THERMAL PERFORMANCE EVALUATION OF PASSIVE AND HYBRID SYSTEMS USING A LOW COST METHODOLOGY

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1. INTRODUCTION

In 1980 the Region of Lombardy, School Building Service, started a pilot program for energy conservation and solar energy applications in educational buildings. During the period 1981-1984 preliminary energy audits were carried out, funds were allocated and several energy saving measures were implemented.

In order to assess the cost-effectiveness as well as technical performances it was decided that field monitoring should be performed on these buildings.

As a first step a suitable methodology was developed. The main aim of this methodology is to answer the question:

how well do the retrofit measure perform ?

No attempt is made to understand the details of the performance mechanism. The cost and ease of implementation of the methodology were important considerations for the final choice.

In the fall 1984 the methodology was set-up to monitor two school buildings. The Montorfano School and the Lanzada School were instrumented as case studies in the late fall of 1984 and they are presented here.

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2. SITE AND BUILDINGS DESCRIPTION

The Montorfano Elementary School (Fig. 1A) is located about 5 Km. south east of the city of Como. The microclimate of this site feels the effect of the region around the lake of Como with moderately cold winters and warm summer.

The school building is made with concrete frames. Two class room wings are built on a gently sloping hill side and are partly below ground level on the corridor side (Fig. 1B). The section connecting the two wings is two storey. The ground floor has a custodian's apartment and school offices. The first floor contains the gymn.

The major retrofit measures were:

- increased envelope insulation,
- double glazing of the classroom windows,
- installation of a ventilation system with a solar air heater
- improvement of regulation system

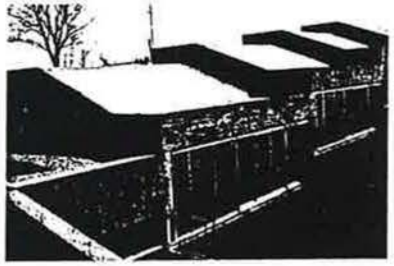
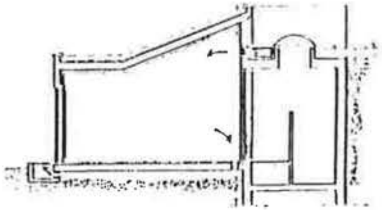


Figure 1 B SECTION



The Lanzada Elementary School (Fig. 2A) is located 20 Km. north of the city of Sondrio in Regione Lombardia. It is at the end of Valmalenco (a side valley of Valtellina), below the Bernina Range - in the Alps.

The microclimate is typical of the high alpine belt: snowy winter and spring with sunny days and cool nights. Summers are moderately warm.

The school is a masonry building made with massive stones, internally covered with bricks (average thickness 70 cm.). The school has a compact shape with all the classrooms facing south. It is a three storey building with a small gymn at the lowest level (Fig. 2B).

The major retrofit measures were:

- Increased envelope insulation on North side.
- Double glazing of all windows on the North side.
- Insulation of the loft.
- Installation of solar air heaters on South facade connected with a ventilation system.

Figure 2 A LANZADA SCHOOL FACADE AFTER RETROFIT

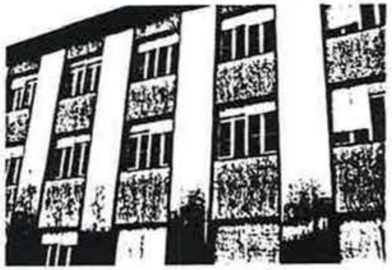
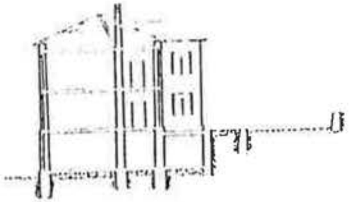


Figure 2 B SECTION



3. METHODOLOGY AND DATA COLLECTION

The chosen methodology is aimed to determine the passive gains and to evaluate the thermal performance of various building subsystems (conventional boiler, solar air heater, etc). The conduction heat loss coefficient (UA) and the infiltration rate were obtained respectively by means of co-heating and tracer gas measurement techniques. Both of these are standard techniques and are briefly described later in this section.

All energy sources, such as the heat supplied from auxiliary heater and solar air heaters and internal gains were monitored. Using these monitored data, energy balance for the whole building is performed. The following equation is used to determine passive solar gains:

$$Q.passive = Q.loss - Q.auxiliary - Q.internal - Q.collector \quad (1)$$

Q.loss is made up of three parts:

$$Q.loss = Q.conduction + Q.infiltration + Q.ventilation \quad (2)$$

were Q.'s are the various net heat losses or gains through the building envelope. The measured indoor-outdoor temperature difference, total heat loss coefficient (UA) and infiltration rate are used to calculate Q.loss assuming steady state conditions.

For short time intervals (less than a few days) this assumption is not valid, since the time constants of the buildings are of the order of few days. However, for periods greater than a week the thermal mass effects are small, and fully neglegible for seasonal energy balance.

The heat delivered to the building is composed by: (i) heat given off by the hot water circulating through the convectors, (ii) the heat supplied by the forced hot air, which is preheated by the solar air heater and further heated by passing over a hot water radiator (only for the Montorfano system) and (iii) the passive gain through glazings and opaque surfaces.

The measured values of inlet-outlet temperature differences and the flow rates of hot water and forced air at various points along the flow paths, are used to determine the heat delivered by the hot water convectors and the solar air collectors. This information, when used in equation (1), yields both opaque as well as transparent passive contributions.

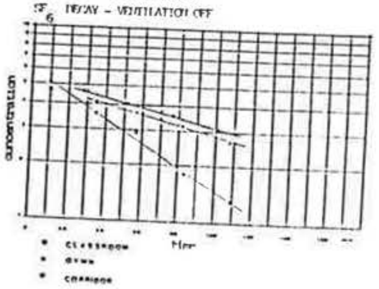
The data collection was limited to a level adequate for carrying out the performance evaluation using the methodology outlined above. This includes the measurements of temperatures, insolation, auxiliary heating, hot water flow rates, mixing fan on/off time, humidity, wind speed etc. All probes were calibrated in the laboratory before field installation.

The Solartron Schlumberger ORION is used for data logging. It allows some conversion on probes, counters unit and measures of events. The data were recorded on a cassette tape and later transferred on to the VAX 11/750 system via Modems and Telephone Line.

Tracer gas measurements.

The tracer gas measurements were done at different places in each building: class rooms, corridors and gymnasium. The measurements were made under natural as well as forced ventilation. The gas (SF6) was injected and allowed to mix for approximately half an hour. Four to five samples were taken from each space at successive intervals of 15 minutes. The concentration of SF6 was then measured using gas chromatography. From the SF6 concentration decay rates, the air exchange rates were obtained. Figure 3 shows gas decay at Lanzada school in three different building zones.

Figure 3 - LANZADA SCHOOL
SF_6 DECAY - VENTILATION OFF



Coheating measurements.

The main purpose behind coheating technique was to check the calculated heat loss coefficients with field measured values. Due to several technical problems, the standard coheating method using electrical heating could not be carried out for the whole buildings. It was therefore decided to perform tests on single rooms and to use the results for evaluating the conduction loss coefficient for other part of the buildings. The following procedure was used: electrical resistance heaters replaced normal auxiliary system in the zone under test. Corridors and adjacent rooms were kept at constant temperature by using the regular heating systems. From the information on temperatures, electrical auxiliary heating supplied and the SF6 decay rate during the test, the heat loss coefficient could be calculated. Since the buildings have large thermal mass, special care was taken to ensure that the indoor temperatures were constant. Furthermore the experiments were conducted during a night proceeded by many overcast days. It was found that this brings to values 30-40% lower than the values calculated according to Italian Standard UNI-CTI procedures. (see Table I)

TABLE I - UA Values (W/C)

	(UNI-CTI) Before	(UNI-CTI) After	Measured After
Montorfano Classroom	313	187	130
Montorfano Whole Blg.	6054	5044	3430
Lanzada Whole Blg.	2311	1744	1145

TABLE II - Infiltration Rates (ACH)

	Occupied Fan ON	Unoccupied Fan OFF
MONTORFANO		
Classroom	2.78	0.50
Corridor	2.28	0.50
Gymn	1.96	0.50
LANZADA	Fan OFF	
Classroom	0.60	0.41
Corridor	2.00	1.86

4. DATA ANALYSIS

The main objective of the data analysis was to determine the total heat losses, auxiliary energy used, internal and solar gains. The solar energy contributions consist of two parts: the energy provided by the solar air collectors (active part) and the passive solar gains.

Total Heat Losses. The heat losses through the building, due to conduction, infiltration and ventilation, were calculated assuming steady state conditions. As mentioned earlier, this assumption is valid for periods longer than the time constant of the building. The conduction heat losses were calculated using the value of conduction loss coefficient (UA) as determined above and the measured indoor-outdoor temperature difference (DT).

$$Q.conduction = SUM_j \ (UA)_j * DT_j * Dt \qquad (3)$$

The infiltration heat losses were calculated using the infiltration rate determined from tracer gas measurements and indoor-outdoor temperature difference.

$$Q.infiltration = SUM_j \ (V_j * R_j * ra * Ca * DT_j * Dt) \qquad (4)$$

The Ventilation Losses were calculated using the ventilation rate and indoor-outdoor temperature difference. An equation very similar to Equation (4) is used to calculate ventilation rate for the fan-on periods.

Auxiliary energy is provided by hot water radiators. The energy supplied by the hot water was calculated from the information on inlet-outlet water temperature differences and water flow rates, and the on-time of the circulating pump.

$$Q.auxiliary = F * rw * Cw * DT * Dt \qquad (5)$$

were: Vj = Volume of the j th space
Rj = Air Infiltration Rate for the j th space
DTj = Temperature difference between the j th space and outdoor
ra/rw = Density of air/water
Ca/Cw = Specific Heat Capacity of air/water
Dt = Durations
F = Water Flow Rate

Internal Gains: the information on the number of occupants, time of occupancy and the lighting level was used to evaluate internal gains.

Boiler Efficiency: the fuel flow rate and the burner on-time gives the total oil burned and finally the oil burned along with the auxiliary useful energy delivered, gives the heating system efficiency.

Solar contributions: the measured values of the air flow rate through the collector, the inlet-outlet air temperature difference and the time for which the fan is on, were used to calculate solar active contributions supplied by the solar air collectors. An equation similar to Eq. (5) is used for this calculation. Finally the passive solar contributions are calculated subtractively using Equation (1). However any errors made in the calculation of Q.loss and Q.aux are lumped into the passive contributions.

5. RESULTS AND DISCUSSION

Montorfano Elementary School

The heat balance for the building was performed in three stages. In the first stage only the classroom heat balances were analyzed (see Table III A). The class rooms have large glazings and hence collect a considerable amount of solar energy. The value of 28% (20% passive; 8% active) for the 10 day period looks good.

The corridors which have strong thermal coupling with rooms receive very little direct solar energy. As expected the solar contributions drop to 15% (11% passive, 4% active) for 10 day period (see Table III B).

For the whole building the solar contribution is 18% (15% passive and 3% active). The slight increase in solar gains over that for the rooms and corridor case is due to the fact that the main building has considerable south facing glazing (see Table III B).

The heating system efficiency varied between 50.1% to 58.7%. The boiler was sized for the heating requirements before the retrofit measures. Since the retrofit measures reduced the heat load considerably, the boiler operates more intermittently, thus lowering the efficiency.

The highest hourly efficiency for the solar air collector system is 50.7% and the average for the 10 days period presented here is 34.6%. These values are rather low and the reason is due to the fact that the glazing of some collectors were found defective. For clear sky days, the solar air heater system is nearly 40% efficient with istantaneous value as high as 65.7%.

TABLE III A
CLASSROOM – MARCH '85

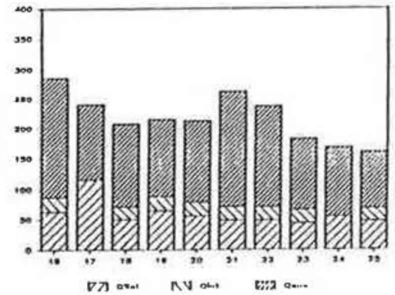


TABLE III B
CLASSROOMS & CORRIDORS

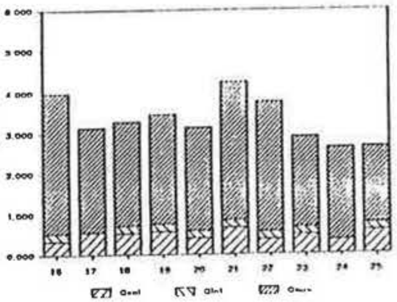
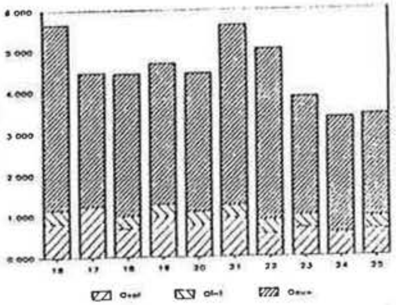


TABLE III C
WHOLE BUILDING



To understand the performance of the solar collector, the heat balance for one day is presented in Table IV.

The solar contributions to the heating energy requirements are quite reasonable although, for building licensing constraints, only 42.5 m2 of solar air collector were installed instead of the 130 m2 originally planned.

Lanzada Elementary School

Two 12 day periods were analyzed. The two periods are representative of typical spring and autumn climate.

During the twelve day period in autumn (November) six days were sunny and six days were overcast. In March, eight days were sunny and four days were overcast. The average ambient temperature is nearly the same during these periods.

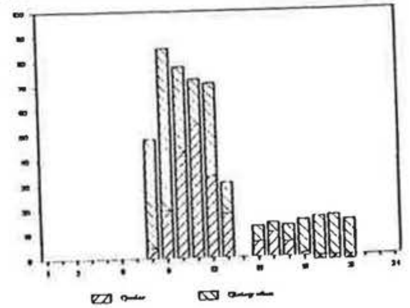
The bar chart in Table V shows the hourly auxiliary delivered to the building and the solar energy incident on collector plane for a period of three sunny days.

The heat balance calculations were performed for the whole building. The results for 12 days period in March and November 1985 are presented (Table VI and VII).

The daily energy balance has little meaning, because of different shifts in the various contributions due to the transient effects through the thick walls, but the results avereged over twelve day periods are nearly free of thermal mass effects.

The building collects a considerable amount of solar energy: the south facade has 84 m2 of direct gain aperture (windows) and 130 m2 of collector area out

TABLE IV
MONTORFANO MARCH 20, 1985
SOLAR COLLECTOR HEAT BALANCE



'TABLE V
LANZADA 14-15-15- NOVEMBER'85

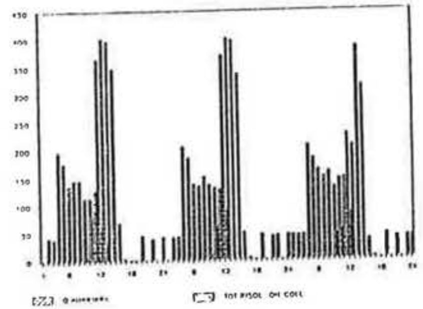
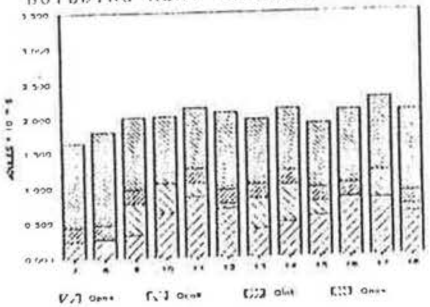


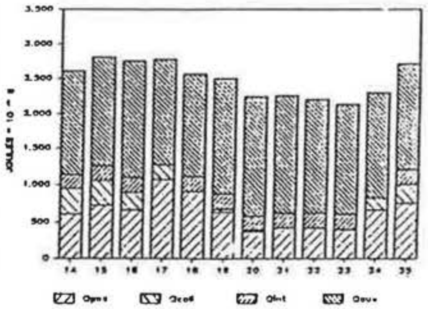
TABLE VI
LANZADA MARCH '85
BUILDING HEAT BALANCE



of a total of 380 m2 of the south facade area.

The collector efficiency in the two periods doesn't exceed 30% and 20% respectively. This low efficiency was mainly due to incorrect positioning of the fan in the air circulation loop (at the inlet to the collector instead of the outlet) which provoked excessive air leakages in the region of the collectors. The measured air flowrate is 1200 m3/h leaving the collectors versus 3200 m3/h of air forced into the collectors and pushed through.

TABLE VII - LANZADA - NOV. '85
BUILDING HEAT BALANCE



The total solar contribution, with respect to the total load, is 30% in November and 39% in March; respectively 25% passive, 5% active and 27% passive, 12% active. The results are good and the collector contribution will increase if the existent ventilation unit is moved to the attic as suggested.

6. CONCLUSIONS

The results show how trivial errors in installing solar components can lead to lower energy performance and considerable waste of energy. To date, many solar systems have been installed in Italy. However, due to lack of detailed knowledge of solar systems and to underestimation of increased complexity of hybrid systems, the effect of these systems often does not correspond to design expectations. These constructive deficiencies are very dangerous, because, by giving a negative demonstration, they reduce the potential uptake of correctly installed systems. The defects noted show an impelling need for the training of qualified personnel in design, installation an management in hybrid solar systems.

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ERDBEDECKTES BUEROHAUS MIT HYBRIDEM SONNENENERGIESYSTEM, KONVEKTIVER CHAMAELEON-FASSADE UND GEROELLSPEICHER

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1. Konzept

Der längliche Bürotrakt von 10/20 m nimmt die ursprüngliche Hügelkuppe links ab und ersetzt diese in künstlicher, erdbedeckter Bauweise. Das ganze Gelände steht dem Wohnhaus als Grünfläche wieder zur Verfügung. Die konsequente Ausbildung einer Temperaturschichtung von Süden nach Norden, in Form von Pufferzonen, reduziert die Wärmeverluste. Das Fensterband ist mit 3.20 m im Süden weit geöffnet. Dies leuchtet am 22. Dez., mittags, den Arbeitsraum in seiner ganzen Tiefe aus und macht so aus der "erdbedeckten Höhle" einen lichtdurchfluteten Arbeitsraum. Mit dem Luft- und Fensterkollektor wird bei Sonneneinstrahlung warme Luft erzeugt, die durch einen Ventilator in den Geröllspeicher geblasen wird. Dieser erwärmt sich und gibt die Wärme passiv, durch eine Zwischenisolation verzögert, an den Raum ab. Die Arbeitsräume sind von diesem geschlossenen Warmluftsystem unberührt und werden individuell durch Fensterflügel belüftet. Freie Luftzirkulation zwischen Büro und Reduit sowie Oberflächenmaterialien mit hoher Wärmeleitfähigkeit führen die eingestrahlte Wärme in die Gebäudemasse ab und sorgen so für eine hohe thermische Trägheit und somit für ein ausgeglichenes Raumklima. Zur Erweiterung des Strahlungsangebotes, ist vor der Fassade ein weisses Band aus Steinplatten als Reflektor angelegt.

Bild 1. Gesamtansicht von Süden; links erdbedeckter Bürobau, rechts Wohnhaus

Bild 2. Dachaufsicht erdbedeckt, bepflanzt. Die Spielwiese ist vollständig begrünt und mit einer Randbepflanzung versehen

2. Gebäudehülle, Erdbedeckung

Der Gebäudehülle kommt bei jedem energiebewusst konzipierten Gebäude grosse Bedeutung zu. Dies gilt natürlich umsomehr bei erdbedeckter Bauweise. Der Dachaufbau ist wie folt ausgeführt:

18 - 24 cm	Beton
	Dampfsperre
2 x 60 mm	PU
1.2 mm	Kunststoff-Folie
60 mm	Polystyrol-Sickerplatten
200 g/m2	Filtermatte
30 - 50 cm	Humus

Zudem wird durch die Erdbedeckung ein erheblicher, oekologischer Beitrag gegen die Verbauung unserer Landschaft geleistet.

Der Wand- und Bodenaufbau ist analog. Die Isolation ist im Bereich Boden/Wand in einer Stärke von 200 mm durchgezogen. Nur statisch notwendige Punktauflager durchdringen diese.

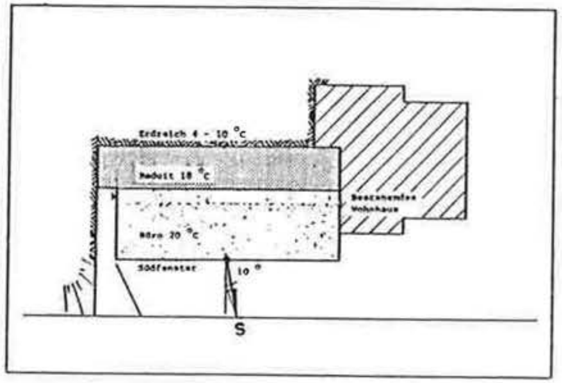


Bild 3. Pufferzonen. Die Temperatur nimmt von Süden nach Norden ab

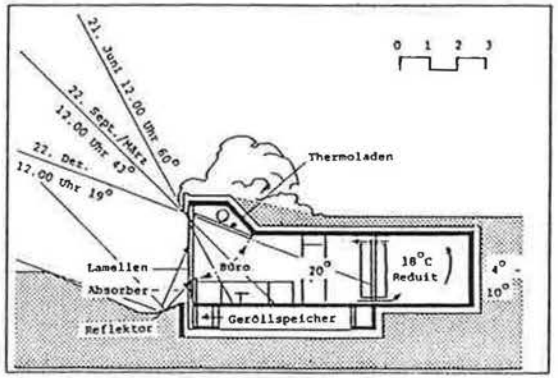


Bild 4. Schnitt durch das Gebäude

3. Kollektorfassade, Geröllspeicher

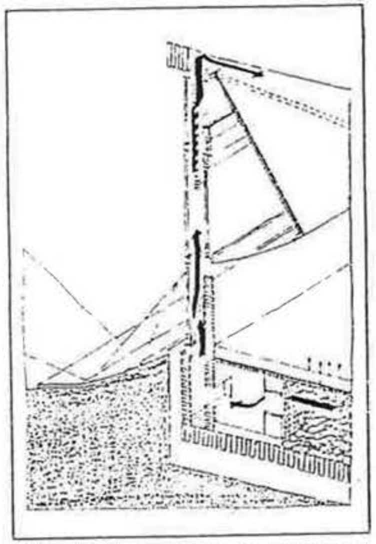


Bild 5. Perspektive Kollektorfassade/Geröllspeicher

Die Kollektorfassade besteht vertikal aus drei verglasten Teilen: der Brüstung, dem Sichtteil und dem Oblicht. Im Querschnitt von aussen nach innen folgen: Stahlfenster, thermisch getrennt, Isolierglas 2-fach; Luftzwischenraum 15 - 20 cm; Holzfenster, Isolierglas 2-fach, resp. Brüstung als Sandwich aus Eternit, weiss, und 100 mm PU.

Die Fassade kann - einem Chamäleon gleich - der thermischen Situation entsprechend, farblich verändert werden. In der Speicherperiode (21. Aug. bis 13. Apr.) werden im Brüstungsbereich schwarze Absorber aus Steckmetall eingesetzt; im Oblicht- und Sichtbereich stehen die Lamellenstoren - mit der brauenen Seite nach aussen - unter 45°. Die Fassade ist dunkel, auf Absorption eingestellt. Im Sommer werden die Absorber aus dem Brüstungsbereich entfernt, der weisse Eternit wird sichtbar; im Oblicht- und Sichtbereich stehen die Lamellenstoren mit der weissen Rückseite zur Sonne. Die Fassade ist weiss, auf Reflexion eingestellt. Grosse Thermo-Klappläden, die am Tag einen Teil der Decke bilden, werden im Winter in der Nacht und übers Wochenende von Hand heruntergeklappt und reduzieren so den Bruttowärmebedarf um 28%. Ein zweistufiger Ventilator wälzt die Luft temperaturgesteuert um. Thermosyphonzirkulation in der Nacht kann nicht ausgeschlossen werden.

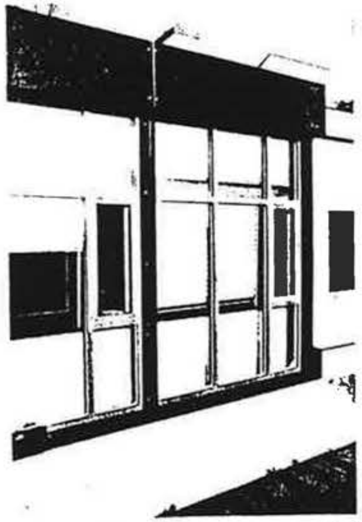


Bild 6. Die Chamäleonfassade dunkel, auf Absorption eingestellt

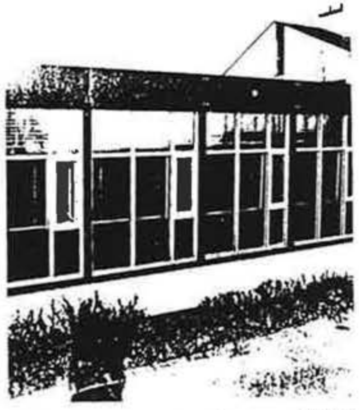
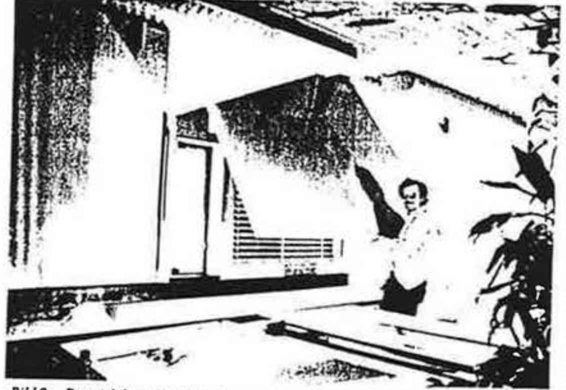


Bild 7. Die Chamäleonfassade weiss, auf Reflektion eingestellt

Bild 8. Thermoladen beim Herunterklappen

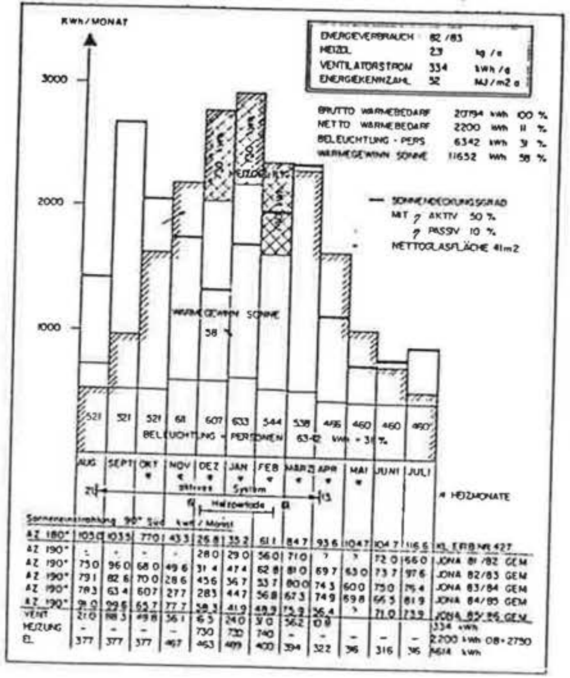


4. Energiebilanz 82/83, Energiekennzahl

Durch die konsequente Isolation beträgt der Bruttoenergiebedarf noch 94.8 kW/m2a. Dieser wird zu 31 % durch Beleuchtung und Personen (Strom gemessen) und zu 11 % als Nettowärmebedarf durch die Oelheizung des Wohnhauses gedeckt (gemessen). Die Wärmeverteilung erfolgt durch Niedertemperaturheizkörper mit Thermostatventilen. Die Heizsaison dauert vom 6. Dez. bis 19. Febr. Es wird nur an Wochentagen - vor und während der Arbeitszeit - geheizt. Der Restwärmebedarf (ca. 58 %) wird durch die Sonne gedeckt. Ein Solarimeter misst die momentane, tägliche und monatliche Einstrahlung auf die vertikale Fassadenfläche. Der Stromverbrauch für den Ventilator beträgt 1-1.5 % der Bruttoeinstrahlung.

Die Heizenergiekennzahl beträgt 52 MJ/m2.a und liegt, verglichen mit konventionellen Bauten, bei ca. 10 %.

Bild 9. Energiebilanz 1982/83, Sonneneinstrahlungswerte AZ 190° vertikal, Jona gemessen



5. Behaglichkeit, Gebäudeträgheit

In Diagrammen wurden die gemessenen Temperaturwerte als Wochenminima und -maxima aufgetragen. Die Raumtemperatur (Bild 11) erreicht in den Sonnenspitzenmonaten das Maximum am Nachmittag bei +29°C. Durch Nachlüftung sind dann die Temperaturen am Morgen wieder auf 24-25°C. Die grössten Schwankungen pro Woche sind in den Monaten Dezember und Januar zu verzeichnen, da bei diesem kleinen Sonnenangebot - auch bei einem strahlenden Tag - die Storen kaum gezogen werden, sodass volle passive Sonnenenergienutzung vorliegt. In der Periode vom 16. Dezember bis 5. Januar wurde das Gebäude während 18 Tagen ohne Fremdenergie sich selbst überlassen. Die Raumtemperatur betrug am 5. Januar noch +17°C.

Die Speichertemperatur (Bild 12) hat Ende August ca. Raumtemperatur angenommen und steigt dann bei Speicherbeginn, durch das grosse Sonnenangebot im September, um ca. +3°C/Woche. Aus den Kurven ist zu entnehmen, dass nicht ein Wochen-/Monats-/ oder Saisonspeicher definiert werden kann. Grob gesagt, lässt sich die Septemberwärme in den November "retten". Dies sind immerhin 2 Monate.

Die Bodentemperatur (Bild 10) weist wesentlich kleinere Schwankungen auf als die Speicher- oder Raumtemperatur. Die Klinkerplatten wirken sehr temperaturausgleichend.

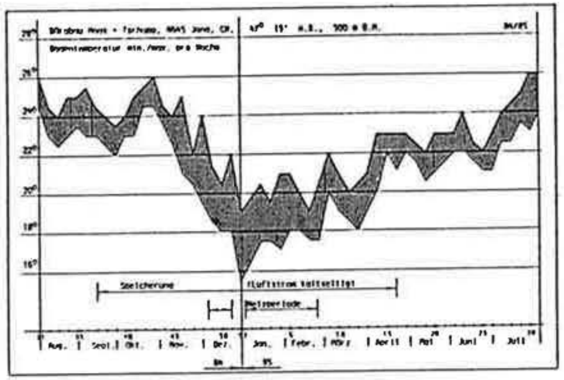


Bild 10. Bodentemperatur, min./max. pro Woche

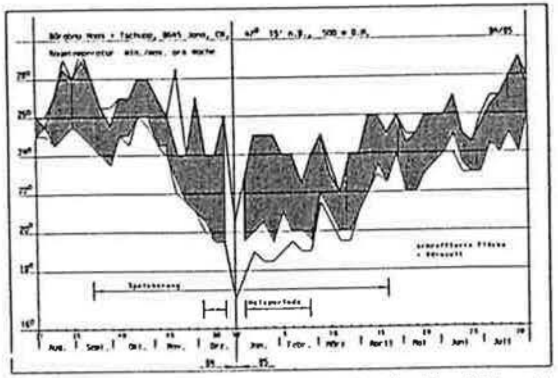


Bild 11. Raumtemperaturen min./max. pro Woche (schraffierte Fläche = Bürozeit)

Bild 12. Speichertemperatur min./max. pro Woche

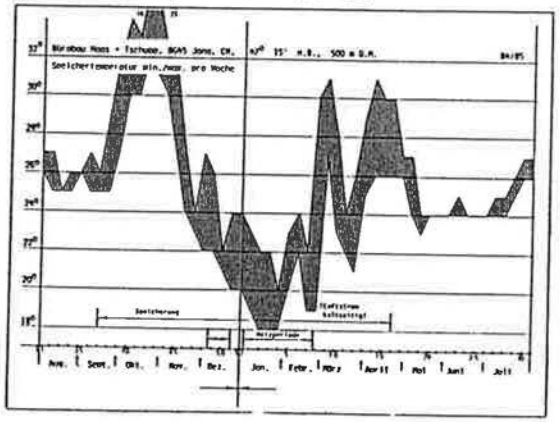


Bild 13. Aussentemperatur min./max. pro Woche

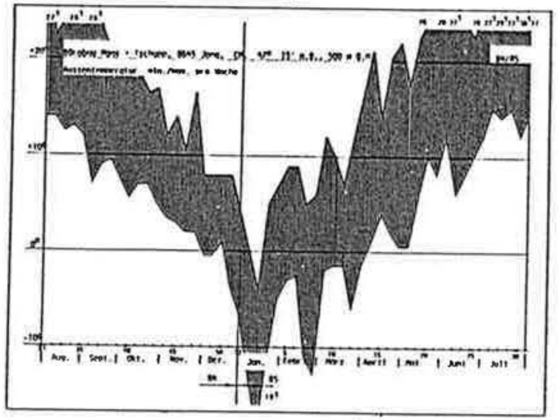


Tabelle 1. Klima und Gebäudedaten

Klima:	
geogr. Breite	47° 15′
Höhe über Meer	500 m
Fassadenorientierung	AZ 190°
Heizgradtage (ZHSMA)	3718 HGT (Jahr)
Gebäudeabmessungen:	
Energiebezugsfläche	213 m²
m³ SIA mit Speicher	1180 m³
m³ SIA ohne Speicher	1075 m³
Kollektorflächen netto	41 m²
Geröllspeicher	60 m³
Thermische Gebäudemasse	C = 80 kWh/K

6. Kosten, Wirtschaftlichkeit

Vergleicht man die Jahresgesamtkosten (Kapitalkosten + Heizkosten) pro m3 für den Büribau H + P mit einem konventionellen Bau, setzt den konventionellen Bau 10 % billiger, die Energiekosten aber 10 x höher ein, so ergibt sich (Zins 6 %, 50 J. a = 6.34 %, Heizoel Fr. 80.--/100 kg, Geschosshöhe 3.0 m):

Bürobau	H + P	konventionell
m3-Preis	Fr. 347.--	Fr. 312.--
EH MJ/m2a	52	520
Kap. + Amort./m3.a	22.43	19.78
Energiekosten/m3.a	0.33	3.25
Gesamtkosten/m3.a	Fr. 22.76	Fr. 23.03
	98.8 %	100 %

Das Gebäude ist also auch gegenüber einem günstigeren Bürobau mit einem relativ kleinen Energieverbrauch wirtschaftlich. Rechnet man jedoch das gleiche Gebäude mit und ohne aktive Sonnenenergieanlage, so lassen sich die Fr. 86'000.-- Mehrkosten kaum amortisieren.

Tabelle 2
K-Werte, Brutto-Wärmebedarf, Energiekennzahl

Decke	12 cm PU.		0,210 W/m^{2}K
Wand	12 cm PU.		0,230 W/m^{2}K
Boden	20 cm PU.		0,170 W/m^{2}K
Fenster:	Tag		1,600 W/m^{2}K
	Nacht		0,350 W/m^{2}K
Tag	Betrieb	QH = 6400 W	(n = 0.30)
Nacht		QH = 4600 W	(n = 0.15)
Energiekennzahl:			
EH	Öl (η = 80%)		= 46 MJ/m^{2}a
EH	Ventilator		= 6 MJ/m^{2}a
EH	= Heizenergiekennzahl		= 52 MJ/m^{2}a
EEL	= Energiekennzahl Strom		= 70 MJ/m^{2}a
E	= Total.		= 122 MJ/m^{2}a

7. Probleme

Die Isolation über dem Geröllkoffer ist zu dünn, es liesse sich länger und höher speichern (ev. ohne Fremdenergie). Der sommerliche Wärmeschutz kann noch verbessert werden. Im Winter setzt sich Kondenswasser im Luftkollektor an (äesthetisch), das aber problemlos abgeleitet werden kann. Das Betreiben der Anlage ist technisch einfach (nur ein Ventilator), bedingt aber gute Wetterbeobachtung und ein Gefühl für die einzelnen Einflussgrössen. Durch Fehleinschätzungen des Wetters, können die Solltemperaturen in den Randzeiten unterschritten werden.

Tabelle 3. Daten Luftkollektor/Geröllspeicher
(Vergleiche mit weiteren Luftkollektoren siehe [4], S. 117)

Ventilatorstufen		ST 1		ST 2	
Ventilatorleistung		265	W	630	W
Ventilatorleistung/m^2 Koll.		6,5	W/m^2	15,4	W/m^2
Luftgeschwindigkeit					
	Kanal	1,53	m/s	4,56	m/s
	Kollektor	0,07	m/s	0,20	m/s
Max.	Stundenleistung	590	m^3/h	1760	m^3/h
Max.	Stundenleistung/m^2 Koll.	14,4	m^3/h	43	m^3
Steuerung:					
Temperaturdifferenz Lamelle/Speicher		10 °C		-	
Kollektortemperatur		-		40 °C	
Max. Tagesleistung		14 670 m^3/d			
Kollektorfläche netto		41 m^2			
Geröllspeicher		60 m^3, 30 kWh/K			
Geröllspeicher/m^2 Koll		0,73 kWh/Km^2 1,46 m^3/m^2			
Druckdifferenz total		11 mm H20			