A CASE STUDY OF LOW-ENERGY HOUSES IN NORTHERN ITALY

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Summary

In 2007, the "passive house" concepts were applied at the construction of 16 houses in Selvino Bergamo, Italy. Using a holistic design process characterized by the integration of architectural and technological choices, the ambitious target of 30 kWh/m²a was reached (useful energy). Passive strategies are used to keep the indoor comfort: very high insulating levels (a combination of traditional and thin multifoil insulation layers); high winter solar gains; small window area in the north façade with high performance; large openings and conservatory space in the south façade. The mechanical plant system is designed in order to limiting the CO_2 emissions. Particularly it is composed by solar photovoltaic panels installed on the south-facing roof; electrical radiant floor heating system; high efficiency electric boiler; mechanical ventilation with heat recovery. This paper shows a real example of a holistic design process integrating architectural, technological and energetic issues; the result is a low-energy building with a contemporary architecture that suite perfectly to the specific context.

Keywords: low energy consumption, sustainable building, high thermal insulation, conservatory space.

1 Introduction

1.1 Motivation

In Europe 40% of energy is used in buildings, more than by industries or transports. In the residential sector, especially in mid temperate climate, about 57% of the total final energy consumption is used for heating space, 25% for domestic hot water and 11% for electricity. Moreover, it offers a large potential for energy efficiency with low investment costs. According to the United Nations Environment Program (UNEP), over a fifth of energy consumption and more than 45 million tons of CO_2 could be avoided in Europe by 2010 applying more ambitious standards to new buildings. This could represent a considerable contribution to meeting the Kyoto targets. Several standards already exist in Europe like the Passive house standard, Minergie, CasaClima and much more (Masera, 2004). Because all these standards are climate dependent, the design group of this settlement in Northern of Italy decided to follow the CasaClima standards that is a promising solution in winter dominated climate (Imperadori et. al, 2004).

1.2 Aims of work

The new settlement in Selvino was born after the approval of the new local energy code (Regolamento per l'Efficienza Energetica degli Edifici) in 2006. Selvino is a small village in the north of Italy (it is lies at more than 900 m above the sea level) where about the 70% of the house are for vacation. The aim of the new construction regulation the administration of the city, developed by a group of the Politecnico di Milano (Regional Campus of Lecco), was to give guidelines to support the architects during the design stage of the project to achieve ambitious low energy targets. The municipality decided to join the CasaClima standard and to promote the large use of renewable energy sources, passive strategies and ecological traditional material (like stone and wood). The design group answered to these goals and in particular: satisfying the need of social housing, providing a good example of low-energy architecture, testing innovative construction and systems services technologies. Properly designing the built environment has become a complex matter. Comfort expectations and energy efficiency imperatives require the control of environmental conditions by adjusting room temperatures, luminance levels and ventilation rates. This requires a very strict integration of building envelope and technical services, in order to reduce the use of non-renewable energy. Every building should be suited to climate, function and local technical standards (Isaksson et al. 2006). In order to answer to this challenging situation, it was important to bring together the architect, the mechanical engineer, the municipality and the energy consultant at the very short of the project. The holistic approach, adopted by the group, permits to define immediately different energy and architectural concepts and to save time afterwards to adjust the design.

1.3 Architectural project and general sustainable strategies

The ecological settlement in Selvino (Fig.1) is an ambitious initiative aiming for a sustainable development of the village (Salvalai et. al, 2010). The climate is characterized by cold winters and temperate summers. This is represented by 200 heating days and 3433 heating degree days (the design temperature is equal to -9 °C).

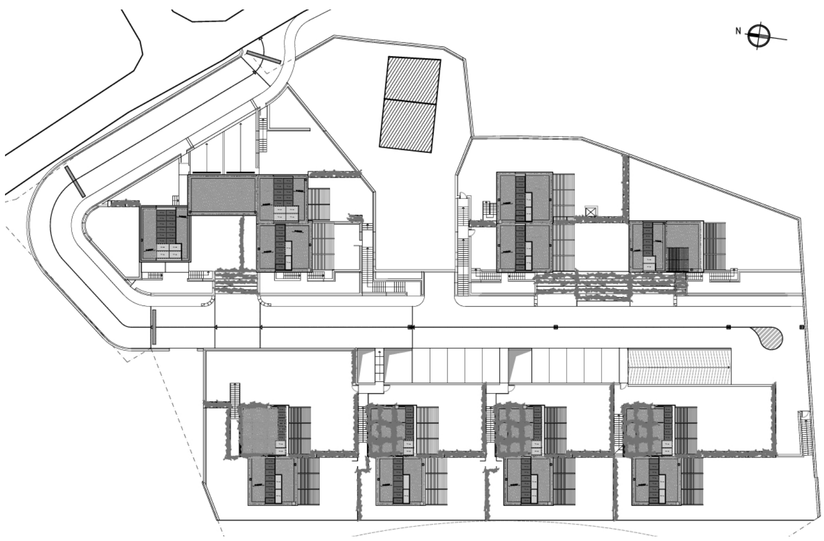

Fig. 1 Plan view of the settlement

From the sustainable point of view the project aimed for a high level of comfort, allowing at the same time a significant reduction of energy consumption and CO_2 emissions. The project consists of 16 residential units of different sizes (from 50 to 115 m²) (Fig.2), located sideways to the district street.

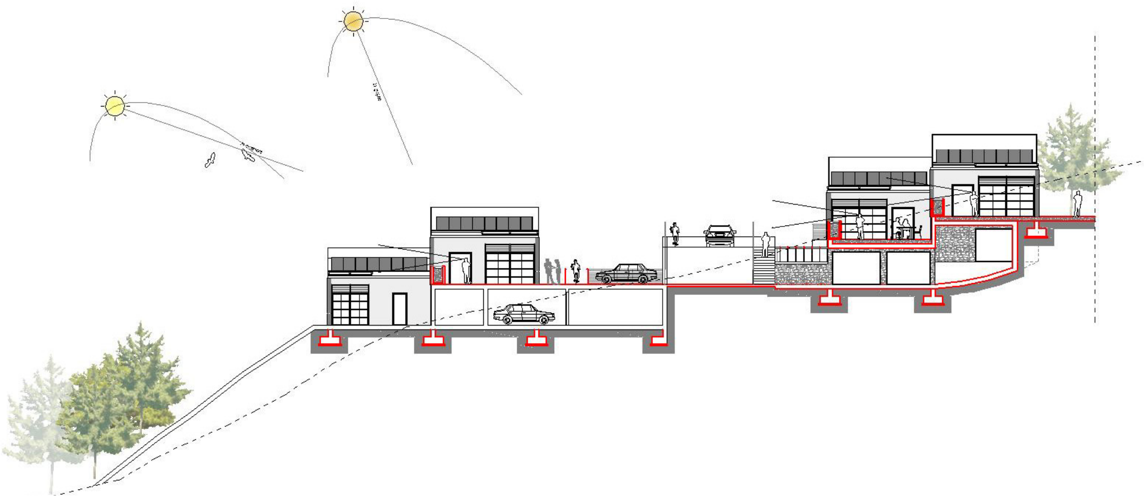

Fig. 2 East-West section of the settlement

The aim of the architectural design was to establish morphologically innovative buildings with the capacity to maintain comfortable internal conditions in every season, through direct control of some parameters including: building orientation, use of solar radiation in winter and solar protection in summer, reduction of heat losses through good insulation and using a high efficiency heat recovery (Fig.3).

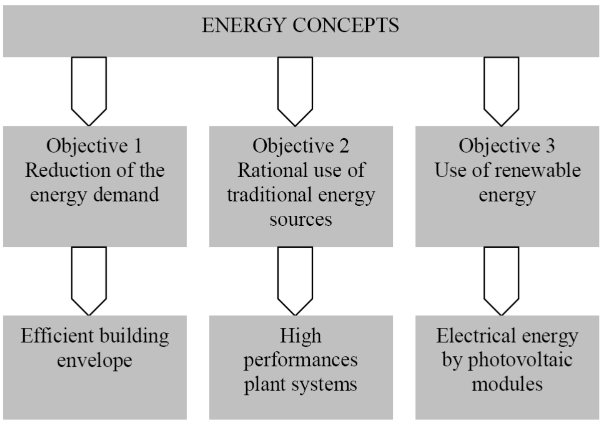

Fig. 3 Energy concepts

First of all the design group focused the attention to the urban planning studying the relationship between the settlement and the environment. The group would like to gains, as much as possible, from the environment and on the other hand established a good relationship with it. As consequence the shadow design was planned dependent from the sun path for maximise the sun penetration (minimising the reciprocal shadows between the houses) in winter and the light in summer.

Thanks to the close cooperation between designers (architectural and mechanical), the owner and the building constructor, the project is scheduled, in according with

CasaClima labeling, as "Class A" with an energy demand (for the winter seasons) lower than 30 kWh/m²a. Moreover, the buildings will also have the "ECO" label due to the material quality, the use of renewable energy sources and the environmental impact (Zambelli et al. 2002). From the architectural point of view, the buildings are characterized by a large windows facing south, with a greenhouse to maximize the solar gains in winter and to reduce the heating energy demand of about 5 kWh/m²a (an horizontal shading device reduces the summer solar gains and the possibility to tilt the windows reduces the risk of overheating) (Persson et al.2006) (Salvalai, 2008). The greenhouse (Fig.4) has an important function in terms of spatial distribution allowing the extension of living room to the south facing garden. The north and east façades are opaque in order to minimize the transmission losses and improve privacy. The internal spatial distribution is done optimizing the space; the result is simple but really comfortable: each module has a living room-kitchen (20 m²) expandable through openings windows to the greenhouse (4.5 m²), a bedroom (14 m²) and a toilet (4 m²). Laundry and storage facilities take place into the basement, connected by external stairs.

Fig. 4 Interior design of a residential module

1.4 Building envelope

According to the design strategies, to reduce as much as possible the heat loss (due to the envelope transmission and to the infiltration), the building is designed with high insulation layers and accurate construction (Zambelli et al. 1998). Specifically, the houses are assembled using prefabricated panels, with solid wood substructure, floorboards, polystyrene (EPS) for thermal insulation and static functions and externally closed with a concrete layer. The concrete layer works together with the wood structure thanks to several small holes placed in the upper part of the beams. The underground floors (box, laundry etc.) are designed with traditional concrete structure (Fig.5).

Fig. 5 Construction phase of the underground floors.

Within this new system it is possible to save time during the installation phase and no more extra systems for the rigidity of the structure are needed (with consequently less use of building material). The combination of polystyrene (resistive layer) and concrete (capacitive layer) guarantees high thermal insulation, minimizes the thermal bridges and last but not the least permits high quality of the industrialized production (Fig.8 and Fig.9). Depending on the wall exposition and on the floor area the building envelopes are designed with at minimum 200 mm EPS insulation or adding an additional thin reflective insulation layer. The solution reaches a U-value of about 0.1 W/m²K (Fig.6 and Fig.7). The vertical external wall is composed as follow:

- Double layer of plasterboard 12.5 mm
- Reflective multilayer insulation 21 mm
- 10 x 20 cm timber joists with maximal distance of about 250 cm
- OSB 15 mm
- Polystyrene insulation density 60 Kg/mc 200 mm thick
- OSB 15 mm
- Concrete Rck 400, 50 mm.

The same timber/concrete structure is used for the roof structure:

- The following layers are combined:
- Double layer of plasterboard 12.5 mm
- Floorboard wood 20 mm
- 12x32 cm timber joists with maximal distance of about 60 cm
- Polystyrene insulation density 60 Kg/mc, 200 mm
- Concrete Rck 400 50 mm
- Waterproofing layer, soil and sedum 12 cm.
- Sedum roof

A green roof provides valuable unsealed surface in the green context, mitigates the summer climate in the main floor and it also guarantee a good microclimate environment.

The windows are double glazed units with plastic frame (U-value of 1.4 W/m²K). The facade claddings are treated differently depending on their orientation: coat and plaster in the south and north sides and pine with ventilated gap in the east and west.

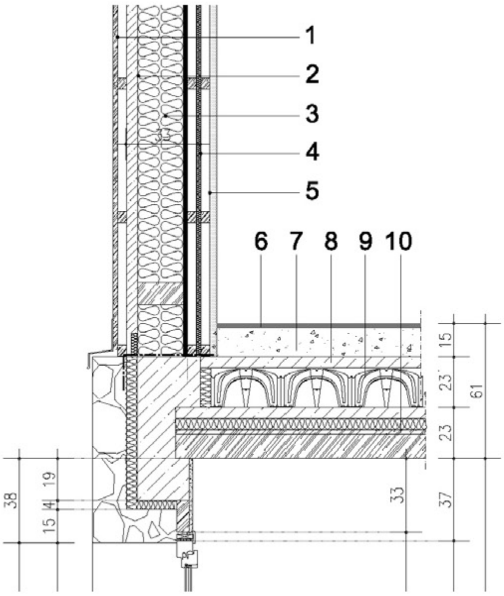

Fig. 6 Construction details. 1- Floorboards pine, 2- Concrete, 3- Polystyrene, 4- Reflective multilayer insulation, 5- Double plasterboard, 6- Ceramic floor covering, 7- Light concrete, 8- Concrete, 9- Air gap, 10- Wood floor structure.

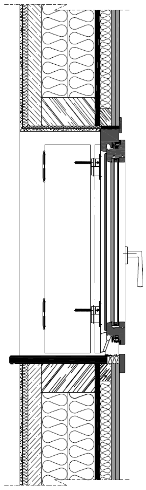

Fig. 7 Connection between window and wall. The heat bridges are avoided due to a carefully design

The adopted building envelope allows achieving the goals in terms of energy efficiency, defined in the preliminary phase of the project (Objective 1 of Fig.3). In fact, the transmission losses are significantly reduced and the solar gains maximized. At this point, since the reduction of the heating load the size of the plant system can be reduced thus take advance of the renewable energy resources (i.e solar energy).

Fig. 8 Prefabricate wall panels before the construction phase

Fig. 9 Construction phase: prefabricate wall panels installed under de concrete floor

1.5 Plant systems and energy consumption

Considering the ambitious target of the houses, characterized by long unused period (the settlement is planned to be use for vacation and holidays), the mechanical system is designed to take advances from the solar energy, thus limiting CO_2 emissions.

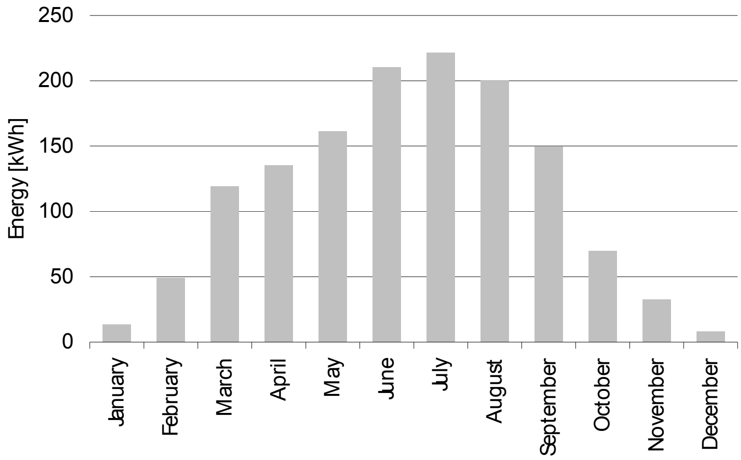

Fig. 10 Monthly energy produced by 2.5 kW roof photovoltaic modules

The PV panels convert directly the solar energy in electricity to meet the energy needs (heating and electrical use) of the building. The 2.5 kW of photovoltaic roof allow producing 2722 kWh of electrical energy, distributed as reported in Fig.10. The electricity produced can be directly used when the user are at home or sell it to the grid (40 Euro cents per kWh) when it is not needed or is over-produced (summer time mainly). In detail the system is designed as following: solar photovoltaic panels installed on the south-facing roof with an energy peak production of 2.5 kW, electrical radiant heating system placed in the floor, high efficiency electric boiler producing domestic hot water, mechanical ventilation with heat recovery (90% efficiency) to reduce ventilation losses and improve the air quality. The Fig.11 considers a hypothetical occupant schedule for the energy analysis: it is assumed that the houses are occupied regularly during the week-end and in the winter and summer vacation.

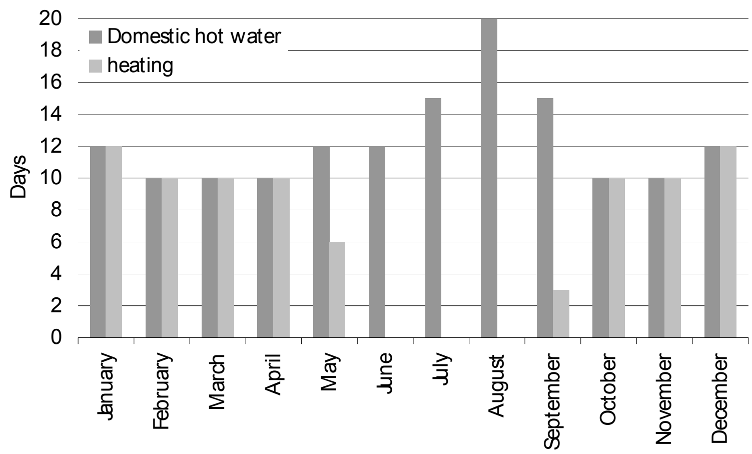

Fig. 11 Schedule of use

Particularly, the graphics of Fig. 12 and Fig. 13 shows the monthly energy need for heating and domestic hot water. During the summer months, the balance between the produced and used energy, is negative and the over-produced energy will be sold to the national grid. In winter the “free energy” is used in order to satisfy the energy demand of the electrical floor heating and of the boiler. Considering the complete year, the energy need for heating and hot water is about 9 kWh/m²a.

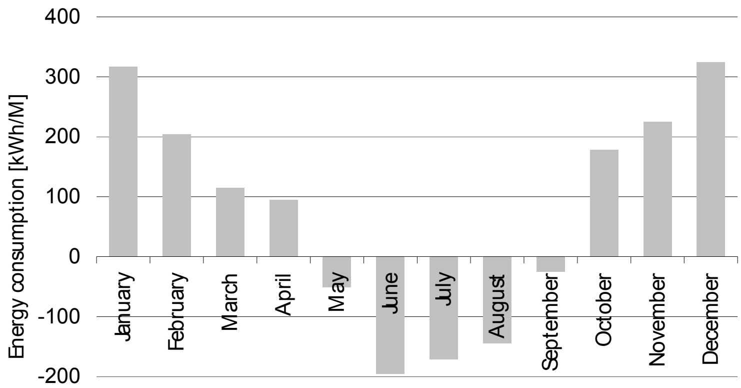

Fig. 12 Monthly energy need [kWh/mqM]

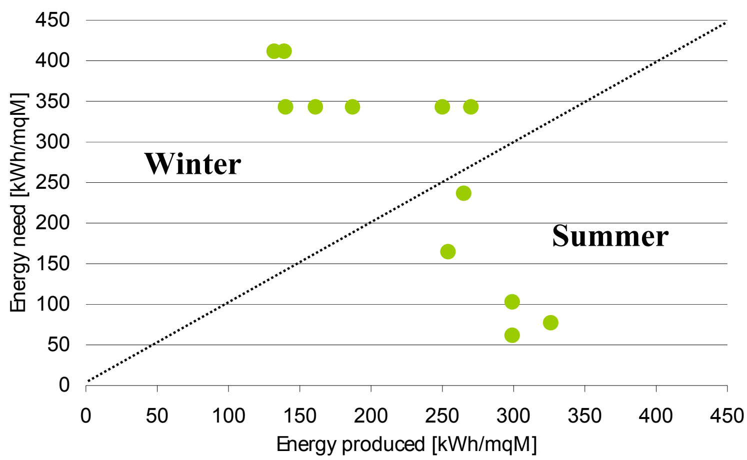

Fig. 13 Energy produced versus energy need [kWh/mqM]. The straight line represent the balance between the local energy produced and the energy need of the building. The green dots indicate the real energy consumption, under the line we have over-produced energy and over the line under-production energy.

2 Conclusions

This paper showed a practical example of a holistic design process integrating architectural, technological and energetic issues; the result is a low-energy building (heating and electrical useful energy demand below 10 kWh/m²a) with a contemporary architecture that is suited to the specific context. The settlement is now in the final construction phase. Up to now the authors have not monitoring data to assess the real behavior of the houses, but the first inspection reveals the good quality achieved by the design group. To pursue the CasaClima ClassA standard the team adopted different active and passive solar strategies since the early design stage, together with a large use of renewable energy sources and ecological traditional materials.

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