Design of a multi-purpose building "to zero energy consumption" according to european directive 2010/31/ce: architectural and plant solutions

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Abstract

Considering the significant impact that the residential sector has on energy consumption, it is particularly important to implement policies aimed at improving energy efficiency in buildings for saving primary energy, and also to spread the concept of sustainable development through the use of appropriate technology and proper project criteria for new constructions. For these reasons the Municipality of Città della Pieve promoted the creation of a "Renewable Energy Park" in a deprived area of its territory, so that there were the main technologies for the production of green energy. In this context, it could not be lacking an educational/demonstrative "zero energy consumption" building for multifunctional activities realized with the most innovative techniques to save energy. The building will exemplify the optimization of the benefits derived from improved energy efficiency in synergy with systems of energy production from renewable sources, such as to make possible the transition from "passive" building to get to "active" building. In this paper we describe the technical solutions adopted both in the building envelope and the system concept for the project of that "zero energy consumption" building according to Directive 2010/31/CE. In order to validate the proposed solutions, it has also been carried out a simulation of the behaviour of the building in summer and winter so that it is possible to assess the actual benefits obtained both in terms of energy and in economic terms following the adoption of the proposed solutions.

Keywords

Sustainability, building, insulation materials, energetic performances

1. Introduction and regulatory background

The precarious state of health of our planet and the awareness of the limited non-renewable energy sources, made it inevitable a reform of the human activities' process of development, directed toward a policy of energy saving and promoting the use of alternative energy sources [1]. Data from ENEA MSE show that the building sector in Italy consumed in 2008 about 45 Mtoe of energy out of a total of 192 Mtoe, showing an increase from about 42 Mtoe required in 2005. From this emerges that civilian use of energy have continued to grow up despite the economic crisis of these years that, however, have affected other fields [2].

Considering the impact of residential sector in the emissions of climate-altering gases and in the use of primary energy, it is of main importance to implement policies aimed to improve the energy efficiency of buildings, thus saving primary energy. It is also important to disseminate the concept of sustainable development through the use of appropriate technology and appropriate design criteria for new constructions and for the rehabilitation of existing ones [3].

In recent years, several agreements were signed at international level, starting with the Geneva Convention of 1979, to arrive in the 1997 to Kyoto Protocol. This document defines timing and extent of the reduction of greenhouse gases emissions by 2012, and explicitly identifies the policies and actions to undertake. In the EU context, this is a new reference frame for the development of

standards related to energy conservation, to the climate change and to the management of environmental resources and energy. In this perspective, the Energy Certification of buildings determined by the European Directive 2002/91/EC assumes particular importance [4]. The creation of an energy label associated to the buildings, allows to classify them according to their energy performance and allows to limit consumption during the construction and/or restructuring. The recently published Directive 2010/31/UE [5] integrates the 2002/91/EC and promotes the improvement of buildings' energy performance in the Union. It is also applicable to all types of business, both in the civilian and industrial sector. In the cost-benefits analysis perspective, already provided by Directive 2002/91, Directive 2010/31 defines the evaluation of energy performance level in relation to costs (Art. 4). The obligation to build near-zero energy buildings starts on December 31, 2020, for private homes, and on Dec. 31, 2018, for the local government buildings, whether occupied or not (Art. 9). The limit size of the buildings surface subject to important renovations disappears and it is established by Directive 2002/91 to 1000 m^2. Beyond this limit there is the obligation to comply with the minimum energy performance requirements set by the State (Art 7). Besides, Directive 2010/31 introduces the obligation to report, on all the advertisements of commercial media, the energy performance indicator in cases of sale and lease (Art. 12). Lastly, the Member States have the chance of reducing the frequency of heating systems inspections in the presence of an electronic system of control (art. 14).

The measures to be undertaken vary depending on the type of building. For new buildings it is necessary to submit, before work, an assessment of technical, economic and environmental feasibility for the use of alternative energy production systems. It is fundamental to take into consideration: the decentralized energy supply systems based on renewable energy sources; cogeneration; urban or collective district heating or cooling , particularly if it is based wholly or partly on renewable energy, heat pumps. The preliminary study, which must be documented and made available for inspection, can be made for individual buildings, groups of similar buildings or for common types of buildings which are in the same area. In the case of existing buildings, a renovation can be defined as important and therefore be subject to the requirements for new buildings in two cases: with regard to the building envelope or buildings' technical systems, the cost of the renovation exceeds 25% of the value of the building, excluding the value of the land upon which it is located; on the other hand, the renovation concerns more than 25% of the building envelope. With regard to the Energy Performance Certificate, it allows to evaluate and compare the energy performance of different buildings / housing units with the same method of judgment. The novelty is that, in case of sale or lease, the energy performance indicator contained in the certificate of the building or building unit, is shown in all advertisements of commercial media in Italy. The directive is in effect from 8 July 2010, but States of EU have time until July 9, 2012 to adopt it.

This article concerns the study of plant and architectural solutions aimed to the creation of a multipurpose building in a near zero consumption to be realized in a town of central Italy. This building is part of a project for the upgrading of a degraded industrial area, where will be created a renewable energy park.

The main objective of this project is to promote, on a broader scale, the use of technologies aimed at energy savings while providing the same level of service and to stimulate the energy production from renewable sources; for this purpose, several measures of energy production from renewable energy sources, such as solar and wind power plants, will be designed, constructed, managed and monitored. The Park project will also involves an educational course and a training center for young people from Città della Pieve and neighboring towns, in order to sensitize the community on these issues.

2. Case study

2.1 General framework

The project is set in the territory of Città della Pieve in Umbria on a hill at 508 m sea-level dominating the Valdichiana and Trasimeno Lake. A town with about 7,800 inhabitants and a territorial extension equal to 111 square kilometers which is situated on the border between two regions, Umbria and Tuscany, and three provinces, Perugia, Terni and Siena. The hill is like a plateau (Fig. 1), characterized by ridges alternating with deep ditches with layers of sands and conglomerates and large amounts of fossil fuels. This is the area where, several geological ages ago, there was the ancient delta of the Tiber.

Figure 1- landscape of Città della Pieve

The area identified by the city Administration for the implementation of the Technology Park for Energy and Environmental Sustainability, is located in the north of the village of Ponticelli, and covers an area of approximately 9 ha and is located in a flat depression bounded to the east by the channels Chiana and Astrone and to the west by the two railway lines Rome-Florence. To the south there is an industrial area in a strong deteriorating state with some disused craft buildings.

The whole area is particularly suited for the creation of a Technology Park for Energy and Environmental Sustainability. The park project involves the construction of an educational course and a training center for young people from Città della Pieve and surrounding municipalities. In detail, the functional program for the entire area provides the realization of:

- No.2 fixed solar fields with peak powers respectively of 900 kW and 800 kW for a total of 1700 kWp;
- No.3 "Sunflowers" made up of three sail of 12 kWp for every biaxial solar tracker, for the production of electricity in addition to the n. 2 fixed solar fields;
- No.4 micro-wind blades, two with horizontal and two with vertical axis, for a peak power of not more than 10 kWp;
- A multipurpose building designed in a single floor for education and training (about 50/60 sqm), built with green building techniques and completely sustainable. It will be a passive building designed with lightweight technologies and it will be the best expression of contemporary architecture in compliance with European Directive 2010/31/CE.

Thereafter, may be also realized an experimental section in which it will be possible to monitor some technologies, still in testing phase, to make them usable by public and private entities wishing to implement interventions in pilot scale. So it will be possible to create an attraction pole for all companies operating in the business. Companies will thus benefit from incentives and support in both financial and bureaucratic fields and in the connection with academic research and innovation.

Subject of this work is the analysis of solutions to "near-zero energy" suggested for the multipurpose building.

2.2 Architectural-Structural Analysis

The multi-purpose building at the service of the Renewable Energy Park was designed with architectural solutions that allow to take into account the context in which it is built, the energy conservation and the use of low environmental impact materials.

The building is constituted by a single floor, made in a raised position compared to the ground level through the presence of a ventilated crawl space 120 cm high. There are two spaces used for teaching purposes:

1. an interior space which consists of a multipurpose hall and an exhibition hall. The two rooms are characterized by large windows that allow an optimum observation of the external technological plants;
2. an outdoor space, located to the west, consisting of a staircase covered with photovoltaic panels made of polycrystalline silicon, for a pleasant use in summer.

Since the extent of glazing surfaces is considerable, the design includes low emissive elements to offer a comfortable shielding from solar radiation, especially during the summer. The windows' frames are made of aluminum in modules of 120 x 180 cm.

In addition, there is also a reinforced concrete septum that allows to isolate the building, visually and acoustically, from the nearby railway line. This septum is also the structural technological backbone on which are installed technical plants of the educational areas, in the south-west, and the mechanical room, containing electrical panels, on the east façade.
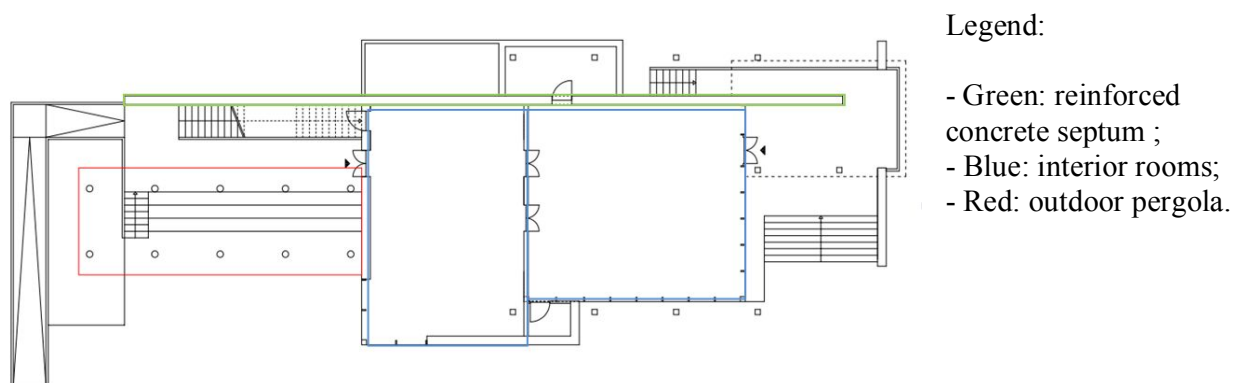

Legend:

- Green: reinforced concrete septum ;
- Blue: interior rooms;
- Red: outdoor pergola.

Figure 1 - Ground Floor: educational and external areas and reinforced concrete septum

Figure 1 shows the plan of the ground floor where is possible to identify the reinforced concrete septum, the interior rooms and the external pergola.

The building's roof is on two levels and it is made up with different construction types (Figure 2). In particular, there are:

1. an accessible green roof, to cover the exhibition hall, made with a suitable stratigraphy and placed at 4.5 m;
2. a not accessible green cover, positioned above the right entrance's porch;
3. a not accessible self-supporting cover over the multipurpose room, with an average height of 6,15 m with slope equal to 2% in the direction of the septum. On this cover there is also a solar-thermal integrated solution (Figure 3);
4. a photovoltaic roof, to cover the external pergola on the left, made of steel structural elements.
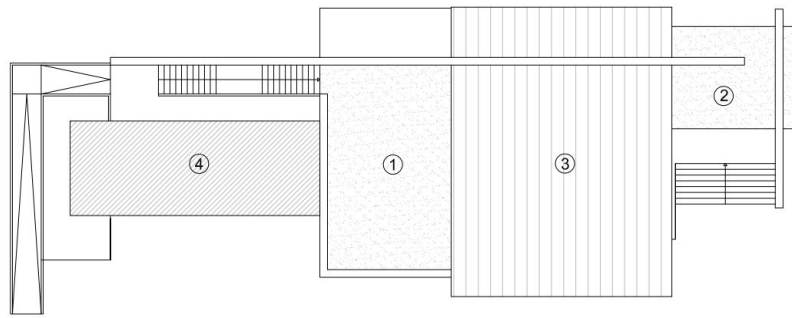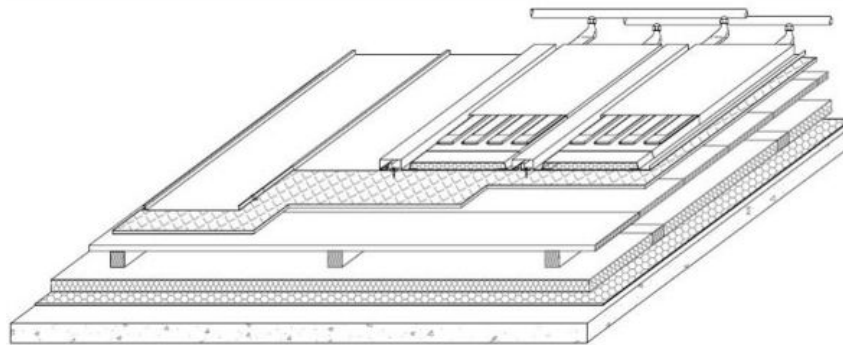
Figure 2 - Plan of the coverage

Figure 3 - Detail of the thermal solar integrated cover

From the structural point of view, the design of the complex was performed by limiting the use of hydraulic binders and traditional materials such as concrete and masonry.

The building presents a punctual structure with lamellar wood pillars of size 24 x 24 cm connected directly to the foundation platform. The point elements were also used in the definition of outer space in particular for the two porches.

In addition to the point structure, were also designed some continuous self-supporting elements (walls) that realize the internal division and define, together with windows, the perimeter of the rooms.

With the exception of the septum, the foundation (a reinforced concrete strip foundation that retrace the perimeter of the structure), the low walls (which allow to raise up the floor from ground level) and external walls of the technical services room (made of masonry), the remaining part of the structure was made using a dry technology.

The building's roof, set on two levels with different lights, was made of beams of different sizes: 60 x 24 cm first level, 90 x 24 cm second level .

The building will then be equipped with disabled access.

All the solutions, both in terms of materials and plants solution, are inspired by the principles of bio-architecture, thus creating an element of very low environmental impact and high energy self-sufficiency.

2.3 Building packages' stratigraphy

The energy analysis, performed in accordance with the DPR April 2, 2009 No. 59 came into force on June 25, 2009 [6] for the values of transmittance and according to UNI EN ISO 13788 [2] for Thermohygrometric testing, has led to the choice of particular stratigraphy for the building packages. The study was carried out through a specific software (Edilclima EC700), which allowed the determination of the thermal performance and the energy class of the building.

Below there are the details of the Construction layers of the building elements used. In particular, in Table 1, are shown the details of the walls.
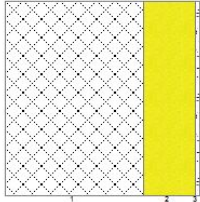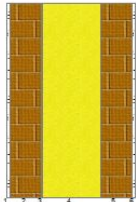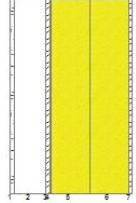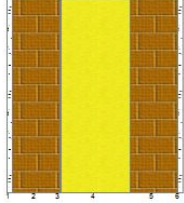
Wall	Layer description	Depth (mm)	D_{TOT} (mm)	U (W/m^{2}K)	U_{LIMIT} (W/m^{2}K)	Picture
Concrete reinforced septum	Reinforced concrete	400	563	0.24	0.34	
	Feldspar mineral fibers	150				
	Plasterboard	13				
Toilet facilities/technical premises' dividing wall	lime and gypsum plaster	10	331	0.219	0.8	
	Brickwork, internal wall	80				
	Bitumen felt/sheet vapour barrier	0.5				
	Feldspar mineral fibers	150				
	Brickwork, outer wall	80				
	lime and gypsum plaster	10				
Dry wall	Plasterboard	13	314	0.179	0.34	
	Non-ventilated air gap	80				
	OSB panels	10				
	Bitumen felt/sheet vapour barrier	0.5				
	Feldspar mineral fibers	100				
	Feldspar mineral fibers	100				
	OSB panels	10				
Toilet facilities' outer wall	lime and gypsum plaster	15	451	0.194	0.34	
	Brickwork, internal wall	120				
	Bitumen felt/sheet vapour barrier	0.5				
	Feldspar mineral fibers	180				
	Brickwork, outer wall	120				
	lime and gypsum plaster	15				

Table 1 – Walls' stratigraphy

The calculations show that the average transmittance of the walls is equal to 0.208 W/m2K, that the verification of absence of surface condensation is satisfied and that the interstitial condensations of opaque walls are limited to the evaporable amount.
In the following part, there are the stratigraphy of the proposed solutions for the covers (Table 2). The self-supporting cover is realized with panels composed by an insert of non-combustible mineral wool covered with a vapor barrier which allows to achieve excellent thermal insulation values.
The extensive green roof is a system that combines thermal insulation, energy saving, mitigation of environmental impact and water drainage system. It is particularly suitable for all those coverings that can not be subject to frequent maintenance, because it does not require an irrigation systems.

The vegetation used, *sedum*, easily adapts to the weather conditions because it can regenerate itself quickly and it can resist to long dry periods.

The estimated cost is around 100 € / m2 for a total of 8000 €.

At the ground floor has been suggested the insertion of a conventional ventilated attic made up with cupolex and underfloor heating, as shown in Table 2.
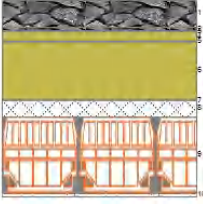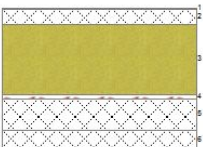
Covers	Layer description	Depth (mm)	D_{TOT} (mm)	U (W/m²K)	U_{LIMIT} (W/m²K)	Picture
Self-supporting cover	Fir wood	10	221	0.179	0.3	
	Feldspar mineral fibers	200				
	Bitumen felt/sheet vapour barrier	0.5				
	Fir wood	10				
Green roof	Wet soil	70	506	0.172	0.3	
	Living loose pumice	10				
	Nonwoven fabric	1,3				
	Extruded polystyrene	24				
	Polyester fabric	0.5				
	Extruded skinless polystyrene	150				
	Bitumen felt/sheet vapour barrier	0.,5				
	Sand and gravel concrete	40				
	Brick floor	200				
	Lime and chalk plaster	10				
Airy floor	Ceramic tiles	1	362	0.194	0.33	
	Lean concrete	40				
	Extruded polystyrene in plates	180				
	Thermoliving 3B	11				
	Lean concrete	80				
	Screed coat	50				

Table 2 - Covers and airy floor

The calculation shows that the average transmittance of the covers is equal to 0.176 W/m² and that the thermohygrometric tests are met.

The glass wall is equipped with a continuous insulating glass with double function of low emissivity and solar control. This glass gives to the wall reinforced thermal insulation properties in winter and sun protection in summer. The glass is made through a process which provides the presence of an airtight space filled with insulating gas (argon 90%) between the two panes, allowing to reach a transmittance value of 1.1 W/m²K.

In winter, the glass provides a thermal insulation three times higher than a normal double glazing allowing a reduction in heating costs. Besides, the ability to achieve greater comfort in the proximity of the glass walls, reduces the risk of condensation inside. It also protect the environment by reducing greenhouse gas emissions and allows to have large windows yet respecting the constraints of regulations existing on thermal matter [5]. In summer, the glass reduces by twice the direct transmission of solar heat allowing the maintenance of a pleasant indoor temperature, limiting

the costs for air conditioning and reducing the transmission of ultraviolet radiation. In particular, the free solar contribution both on opaque elements and glass windows elements has been calculated. This value is equal to 32371 kWh for the entire summer season (April 15 - October 15), as measured according to UNI TS11300. This thermal load is brought down, as well as the sensible load and the latent load, through the use of the air conditioning, which is able to maintain an internal temperature of at most 5° C lower than the outdoor temperature.

The aluminum frame has permeability class 4 according to UNI EN 12207 [9] and transmittance equal to 1.34 W/m^2K. The total transmittance takes account of the features of glass package and aluminum frame and reach the value of 1.274 W/m^2K (Table 3). The average transmittance of the glass walls is equal to 1.407 W/m^2K.

Building package	Depth$_{TOT}$ (mm)	U (W/m^{2}K)	Permeability class	U$_{LIMIT}$ (W/m^{2}K)	U $_{GLASS}$ $_{ONLY}$ (W/m^{2}K)	U $_{LOOM}$ $_{ONLY}$ (W/m^{2}K)
Continuous insulating glass wall	28	1.274	4	2.2	1.1	1.34

Table 3 - Glass wall

2.4 Plant choices

Plant choices have been made by pursuing the theme of environmental sustainability that is improvement of building energy performance, trying to combine the aesthetic and energy options. These reasons have led to the inclusion of a photovoltaic system, that makes a sort of technological bower, and of an integrated solar cover which can be used both for the production of hot water and for the operation of underfloor heating. These systems can significantly reduce consumptions of the building.

In particular, the solar thermal cover is an innovative system made entirely of copper. The surface of the cover absorbs the heat of solar energy which is then transmitted to a system of pipes located under the roof covering. Inside the tubes flows a fluid (water + 40% ethylene glycol) at a pressure of 1 bar that transfers heat through a stainless steel coil, to the water contained in the storage tank and from there to the entire thermal system. The water is stored at a temperature of about 50° C, to be then sent to the users. This solution is ideal not only for residential building but also for sports facilities, public buildings, hotels and multi-purpose complex as in this case.

According to the size of the cover, 24 solar collectors have been provided. Their dimensions are 46,7 cm x 5 m and in each one flows, through the ovoid section, an operating flow rate of 87 l/h for a total of 2088 l/h.

This flow rate satisfies completely hot water demand and partly heating demand (3729.78 l/h).

Table 4 shows the percentages of the requirements of Domestic Hot Water and Heating met by solar thermal cover.

Domestic Hot Water	Heating

Months	Primary Energy (excluding solar energy) [kWh]	Coverage Percentage [%]	Primary Energy (excluding solar energy) [kWh]	Coverage Percentage [%]
Jan.	29	98.7	1534	6.3
Feb.	25	100.0	961	9.7
Mar.	26	98.7	207	41.6
Apr.	23	100.0	15	99.1
May	23	95.1	0	0.0
June	21	98.3	0	0.0
July	21	95.1	0	0.0
Aug.	21	95.1	0	0.0
Sept.	21	98.3	0	0.0
Oct.	23	98.7	0	0.0
Nov.	24	100.0	275	30.3
Dec.	28	98.7	1416	6.5

Table 4 – Percentages of the requirements covered by solar thermal cover

With regard to the PV system, the choice is to include 30 polycrystalline panels with peak power of 285 W for a total output of 8 kW.

They have been installed with southwest exposure following the inclination of technological bower of 15°. In Figure 4 is reported the graph of the monthly production of the plant.

Figure 4 - Energy monthly produced by the PV plant

The cost of single panel is € 331.21 for a total of € 9936.39, that is € 1242 / kW.

The energy requirements of the heat pump is entirely covered by the energy produced by the photovoltaic system, in particular the heat pump has an absorption of 4 kW in wintertime and of 5.4 kW in summertime.

The features of the heat pump are reported below (Table 5).

Features:	Electric demand:

Nominal power (kW)	COPe	Average power of auxiliaries (W)	Electric power of circulating pumps (W)
16.30	3.94	70	250

Table 5 - Features of the heat pump.

3. Calculation results

3.1 Calculation Methodology

This study used Edilclima EC700, a software elaborated by Edilclima software house. The thermo-physical parameters refer to an internal database (coming from UNI Standards) or to manual input. The thermal-bridges are calculated by a parametric method called "Atlas of thermal-bridges" which follows UNI 14683 Standard [14].

The heating and domestic hot water plant inputs are expressed in global thermal-efficiency or for each plant subsystem and they are referred to UNI TS 11300 part 2 or producer technical database. The outputs are:

a) wintertime power, for the sizing of the heating system according to UNI EN 12831;

b) useful and primary energy winter heating, according to technical specifications UNI/TS 11300 part 1 and 2;

c) useful energy for summer cooling, under the technical specification UNI/TS 11300-1;

d) useful and primary energy for domestic hot water production, according to UNI/TS 11300-2.

Climate data considered in this study come from the Archive of Software and are based on the UNI 10349. They include: winter and summer design temperature, summer design humidity, wind speed, average monthly temperature, monthly average solar irradiance for 9 directions, the monthly average vapor pressure, altitude, latitude, longitude, climate zone, wind area, degree days.

The standard input conditions are UNI TS 11300 standard input data. The input data used are:

- Hours of heating plant operation: 24 h/day;
- Hours of cooling plant operation: 12 h/day;
- Number of days of heating plant operation: 183 day;
- Outside project temperature in winter: -2°C.
- Outside project temperature in summer: 29.5°C;
- Inside project temperature in winter:20°C.
- Inside project temperature in summer: 26°C;
- Indoor dry bulb temperature: 25° C;
- Winter indoor relative humidity: 60%;
- Summer indoor relative humidity: 50%;
- Air exchange peak: 0,5 vol/h;
- Number of persons/m^2: 0,25 persons/m^2;
- Sensible heat per person: 64W/person;
- Latent heat per person: 46W/person.

For the calculation of the energy performance, the internal space has been divided into 2 thermal zones (Figure 5):

1. air-conditioned area, which includes the exhibition room, the multipurpose room and toilet facilities (A);
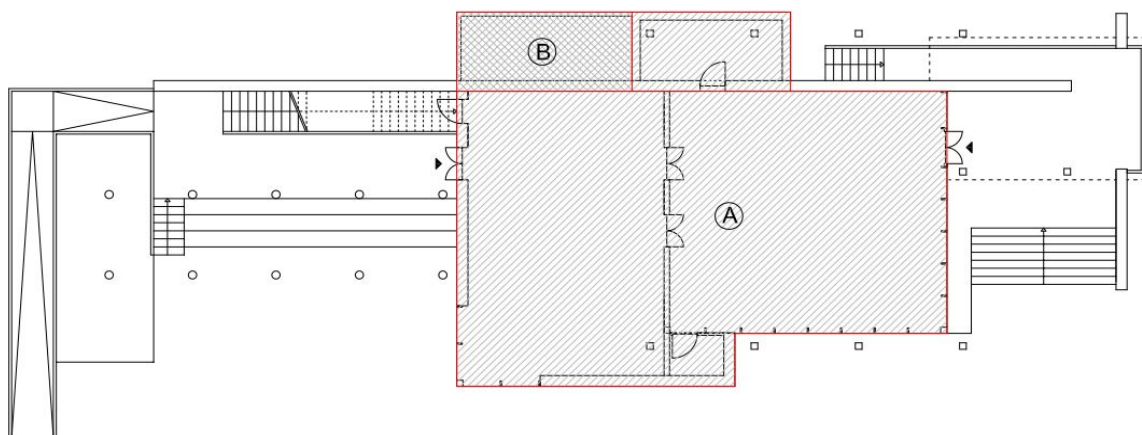2. non-heated area, represented by the equipment room (B).

Figure 5 - Identification of the air-conditioned and non air-conditioned area

3.2 Settings

In this article the energy performance of multi-purpose building have been evaluated, using the software Edilclima EC700 and considering different settings [11, 12, 13]:

1. Setting 1: This scenario considers a building realized with Construction layers of the building elements reported in section 2 (Building on "near-zero" consumption), and the use of renewable energy sources (photovoltaic and solar thermal cover);

   1.a   Setting 1.a: Building on "near-zero" consumption with only solar thermal cover;

   1.b   Setting 1.b: Building on "near-zero" consumption without renewable energies.

2. Setting 2: This scenario regards a building constructed with Construction layers of the building elements with transmittance value according to law limits, and the use of renewable energy sources (solar thermal cover), in which:

   - The depth of the insulating layers and the full-length window reach the limit values of transmittance provided for the rules about vertical and horizontal opaque components and windows (DPR 59/09 [5]);
   - Absence of the photovoltaic system, due to the use of a non electrical heating system;
   - Replacement of the heat pump with a conventional Plant.

   2.a   Setting 2.a: Building according to the limits of law without renewable energies.

Setting n. 1

The results of the evaluations are reported below (Table 6).

Heating service		
Annual primary energy demand	3942	kWh/year
Annual consumption of electricity	1813	kWh$_e$/year
Hot water service		
Annual primary energy demand	5	kWh/year
Annual consumption of electricity	2	kWh$_e$/year
Thermal solar system		
Manufacturability of the solar panels (hot water)	534	kWh/year
Percentage coverage (hot water)	98.2	%
Manufacturability of the solar panels (heating)	778	kWh/year
Percentage coverage (heating)	10.6	%

Photovoltaic system		
Electricity from photovoltaic system	9708	kWh/year
Total electrical demand	1816	kWh/year
Electricity from main	0	kWh/year
Electricity produced and not consumed	7892	kWh/year
Energy primary index (EPi)	0	kWh/m^{3}year
Energy primary index provided for the rules (D.Lgs. 192/05)	21.26	kWh/m^{3}year

Table 6 - Energetic ratings Setting 1

From the analysis of results follows that the annual consumption of electricity for heating and hot water amount respectively to about 1813 kWh/year and 2 kWh/year, for a total of 1816 kWh/year. The PV system can produce 9708 kWh/year, of which 7892 kWh/year are not consumed but put in the mains.

For this reason, the building can be considered as a zero consumption structure.

Setting n. 1.a
The results of the evaluations reported below (Table 7) are referred to the case that the photovoltaic system is removed and the consumption of the building is fully covered by the mains.

Heating service		
Annual primary energy demand	3942	kWh/year
Annual consumption of electricity	1813	kWh$_e$/year
Hot water service		
Annual primary energy demand	5	kWh/year
Annual consumption of electricity	2	kWh$_e$/year
Thermal solar system		
Manufacturability of the solar panels (hot water)	534	kWh/year
Percentage coverage (hot water)	98.2	%
Manufacturability of the solar panels (heating)	778	kWh/year
Percentage coverage (heating)	10,6	%
Energy primary index (EPi)	3.68	kWh/m^{3}year
Energy primary index provided for the rules (D.Lgs. 192/05)	21.26	kWh/m^{3}year

Table 7 - Energetic ratings Setting 1.a

Setting n. 1.b
The results of the evaluations are reported below (Table 8). In this case there is an increase of 16% of annual consumption of electricity due to the absence of the solar thermal system in addition to underfloor heating. The annual consumption of electricity increases from 1816 kWh/year to the value of 2158 kWh/year.

Heating service		
Annual primary energy demand	4408	kWh/year
Annual consumption of electricity	2027	kWh$_e$/year

Hot water service		
Annual primary energy demand	284	kWh/year
Annual consumption of electricity	131	kWh_e/year
Energy primary index (EPi)	4.11	$kWh/m^3 year$
Energy primary index provided for the rules (D.Lgs. 192/05)	21.26	$kWh/m^3 year$

Table 8 - Energetic ratings Setting 1.b

Setting n. 2

For the setting n. 2, the analysis has been performed considering building packages with transmittance values near to the rules limits [6]. The percentage differences in terms of depth of insulating material and in terms of thermal transmittance of the packages have been reported in Table 9.

Building package	Insulating layer	Depth (mm)	Depth$_{STANDARD}$ (mm)	Δ S %	U (W/m²K)	U$_{STANDARD}$ (W/m²K)	Δ U %
Reinforced concrete septum	Feldspar mineral fibers	150	100	33	0.24	0.344	30
Dividing wall facilities – technical premises	Feldspar mineral fibers	150	80	47	0.219	0.354	38
Drywall	Feldspar mineral fibers	100	40	60	0.179	0.351	49
	Feldspar mineral fibers	100	50	50			
External wall of facilities	Feldspar mineral fibers	180	90	50	0.194	0.343	43
Self-supporting cover	Feldspar mineral fibers	200	110	45	0.179	0.310	42
Green roof	Extruded skinless polystyrene	150	60	60	0.172	0.317	46
Airy floor	Extruded polystyrene in plates	180	100	44	0.194	0.316	39

Table 9 - Depth of the insulating layers and transmittances of building packages Setting n.2

The percentage differences in terms of thermal transmittance of the insulating glass wall has been reported in Table 10.

Building package	Depth (mm)	U $_{GLASS}$ ONLY (W/m²K)	U $_{FRAME}$ ONLY (W/m²K)	U (W/m²K)	U $_{GLASS}$ ONLY STANDARD	U $_{FRAME}$ ONLY STANDARD	U$_{STANDARD}$ (W/m²K)	Difference % U

			(W/m²K)	(W/m²K)				
Continuous insulating glass wall	28	1.1	1.340	1.274	1.7	4.4	2.258	44

Table 10 - Depth and transmittance of the glass wall Setting n.2

The average values of transmittance of different building packages reached in setting n.1 and in setting n.2 are reported in Table 11.

	Setting n.1	Setting n.2	
	$U_{AVERAGE}$ (W/m²K)	$U_{AVERAGE}$ (W/m²K)	Δ U %
Walls	0.208	0.347	67
Covers	0.176	0.314	78
Floors	0.192	0.311	62
Glass walls	1.407	2.056	46

Table 11 - Average values of transmittance

The technical features of the traditional boiler, that in Setting n. 2 replaces the heat pump, are reported in Table 12:

Features:		
Nominal power of furnace	**28.00**	kW
Efficiency at nominal power	**93.20**	%
Efficiency at intermediate power	**94.10**	%
Electric demand:		
Electric power burner	**120**	W
Electric recovery factor	**0.80**	-
Electric power of circulating pumps	**0**	W
Electric recovery factor	**0.80**	-

Table 12 - Features of the traditional boiler

The results of the simulation on Setting n. 2 are reported in Table 13:

Heating service		
Annual primary energy demand	16087	kWh/year
Annual consumption of fuel	1597	Nm
Annual consumption of electricity	100	kWh$_e$/year
Hot water service		
Annual primary energy demand	11	kWh/year
Annual consumption of fuel	1.1	Nm
Annual consumption of electricity	0	kWh$_e$/year
Thermal solar system		
Manufacturability of the solar panels (hot water)	534	kWh/year
Percentage coverage (hot water)	98.0	%
Manufacturability of the solar panels (heating)	961	kWh/year
Percentage coverage (heating)	6.4	%
Energy primary index (EPi)	15	kWh/m³year

Energy primary index provided for the rules (D.Lgs. 192/05)	21.26	kWh/m^{3}year

Table 13 - Energetic ratings Setting 2

Compared to Setting n.1, there is an increase of annual primary energy demand equal to 12145 kWh/year for heating service and to 6 kWh/year for hot water service. This second increase is however reduced because the building is still provided with solar thermal system.

Setting n. 2.a
In this simulation, the solar thermal cover is removed. The results are reported in Table n. 14:

Heating service		
Annual primary energy demand	17192	kWh/year
Annual consumption of fuel	1707	Nm
Annual consumption of electricity	105	kWh$_e$/year
Hot water service		
Annual primary energy demand	583	kWh/year
Annual consumption of fuel	58.2	Nm
Annual consumption of electricity	2	kWh$_e$/year
Energy primary index (EPi)	17	kWh/m^{3}year
Energy primary index provided for the rules (D.Lgs. 192/05)	21.26	kWh/m^{3}year

Table 14 - Energetic ratings Setting 2.a

In this case, the increase of primary energy demand from 11 kWh/year in Setting n. 2 to 583 kWh/year in Setting n. 2.a, is due primarily to hot water service that, in the previous simulation, was covered for 98% by the integrated solar thermal solution.

4. Conclusions

The analysis made in this article relate to the architectural and plant solutions of a multipurpose building on "near-zero" consumption. Different plant solutions and different architectural solutions have been evaluated to compare the consumption in the various solutions suggested.
The values of global primary energy demand for winter heating in the different settings considered have been summarized in Table 15:

	EP$_{gl}$ (kWh/m^{3}year)	EP$_{gl,average}$	Δ EP$_{gl,average}$ %
setting n.1	0		
setting n.1.a	3.68	2.7	
setting n.1.b	4.38		504
setting n.2	15.01	16.3	
setting n.2.a	17.59		

Table 15 - Percentage increase of EP$_{gl,average}$

Furthermore, the use of renewable sources, combined with the use of building packages with high performance and with high efficiency plants, allows to obtain in all settings analyzed low emissions of CO_2 (Table 16).

	kgCO$_2$/m^{3}year
setting n.1	0

setting n.1.a	1.6
setting n.1.b	1.9
setting n.2	3
setting n.2.a	3.51

Table 16 - Emissions of CO_2

Thanks to the combination of these elements, which allow the building to reach energy self-sufficiency, the design assumptions applied in Setting n.1. make the multipurpose building a structure on zero consumption with zero emissions of CO_2.

Moreover is very interesting to analyze the situation of the costs of a building realized with a "near-zero" consumption and a "traditional" building. The estimated costs taking in account the elements listed below:

- Construction works;
- Sanitary water systems, and sewer;
- Mechanical plants;
- Electrical plants.

The building costs for a "near zero" consumption building is around 1700.00 €/m^2 (for a total amount of 255,000.00 € VAT excluded) instead a traditional construction building that is about 1400.00€/m^2 (for a total amount of 210,000.00 € VAT excluded). Considering the current market price of thermal and electric kWh, the difference in terms of operating costs between the two solution must be estimated at about 5500.00 €/year. So is it possible to evaluate the pay-back period of the investment is 8.2 years.

Acknowledgments

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