Seventeen Low-Energy High-Rise Buildings in Turin Area (Italy)

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# SEVENTEEN LOW ENERGY HIGH-RISE BUILDINGS IN TURIN AREA (ITALY)

R. Pagani and S. Tonin

SOFTECH s.r.l.
Via Cernaia 1 - Turin 10121 (Italy)

Solar Building Design Monitoring Italy

ABSTRACT

480 solar low-energy multi-family dwellings have been developed and built in Piedmont Region (Italy), as part of a demonstration program supported by the Italian Ministry of Public Building & Works.

This paper gives an outline of the research program, desing tools and technological choices and summarizes the preliminary comparisons between forecasted and actual energy consumption.

## INTRODUCTION

The program, carried out by a consortium of builders (UPSE), is among the largest completed in Europe on Passive and Hybrid Solar applications.

It was sponsored in 1980 by the Italian Ministry of Public Building and Works (CER-Min.LL.PP) and by the EEC-Energy Conservation Demonstration Projects.

The purposes of the program were:

. to design and build 17 buildings (480 dwellings) in the Turin area, with a closely controlled passive behaviour;

. to measure thermal performances of the buildings, via an appropriate monitoring system, in order to get useful technical-economic informations on energy conservation options;

. to assess the impact of energy conservation measures on occupants' behaviour.

The technological solutions suggested to the design teams in the preliminary phase of the program can be summarized as follows:

. to increase insulation levels, reducing the thermal load of buildings below the limits accepted by the Italian Regulation;

. to integrate passive solar systems to improve building thermal performances;

. to equip the building with air solar collectors, for winter ventilation needs and water heating.


Fig. 1

Building Locations : Seventeen Towns in North-western Italy



## BUILDING DESIGN: PRELIMINARY INFORMATION

Considering the wide scale of the demostration, a training program was held in order to give a preliminary information to more than 50 designers and 14 building constructors on the basic implications of energy conscious design. In the same period, software procedures and mathematical models to predict energy behaviour of passive and active systems and building energy consumptions were assembled and tested.

General information to architects, designers and plant engineers was provided by the energy group of the Department of Science and Techniques - Turin School of Architecture (1).
The technical consultancy throughout the whole program was given by SOFTECH s.r.l - Turin.

## DESIGN TOOLS AND ENERGY CONSERVATION TECHNIQUES

Architectural and technological choices of the 17 building projects were systematically checked, according to the following steps:

### Weather data of the area and site

Air movements and winds, temperatures and degree-days, solar radiation, etc. have been recorded and analyzed for every specific building location.

### Building microclimate

Site-microclimate conditions, solar access, wind paths, orientation, shadows were predicted an plotted.

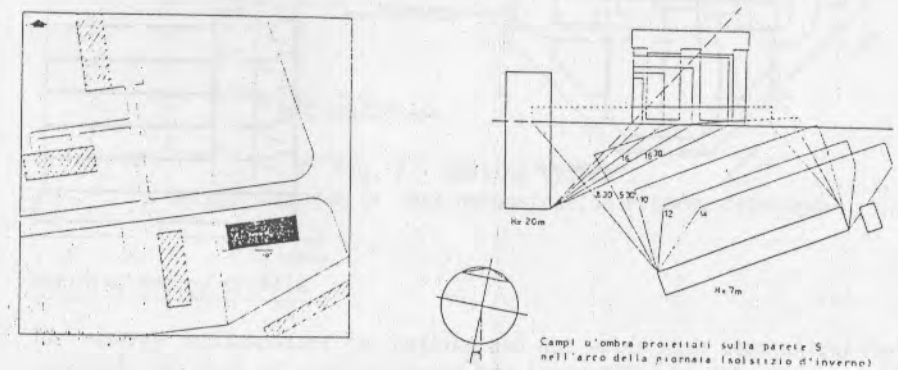

Fig. 2 - Building Area and Solar Access:
an Example from the Upse Demonstration Program Catalogue

## Thermophysical behaviour of building envelopes

The thermal load of buildings has been considerably reduced by using thicker layers of insulation.
Special attention was payed to thermal bridges, in order to avoid condensation phenomena.

## Passive systems analysis

The green-house is the widely applied passive system in the UPSE Demonstration Program.
Depending on the peculiar main thermal performance may be distinguish:.

. direct gain greenhouses, with totally glazed interior wall and movable screen for night insulation and sunlight protection;
. air convection greenhouses, with openings in the back wall to circulate the air, via thermo-switched fans;
. heat storage greenhouses, with mass wall and movable insulated screen.

The "trombe wall", with a black painted heavy wall and openings for natural air loop, has been applied in a unique case.

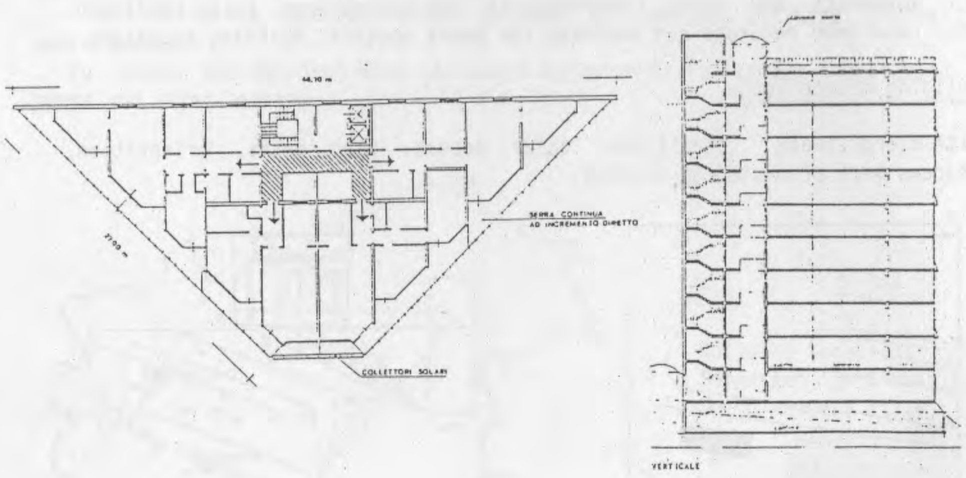

Fig. 3 - Building Shape and Passive Configuration:
an Example from the Upse Demonstration Program Catalogue.



## Active solar and auxiliary system sizing

Each building has been equipped with a rate of 6 to 10 square meters of air solar collectors per apartment.
Collectors, integrated in the roof or in the south facade of buildings, provide the pre-heating of external air during the cold season and are sized on the basis of such a volume.
The system can be by-passed on the "air to water" heat exchanger so as to solve any overheating problem and in order to usefully exploit summer radiation.
The back-up system is traditional low inertia ambient exchanger with control and regulation for each room.

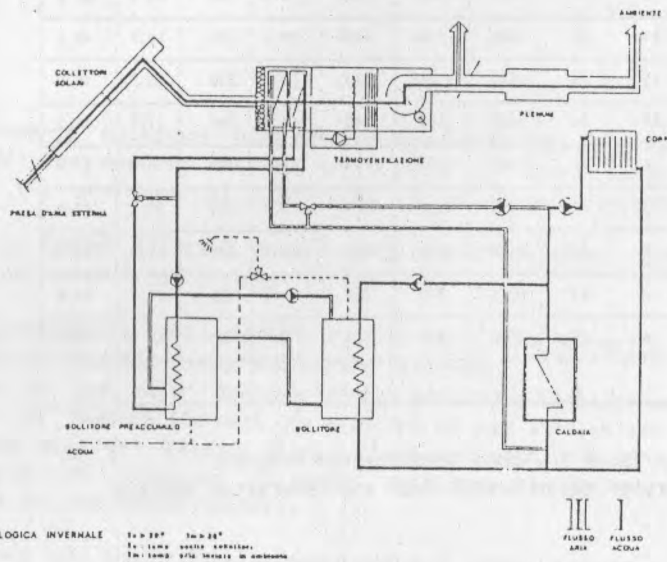

Fig. 4 - Heating System :
a General Diagram of Upse Demonstration Program Catalogue

## Building energy profile

The energy consumptions for heating and hot water have been calculated and compared to that of similar houses built according to the italian building energy standard (Law 373).
The predictions show heating energy consumption values of about 3/5 of that of current new buildings.

In Table 1, a complete picture of UPSE program is shown.
Some design data and related contributions in reducing total energy consumption of buildings are summarized.

| | ORIENT. | N° dw. | VOLUME | EC | area P.S. | %E. P.S. | area A.S. | %E A.S. | %F |
|---|---|---|---|---|---|---|---|---|---|
| ALBA | Ø | 20 | 5373 | 802 | 162 | 16.2 | 158 | 21.9 | 40.6 |
| ALPIGNANO | +35 | 57 | 11847 | 1410 | 613<br>75 | 23.6 | 330 | 20.4 | 47.1 |
| ARONA | -5 | 24 | 7263 | 1033 | 370 | 22.4 | 82 | 12.6 | 50.0 |
| ASTI | Ø | 24 | 6879 | 813 | 291 | 19.0 | 185 | 20.8 | 42.9 |
| BIELLA | -24 | 19 | 4887 | 788 | 402 | 20.7 | 100 | 15.5 | 45.1 |
| COLLEGNO | -15 | 56 | 11524 | 1780 | 613 | 13.7 | 330 | 23.7 | 42.1 |
| FOSSANO | -25 | 36 | 9654 | 1481 | 292 | 16.5 | 266 | 17.9 | 38.7 |
| GRUGLIASCO | Ø | 48 | 11524 | 1776 | 474 | 13.5 | 330 | 18.0 | 37.0 |
| MONCALIERI | Ø | 42 | 12036 | 1597 | 177 | 8.4 | 420 | 26.1 | 42.6 |
| ORBASSANO | Ø | 40 | 9769 | 1396 | 1800 | 24.3 | 205 | 11.6 | 43.6 |
| PIANEZZA | Ø | 18 | 5022 | 827 | 202 | 11.3 | 121 | 17.7 | 43.0 |
| VERCELLI | Ø | 28 | 7780 | 931 | 41 | 2.6 | 126 | 17.9 | 35.5 |
| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |

Table 1 - Upse Demostration Program :
Summary of Major Design Data and Forecasted Results

1. ORIENT. = building orientation (degrees from south, Est: +)
2. N.dw. = numbers of dwellings
3. VOLUME = building volume (m3)
4. EC = heating consumption, under the Italian Standard (GJ/year)
5. area PS = passive system global area (m2)
6. %E PS = energy contribution supplied by passive systems
7. area AS = active system global area (m2)
8. %E AS = energy contribution supplied by active systems
9. %F = forecasted energy saving (total).



BUILDING CONSTRUCTION

Type, size and shape of buildings were heavily determined by previous town-planning decisions, construction systems and costs.

The program comprises most of the building types of the residential italian catalogue:
. 8 to 10 storey blocks (40-56 dwellings)
. 3 to 5 storey blocks (18-36 dwellings)
. 2 to 3 storey buildings (4-12 dwellings).

The building construction phase has been carried out according to the italian building codes and specifications: it started in 1982 and within 2/3 years the 480 dwellings were delivered.

MONITORING

The new low-energy buildings have been equipped with data loggers (Type: HI-TEK CER 32) to monitor thermal performance of energy conservation measures and the environmental conditions in which such performance is achieved.
The monitoring system (class B, according to DOE/NBS standards (2)) shall be run over a period of 3 years starting from 1985.

Setting out instruments and recording systems for a data gathering on 480 dwellings required specific design and careful planning.
In fact, one of the major purpose of the monitoring campaign was (and currently is) to measure the real contribution of each passive and active solution in the long run: activity which is hard to manage in a large scale building program (17 inhabited buildings monitored at the same time in different locations and microclimates).

Basic guidelines of the originally developed data gathering system can be summarized as follows:
* software and hardware were designed to be reliable at the comparably low-cost;
* data processing was implemented to be partly carried out by peripheral units, in order to reduce stand-by memory needs;
* monitoring system was planned to measure building energy flows, minimizing measuring points (sensors and transducers) and providing long-term statistical performance informations on the major heat sources and losses.

Hardware and software desing of the monitoring campaign was developed by HI-TEK s.r.l.- Turin.

PRELIMINARY RESULTS

In table 2, forecasted and actual energy consumption values concerning eight different buildings are presented.
Active and passive solar contributions and extra-costs are also displayed.

| | ECI | %A | %F | EXC | %EXC | CEC a | %OCC |
|---|---|---|---|---|---|---|---|
| ALPIGNANO | 10.0 | 25. | 47.1 | 96000 | 10 | 1045 | 0.80 |
| ARONA | 9.7 | 30. | 50. | 77500 | 10 | 608 | 0.96 |
| ASTI | 10.8 | 24. | 42.9 | 81500 | 11 | 912 | 0.5 |
| BIELLA | 11.8 | 18. | 45.1 | 117500 | 18 | 1416 | 0.56 |
| GRUGLIASCO | 10.5 | 28. | 37. | 95000 | 10 | 830 | 1.00 |
| MONCALIERI | 8.3 | 33. | 42.6 | 130000 | 15 | 1358 | 1.00 |
| ORBASSANO | 7.2 | 46. | 43.6 | 142000 | 17 | 1212 | 0.70 |
| PIANEZZA | 13.7 | 10. | 43. | 47500 | 10 | 1425 | 1.00 |
| | 1. | 2. | 3. | 4. | 5. | 6. | 7. |

Table 2 - Forecasted and Actual Space Heating Consumption Indexes in Eight Upse buildings

1. ECI = Energy Consumption Index (TEP/m3*dd*10^-7);
2. %A = relationship between the Energy Consumption Index (actual data) and the italian current standard (Law 373 Index): (EC-ECI)/EC;
3. %F = relationship between the Forecasted Consumption Index (forecasted data) and the italian current standard;
4. EXC = extra-cost of passive and active systems (kLiras/m2 of dwelling)
5. %EXC = ratio between the extra-cost of passive-active solar and the total building cost;
6. CECa = average value of Cost of Conserved Energy CEC (kLiras/m3 of methane);
7. %OCC = index of inhabited dwellings in the building.



The figure shows that the actual heating consumptions have been larger than the predicted.
This discrepancy is caused by a combination of four different factors:

1. The building monitoring started, in most cases, during the winter 1985/86 and it will last over 3 years, providing a proper validation to preliminary data and results in the next two years.

2. The solar gains' break-down has been determined by applying the same numerical partition worked out in the calculations, because of the delay occurred in the detailed monitoring.

3. The results are strongly affected by the "running in" of heating equipments, funs, electronic controls, and (why not) users!

4. Finally, the 13 buildings completed and monitored are only partially inhabited.

A disaggregated visualization of energy consumption data compared to Law 373 values is presented in the following correlation picture (Fig.5).

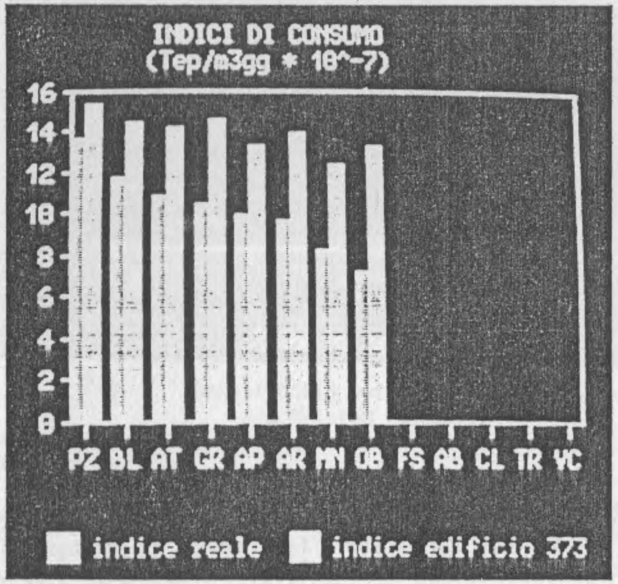


Fig. 5 - Comparison between Actual and Law 373 Consumption Indexes

To facilitate a detailed examination of the economic implications of conservation technologies the extra-cost (expressed in kLiras) has been converted in the Net Present Value of the total investment for the life period of the extra-technologies applied.
The economic effectiveness is, then, quantified in the graph of Fig. 6.
The figure of merit used to compare different conservation options is the Cost of Conserved Energy (CEC), expressed in Liras per cubic meter of methane equivalent. (For the definition of CEC, see Rosenfeld-1980 (3)).

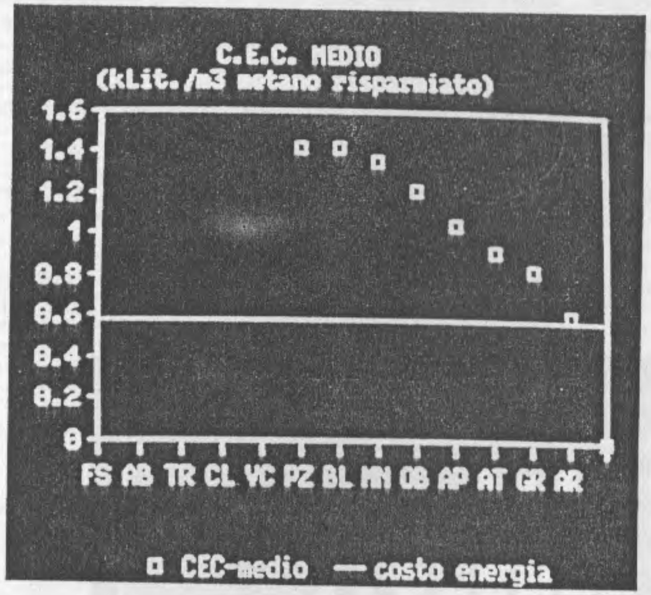


Fig. 6 - Average Cost of Conserved Energy in eight UPSE buildings: Comparison with the Cost of Conventional Fuel

In Table 3 and Figure 7, the relationship between percentage of actual energy saving and the total extra-cost of conservation measures is shown.
The "EFF" index can be regarded as the effectiveness of the technological solution and it could inform new building codes and regulations as well as appropriate strategies of financial incentives deliverable by Italian Public Authorities.



| building | locations | %A | %EXC | EFF |
|---|---|---|---|---|
| ARONA | AR | 30 | 10 | 3.10 |
| GRUGLIASCO | GR | 28 | 10 | 2.73 |
| ORBASSANO | OB | 46 | 17 | 2.63 |
| ALPIGNANO | AP | 25 | 10 | 2.46 |
| ASTI | AT | 24 | 11 | 2.25 |
| MONCALIERI | MN | 33 | 15 | 2.10 |
| BIELLA | BL | 18 | 13 | 1.43 |
| PIANEZZA | PZ | 10 | 12 | 0.86 |

Table 3 - Relationship between Energy Conservation and Related Extra-Cost

EFF = relationship between the % of actual energy saving and the % of extra-cost related to conservation techologies

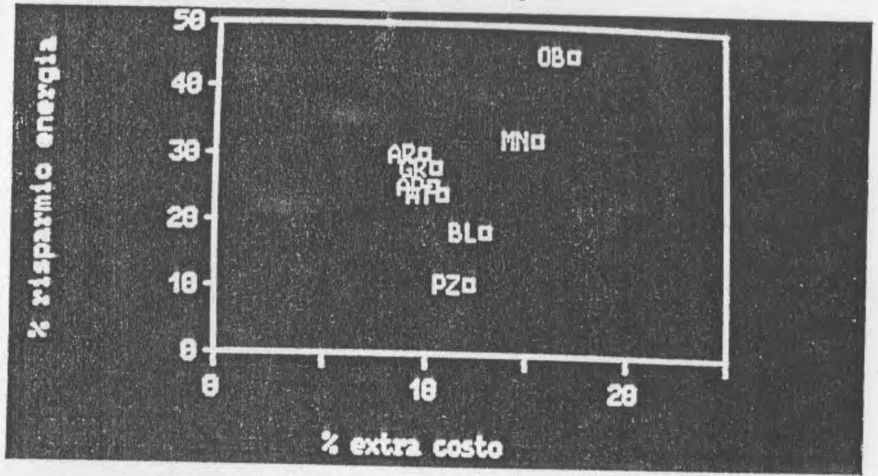


Fig. 7 - Relationship between Energy Conservation and Related Extra-Cost

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(3) Rosenfeld,A. et al. (1980), Building Energy Use Compilation and Analysis (BECA), An International Comparison and Critical Review, Report LBL-8912, Lawrence Berkeley Laboratory, Berkeley (California).