedly improved by sunlight reflected by walls, by closed internal night insulation (shutters) and by radiation of tile stove surfaces.

7. Conclusions

An equally low auxiliary energy consumption was achieved by three different ways:

a. through a **large solar contribution** in fairly well to well insulated houses

b. through **very good insulation** (although not "superinsulation"), minimal window glazing area and an accordingly small solar contribution

c. through unusually **low room temperatures** in an average insulated house along with appropriate clothing of the occupants.

The following statements may be trivial for many experts; they are not so for the public or even for some architects:

- **Passive solar architecture** means "living with the sun". It demands an awareness and occupant response to the weather. Large amounts of south glazing (direct gain houses or houses with window collectors) lead to bright, exposed rooms - exposed, too, during bad weather and at night.

- **Non-solar architecture** with average or reduced glazing reduces the heat loss of the building envelope, but also cuts the amount of sun-generated room heat. The prevailing concept is not opening towards the environment but withdrawal into the interior of the house.

- **Very low auxiliary energy consumption can be achieved by either concept and all variations in between. The concept to be chosen is open to the creativity of the client and of the architect.**

8. References

(1) Schlegel, P.; Filleux, Ch.: Passive Sonnenhäuser. SIA-Doku D 011. Schweiz. Ingenieur- und Architektenverein, Postfach, CH-8039 Zurich.

(2) Faist, A.: IEA Task I "Investigation of the performance of solar heating and cooling systems", Final Report. GRES-EPFL, CH-1015 Lausanne. December 1982.

(3) Schäfer, U.: Messungen an Sonnenhäusern. Verlag der Fachvereine an den Schweizerischen Hochschulen und Techniken, CH-8044 Zurich, 1985.

(4) Arbeitsgruppe "Solar Trap": Analyse eines Pilotgebäudes (with separate appendix of measurement data). Basler & Hofmann, CH-8029 Zurich, June 1984.

(5) Moreno, Ph. et al.: Une serre habitable, mesures et simulations. Rapport final. Ecole d'architecture de l'Université de Genève, CH-1205 Genève, September 1984.

(6) Meisser, C.: Alternative Heizkonzepte für EFH mit hoher Wärmedämmung. In: 3. Schweiz. Status-Seminar Wärmeschutzforschung im Hochbau, EMPA, CH-8600 Dübendorf, October 1984.

(7) Wick, B.: Sparobjekt Einfamilienhaus. Verlags-AG der akadem.-techn. Vereine, CH-8045 Zurich, 1981.

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