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Passive Solar Buildings Concepts for Building Renovation and New Buildings

Keywords:

Direct solar gain.
Summer protection.
Energy recovery
Architectural integration.

1. Introduction

Passive solar systems (passive solar buildings) derive from the fact that the amount of solar energy that enters through a window vertically oriented to the South, with high quality glass, the latitude of 45°- 46°, is greater than that which is dispersed in the same period. If the local rear Windows, properly oriented, is characterised by particular characteristics of thermal insulation, heat-mass and heat recovery from air expulsion, seasonal heat balance of the enclosure can be null. The demand for heating of the venue will be necessary, then, only for limited periods of bad weather during which internal air temperature, for lack of sunlight, falls below acceptable values. These needs are very content and can be supplied from plants active simple and very small. Also, if you accept the conditions of internal temperature variability within certain limits, may renounce after-heating environment.

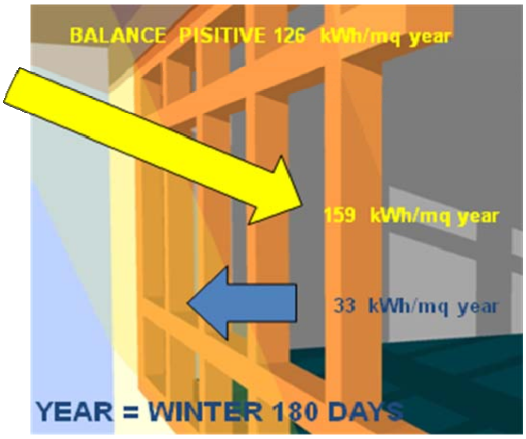


Figure n. 1 The amount of solar energy that enters through a window vertically oriented to the South, with high quality glass, is greater than that which is dispersed in the same period. In order to keep the heating the heat you need a good quality of heat insulation.

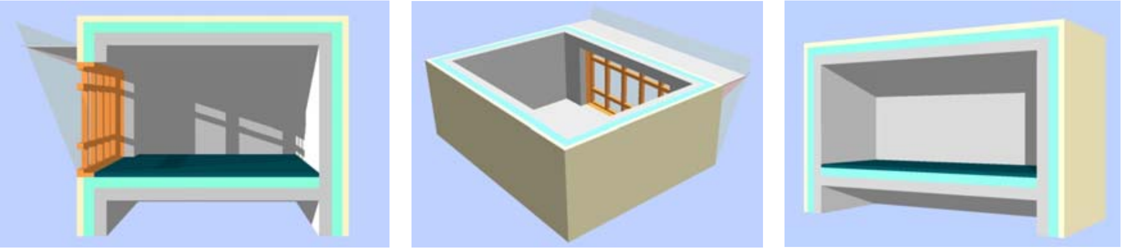


Figure n. 2-3-4 If the local rear windows, properly oriented, is characterised by particular thermal insulation, heat-mass and heat recovery from air expulsion, heat balance seasonal of the local can be null.

The behaviour of passive solar buildings, also equipped with summer radiation shielding, may be known using a suitable calculation program. Reliefs of real consumption of energy and performance internal temperatures, in the cold season, have confirmed the goodness of the simulation of the calculation program adopted.

Below, four cases of passive solar buildings are described. Of these, the first three were built and completed, therefore, their energy behavior in winter and summer, is known. The fourth is, instead, an intervention on an existing building, that we want to re-qualify energetically and relate to a passive solar system, and it is being designed.

2. Solar home in Onigo Treviso - Italy

It was 1983 when I suggested to my client to build a "solar house". The first energy crisis had sensitized public opinion and he accepted. But he had not just been convinced by the potential energy savings, but also by the large amount of natural light that entered the rooms.

Photo n. 1 A large amount of natural light penetrates into the rooms.

Large windows South, a porch that protects the wall and a few openings placed in the North, a remarkable structural mass benefited from the characteristics of earthquake-House and a big thickness of coat isolation on the walls and externally to the floor and the covering (10 cm of PU in situ), are some design features. Sunscreen summer was entrusted to fixed protections both vertical and horizontal-inclined and tree-lined paths. The architectural result and technical content are consequential to the input adopted.

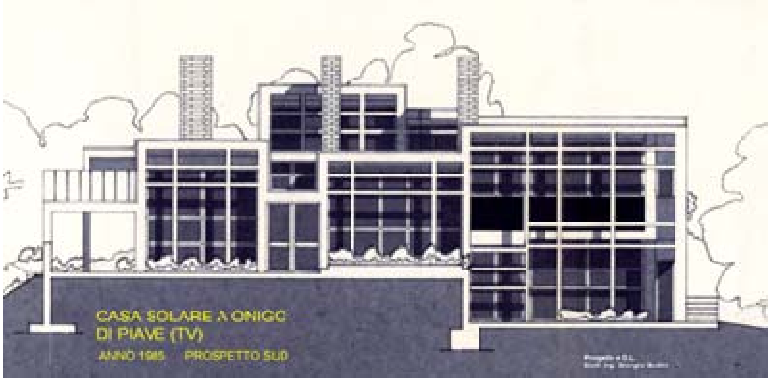
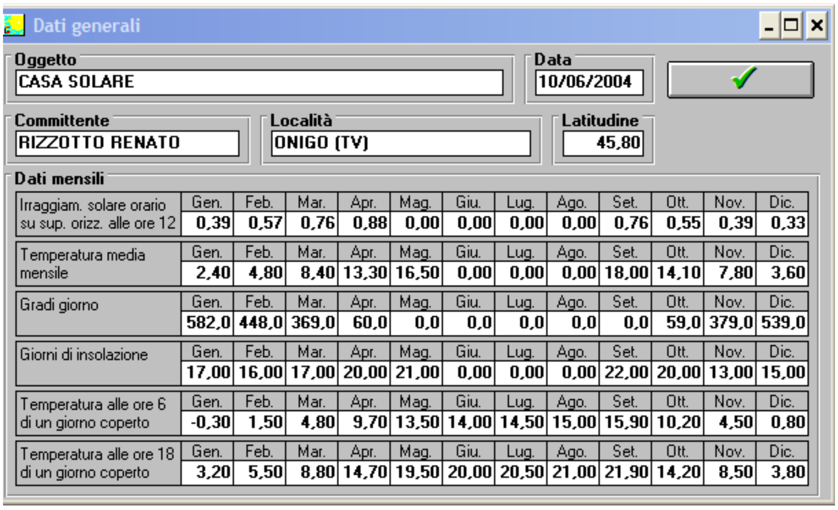


Figure n. 2 The result architectural and technical content are consequential to the input adopted.

The energy performances have been simulated by a graphic-analytic procedure with the use of the cylindrical solar diagram, of the calculator of solar radiation, of the shadows calculator, of the masks of shadowing, of the calculation of the contribution unit solar thermal, of the seasonal needs heating and of the calculation of internal average temperature and the daily temperature fluctuation. The simulation was made for each South-facing window, for each local heated by the Sun and for each month of heating (October to April).

Through the energy calculation resulted very low dispersion heat, and, of these, 70% came from the Sun. We haven't been able to build the house as designed because of obscure limitations by the Municipal Administration, consequently the sleeping area was modified. The performance and "solar" characteristics have been kept in the living area. In the years just after the construction (1985), I developed a simplified calculation program that contained all the procedures and climate data, formal, technical and physical-dimensional, needed for a complete simulation passive solar energy. The application of this program on the manufactured as being built, has confirmed some manual calculation results and has given the new solar system performances as a result of the important architectural solar changes imposed.

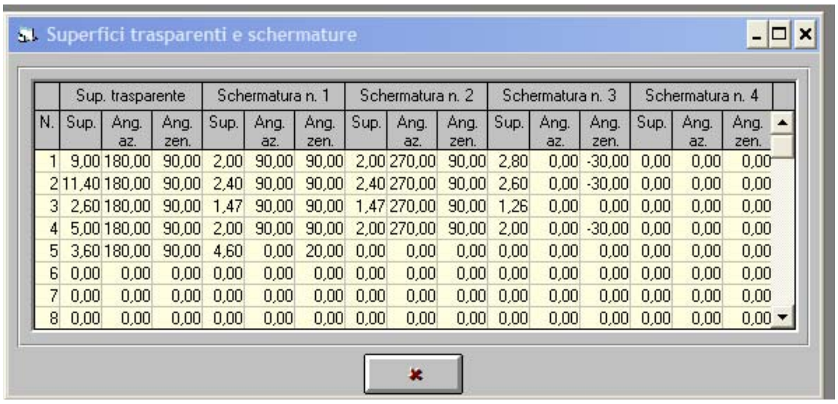


Oggetto: CASA SOLARE
Data: 10/06/2004
Committente: RIZZOTTO RENATO
Località: ONIGO (TV)
Latitudine: 45,80

Dati mensili

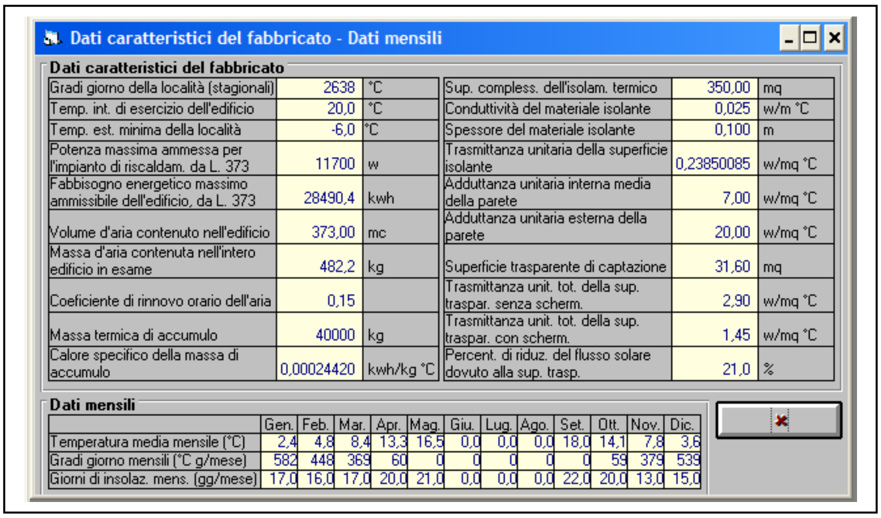
	Gen.	Feb.	Mar.	Apr.	Mag.	Giu.	Lug.	Ago.	Set.	Ott.	Nov.	Dic.
Irraggiam. solare orario su sup. orizz. alle ore 12	0,39	0,57	0,76	0,88	0,00	0,00	0,00	0,00	0,76	0,55	0,39	0,33
Temperatura media mensile	2,40	4,80	8,40	13,30	16,50	0,00	0,00	0,00	18,00	14,10	7,80	3,60
Gradi giorno	582,0	448,0	369,0	60,0	0,0	0,0	0,0	0,0	0,0	59,0	379,0	539,0
Giorni di insolazione	17,00	16,00	17,00	20,00	21,00	0,00	0,00	0,00	22,00	20,00	13,00	15,00
Temperatura alle ore 6 di un giorno coperto	-0,30	1,50	4,80	9,70	13,50	14,00	14,50	15,00	15,90	10,20	4,50	0,80
Temperatura alle ore 18 di un giorno coperto	3,20	5,50	8,80	14,70	19,50	20,00	20,50	21,00	21,90	14,20	8,50	3,80

Grapf n. 5
Climate data locality



	Sup. trasparente			Schermatura n. 1			Schermatura n. 2			Schermatura n. 3			Schermatura n. 4		
N.	Sup.	Ang. az.	Ang. zen.	Sup.	Ang. az.	Ang. zen.	Sup.	Ang. az.	Ang. zen.	Sup.	Ang. az.	Ang. zen.	Sup.	Ang. az.	Ang. zen.
1	9,00	180,00	90,00	2,00	90,00	90,00	2,00	270,00	90,00	2,80	0,00	-30,00	0,00	0,00	0,00
2	11,40	180,00	90,00	2,40	90,00	90,00	2,40	270,00	90,00	2,60	0,00	-30,00	0,00	0,00	0,00
3	2,60	180,00	90,00	1,47	90,00	90,00	1,47	270,00	90,00	1,26	0,00	0,00	0,00	0,00	0,00
4	5,00	180,00	90,00	2,00	90,00	90,00	2,00	270,00	90,00	2,00	0,00	-30,00	0,00	0,00	0,00
5	3,60	180,00	90,00	4,60	0,00	20,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Graph n. 6
Size and orientation of glazed surfaces and shielding.



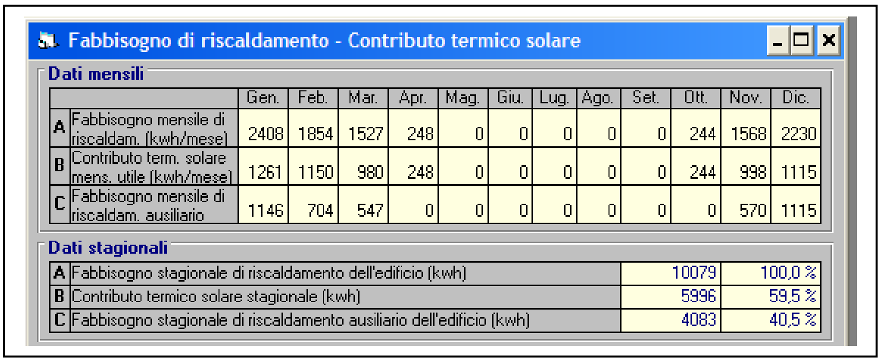
Dati caratteristici del fabbricato

Gradi giorno della località (stagionali)	2638	°C	Sup. compless. dell'isolam. termico	350,00	mq
Temp. int. di esercizio dell'edificio	20,0	°C	Conduttività del materiale isolante	0,025	w/m °C
Temp. est. minima della località	-6,0	°C	Spessore del materiale isolante	0,100	m
Potenza massima ammessa per l'impianto di riscaldam. da L. 373	11700	w	Trasmittanza unitaria della superficie isolante	0,23850085	w/mq °C
Fabbisogno energetico massimo ammissibile dell'edificio, da L. 373	28490,4	kwh	Adduttanza unitaria interna media della parete	7,00	w/mq °C
Volume d'aria contenuto nell'edificio	373,00	mc	Adduttanza unitaria esterna della parete	20,00	w/mq °C
Massa d'aria contenuta nell'intero edificio in esame	482,2	kg	Superficie trasparente di captazione	31,60	mq
Coeficiente di rinnovo orario dell'aria	0,15		Trasmittanza unit. tot. della sup. traspar. senza scherm.	2,90	w/mq °C
Massa termica di accumulo	40000	kg	Trasmittanza unit. tot. della sup. traspar. con scherm.	1,45	w/mq °C
Calore specifico della massa di accumulo	0,00024420	kwh/kg °C	Percent. di riduz. del flusso solare dovuto alla sup. trasp.	21,0	%

Dati mensili

	Gen.	Feb.	Mar.	Apr.	Mag.	Giu.	Lug.	Ago.	Set.	Ott.	Nov.	Dic.
Temperatura media mensile (°C)	2,4	4,8	8,4	13,3	16,5	0,0	0,0	0,0	18,0	14,1	7,8	3,6
Gradi giorno mensili (°C g/mese)	582	448	369	60	0	0	0	0	0	59	379	539
Giorni di insolaz. mens. (gg/mese)	17,0	16,0	17,0	20,0	21,0	0,0	0,0	0,0	22,0	20,0	13,0	15,0

Graph n. 7
Data physical technicians of building



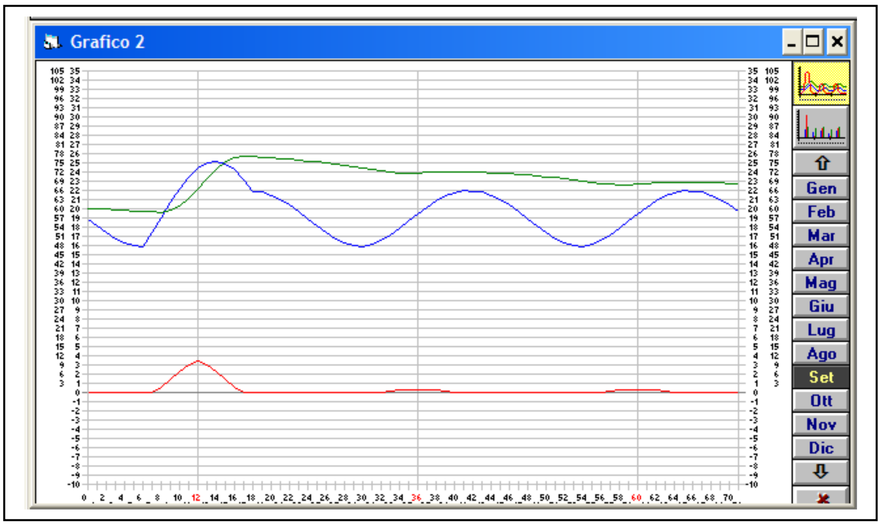
Dati mensili

		Gen.	Feb.	Mar.	Apr.	Mag.	Giu.	Lug.	Ago.	Set.	Ott.	Nov.	Dic.
A	Fabbisogno mensile di riscaldam. (kwh/mese)	2408	1854	1527	248	0	0	0	0	0	244	1568	2230
B	Contributo term. solare mens. utile (kwh/mese)	1261	1150	980	248	0	0	0	0	0	244	998	1115
C	Fabbisogno mensile di riscaldam. ausiliario	1146	704	547	0	0	0	0	0	0	0	570	1115

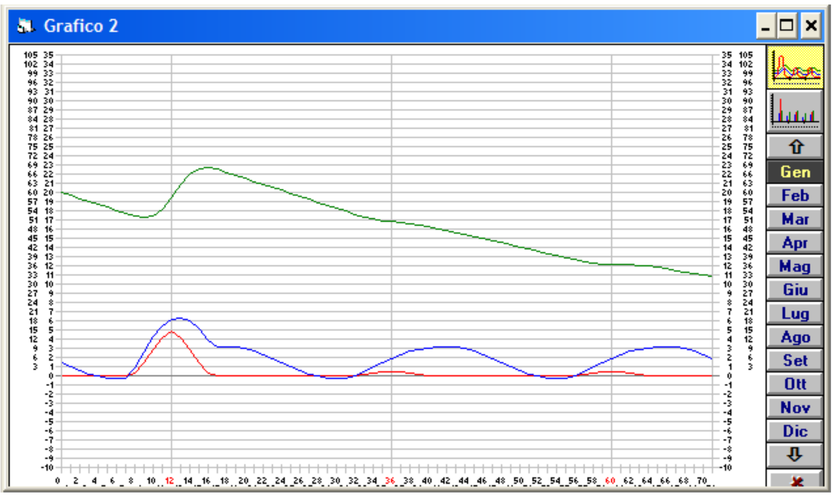
Dati stagionali

A	Fabbisogno stagionale di riscaldamento dell'edificio (kwh)	10079	100,0 %
B	Contributo termico solare stagionale (kwh)	5996	59,5 %
C	Fabbisogno stagionale di riscaldamento ausiliario dell'edificio (kwh)	4083	40,5 %

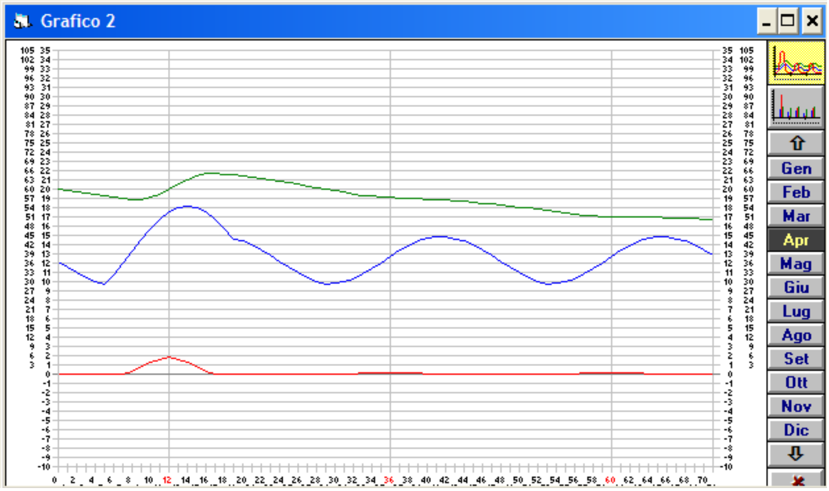
Graph n. 8
Demand for heating, solar heat and contribution of auxiliary heating needs, seasonal.



Graph n. 9
Evolution of external temperatures (blue) and internal (green) on 72 hours after the first day of insolation (red), in September.



Graph n. 10
Evolution of external temperatures (blue) and internal (green) on 72 hours after the first day of insolation (red), in January.



Graph n. 11
Andamento delle temperature esterna (blu) ed interna (verde) su 72 ore dopo il solo primo giorno di insolazione (rosso), in April.

From the graph 8 you notice that the contribution of the building solar heating is 5996 kWh/year, while the auxiliary heating needs is 4117 kWh/year, equivalent to 35 kWh/m2 per year. The calculation refers to the part of the solar building as comparable to the original building. The results are slightly higher than those obtained by chart-analytic which gave, optimistically, 25 kWh/m2 per year. Real consumption are known only to the overall building and amounted on average 70 kWh/m2 per year.

Graphs 9-10 and 11 show the evolution of the internal temperature of the house, extended to 72 hours (in green), when the sun has enlightened the house just in the first day (in red) and the progress of the outside temperature is the one in blue. A well-designed passive solar system should maintain as more horizontal as possible the average temperature inside. When the temperature drops below the limit of acceptability (20 °C), it becomes necessary supplementary heating. An adequate thickness of thermal insulation and a controlled air replacement with heat recovery, maintains an high internal temperature in January. A good amount of internal mass greatly reduces the temperature increase in

September. A proper shielding greatly reduces the solar energy in April, without hindering the radiation in January.

The building has taken very little maintenance and meets the favour of the occupants since 1985.

Photo n. 3-4
The building has taken very little maintenance and meets the favour of the occupants since 1985.

3. Enlargement of ‘Giovanni XXIII’ Secondary School and new Nursery School in Montebelluna (Treviso, Italy)

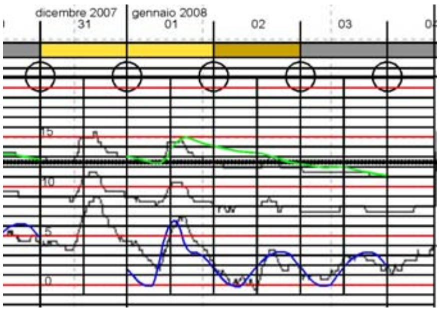
I submit the following two accomplishments of manufactured school: an enlargement of a secondary school, constituted of four classrooms, and a new nursery school of three sections, commissioned by the City of Montebelluna (TV) and completed in 2007-2008.
The major characteristics of the two buildings energetically similar are:
the earthquake resistant structure in reinforced concrete, the orientation South of the windows, with wooden frames, to benefit of the direct sunlight gain, the great internal structural mass and of the closure, the considerable thickness of the insulating placed as coat, heat recovery from spare air, supplementary heat by using heat-pumps air-to-air, natural controlled lighting, low energy consumption, about 20 kWh/m² per year and the traditional construction modes of the area. The energy goals have been developed through a specific calculation program and the results of consumption and performance, temperatures, have subsequently been discovered through continue measures on the buildings. The energy components, physical-techniques and engineering, structural, functional, and all the materials employed, have been incorporated into a pleasant architecture.

3.1 Enlargement of ‘Giovanni XXIII’ Secondary School

The request of the clients (municipality of Montebelluna) was to build four new classrooms, in enlargement to the secondary school who had the fewest consumption of energy for their operation. The four new classrooms spread over two floors, with openings oriented South 11° East, exploit direct solar gain. Because of the reduced thermal dispersions due to considerable thickness of the isolation (10-28 cm XPS), the presence of important structural mass of concrete internal and of closure, the proper disposal and size of the windows and of spare air pre-heating through to the one of expulsion, the direct solar gain ensures the 46% of the heat energy required. The supplementary heat is provided by air heat-pumps air to air. The electricity for lighting, ventilation and heat-pumps operation, is provided by photovoltaic panels placed on flat covering.

Electricity production is equivalent to 5400 kWh/year, while its consumption (both measured in 2008) amounts to 4,785 kWh/year, equivalent to 20 kWh/m² anno. The summer solar control is assured by horizontal semitransparent sunscreens, while winter lighting shall be regulated by ‘venetians’ placed internally to the windows. The air replacement shall take place by four fans, one for each classroom, placed in the basement. These ones withdraw it from the outside, filter it and send it, after a path in an aluminium tube of Ø 25 cm, about 30 m long placed to the ceiling, to the corresponding classrooms. The air expelled from the classrooms is sent in the basement where cedes part of the heat (over 50%) to the one in the entrance. In the basement there are also two external machines of heat-pumps, linked to four internal units (one for each classroom). The external units take the air from the basement and while ejecting it outwards shall recover the remaining heat as a result of the exchange with the air of ventilation. The system greatly reduces the possibility of ice formation in heat exchangers of the external units, boosting the COP. The levy-bearing structures are made up of reinforced concrete pillars and ‘Predalle’ plate ceilings.

The walls are composed of internal walls of cm 12 smoothed bricks of concrete, 28 cm XPS panels and cm 12 external wall in smoothed bricks of concrete. At the pillars, panels in XPS have 10 cm thickness. The ground floor is insulated with 20 cm XPS, while in the roof the insulation becomes 25 cm thick. All the windows are made of wood with safety low-emissivity double glazing and argon gas. All the functions described, engineering, structural and the materials employed, have been integrated in a functional and pleasant architecture. The cost of the intervention built in 2007, has been of 1400,00 €/sqm.



Graph n. 8 Overlap of external (blue) and internal (green) temperatures simulated at the computer, over the datas of relief, in the absence of heating.

Photo n. 5 In winter the South glasses are illuminated by the Sun and the direct light is controlled by internal adjustable ‘venetians’.

Photo n. 6 In summer the South glasses are shaded by sunscreens.

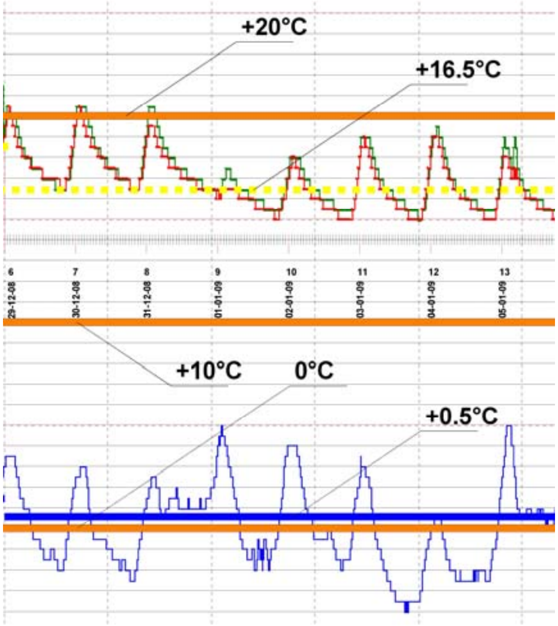
The energy consumption for supplementary heating and the evolution of the internal temperatures in absence of heating, has been calculated using the appropriate dynamic calculation program described earlier.
The development of internal and external temperatures and their reliefs are shown in the graphic number 8. In the same graphic appears the relief of the renewal air of the entrance temperature, placed just a little over the average.
In figures 5 and 6, you can notice the importance of the proper orientation for the control of the direct sunlight. In winter the South glass are fully illuminated and, using internal adjustable ‘venetians’, the light is diverted towards the ceiling. In summer the South glasses are all shaded by the sunscreens, allowing the entrance of the only diffuse light.

3.2 The new Nursery School in Contea

Equally, for the new nursery school, the requests from the clients (Municipality of Montebelluna) was to build three sections equipped of canteen and of warmer food, who had the fewest consumption of energy for their operation. The orientation to the South, Southeast and southwest of any openings, both of the classrooms that of all other rooms, allowed the exploitation of direct solar radiation. Similarly for intervention described above, the direct solar gain covers, in this case, 51% of the heat energy required.

The integrative thermal energy is provided by heat-pumps air by air, but have not been installed solar panels. The electricity consumption for the operation of the heat pump and ventilation (17 October 2008- 18 June 2009) is 14424 kWh, amounting to at 22,10 kWh/m² year. The summer solar control is assured by sloping sunscreen metal, while winter lighting shall be regulated by ‘venetians’ placed internally to windows. The air replacement takes place in the same way described in the previous case, with the addition of a collector connected outside ø 30 cm, two large filters and aluminium pipes of different quality. Reduced consumption are results for need for ventilation, given the large classrooms due to greater internal height. The six external units of heat-pumps have been placed, in this case inside the basement also, they exploit the eject air heat and are linked to nineteen internal units.

The structures are made up of reinforced concrete walls 30 cm of thickness, and the floors are on ‘Predalle’ plates. The load-bearing structures provide a significant and well distributed internal storage, useful for direct solar energy accumulation. The outside walls are made on blades concrete panels, cm 15 XPS on coat and on external wall 12 cm thick concrete smoothed bricks. The ground floor and the coverage were 20 cm of XPS insulated. All doors and windows are wooden, with safety low-emissivity double glazing and argon gas. All functions described, structural, engineering, and all the materials used, have been integrated in a functional and pleasant architecture. The cost of intervention in 2008 amounted to € 1600,00/m². The work described relate the first part, devoid of the fourth section, envisaged in the East in the project, and not yet achieved.



Graph n. 9 Measure of temperatures of two classrooms (green and orange) and the outdoor temperature (blue) during a week of January. In the absence of additional heating. At the same time the external average temperature was +0.5 °C, while the inside average temperature was + 16.5 °C, with a minimum of 15 °C at night.

Energy consumption for additional heating and trends of the inland temperatures in the absence thereof, has been calculated using the appropriate dynamic calculation program described earlier.

We were also detected internal temperatures of two classrooms (green and orange) and the outdoor temperature (blue) during a week of January (graph 9). In the absence of additional heating, with external average temperature of + 0.5 °C, the inside average temperature was + 16.5 °C, with a minimum of 15 °C at night.

Photo n. 7 In winter the South glasses are illuminated by the Sun and the direct light is controlled by adjustable internal ‘venetians’.

Photo n. 8 In summer the South glasses is shielded from external fixed sunscreen.

In figure n. 7, 8 and 9 it notes the importance of the proper orientation for the control of direct sunlight and the effects of the climate. In winter the South glasses are fully illuminated and, using interior adjustable ‘venetians’, the light is turned toward the ceiling.

In summer the South glasses are all shaded by external fixed sunscreen, allowing entry only diffuse light.
In winter, a porch on the north side, protects the wall against the effects of the prevailing winds, heavy rain and snow.

Photo n. 9 In winter, a porch on the north side, protects the wall against the effects of the prevailing winds, heavy rain and snow.

Photo n. 10 The use and the control of natural light, besides contributing to the reduction of consumption, create cozy and healthier environments.

The use and the control of natural light, besides contributing to the reduction of consumption, create cozy and healthier environments (Figure n. 10).

4. Energy requalification of socio-cultural Centre. MontebellunaTreviso Italy

In the year 2009, the Group Naturalistic Bellona of Montebelluna, asked me to make a study of energy requalification of the building, which remained the main structures, the interior finishes and the historical memory.

The size of the rooms and the accomodation current already replied to the needs of Association, except arrangement of electrical installations, than attention has been dedicated to energy improvements. The building erected in the 60s of the last century, has a large and simple façade South oriented, and a more articulated North front. It is located over one hills and it is inserted into a prestigious naturalistic context, characterized by forests and meadows, with a rare presence of other buildings and housing. It treated of operate according to the concepts already described, also in order to make the building self-sufficient in terms of energy consumption for heating, ventilation and lighting.

Photo n. 11 . The building erected in the 60s of the last century, has a large and simple South facade …….

Photo n. 12 ….. and a more articulated North front.

Despite 50 years of construction and of the poor maintenance, especially in recent years, the building appears well preserved, with perimeter and internal bringing masonry massive and intermediate reinforced concrete floor. They are the interesting paving of the ground floor made on tiles. Intervention proposed consist in the use of empty North present volumes to get a compact shape, in the eliminating the coverage at pavilion to the proceeds of a flat cover, in the expansion of all windows South exposed, in the placement of the XPS thickness cm 20-25 thermal insulation on all exterior walls and coverage, to the protection of the external insulation by against-wall in polished concrete blocks and in the replacement actually steel windows with wood and double glass quality windows. In front of cover and sunscreens are installed photovoltaic solar panels and thermal solar panels for generating all the necessary energy for the use of the building. In front of the South facade are placed sunscreens fixed for the summer sunlight control. On the North facade, moreover, we have placed a transparent polycarbonate cover for the protection the wall against the rains prevalent.

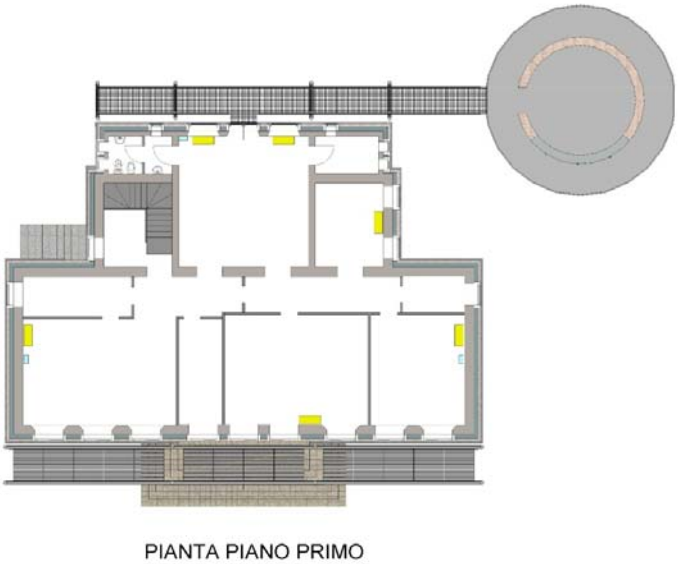


Figure n. 13 . The first floor plant with the measures proposed.

Figure n. 14 . The North South section with the measures proposed.

As a result of architectural interventions proposed, we used the already described calculation program for verifying of the passive solar energy solutions.

The solar contribution is 65.1% and the additional consumption required for heating and ventilation amounts at 8188 kWh, equal 18,04 kWh/m² per year. The electricity produced by photovoltaic panels, with power installed 16 kWhp, is more than enough to feed the air by air heat-pumps, planned in each hall. Overall the manufactured produces more energy than it consumes. The heavy existing wall lets we to accumulate the solar heat and to limit the changing of temperatures.

Figure n. 15 . Overall views from North-West at works completed.

The South facade is entire sunlit on 21 December (fig 16) and completely shaded on 21 June (fig 17).

Figure n. 16. The South facade is entire sunlit on 21 December.

Figure n. 17. The South facade is completely overshadowed on 21 June.

The enlargement of the South windows, in addition to the passive solar energy functions and the natural increase of the brightness of the rooms, allows greater and better vision, from inside, of the surrounding landscape (Fig. 18).

Figure n. 18 . The enlargement of the South windows allow greater and better vision of the surrounding landscape.

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5. SHORT CURRICULUM VITAE

Giorgio Bedin, was born in Pederobba (TV) the 21.12.1951.
He graduated in civil engineering construction in Padova in 1975 with a thesis on industrial architecture.
You are interested in energy issues since the first oil crisis and designing a "solar house" low-energy in 1983.
Participates in the national competition "the Sun for sports facilities", organized by the CONI-ICS, in the year 1983, with the project of a Multi-purpose Gymnasium. Project winner a second prize ex aequo.
In 1985 he won a first prize ex fair in "Ideas competition for the renovation of downtown Pederobba".
In 1985-86 attend course "Energy and Architecture" at the Politecnico di Milano.
Writing from 1991 at the "National Institute of Bio-Architecture ".
Continues to update itself on energy and sustainability issues in architecture and urbanism following refresher courses and conferences.
Participates in training "Solar thermal installations in buildings" held in collaboration with ISES Italia and Solarexpo in Vicenza from 19 to 22 May 2004.
In September 2004, to take part in the first RECAM PRIZE for innovation (the trade fair Recam Montebelluna), with the construction of a house to low power consumption, passive solar system. The realization took an expense reimbursement and a reporting.
Join the refresher course for engineers "Installations in the building design, the total of 40 hours, taking in Treviso from 14/10/2005-27/01/2006.
Speaker at the Conference "Building Sustainable: Architecture and school" of Godega di Sant'Urbano, Treviso in 2008.
In 2008 and 2009 speaker meetings on "Sustainable bioarchitectural and urban planning" at Montebelluna Treviso.
It has recently been commissioned the extension of a Secondary School and a New Nursery by the Municipality of Montebelluna, both completed and characterized by high sustainability.
Speaker at the International Conference "Energy Forum" of Bressanone, in December 2009.
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