Building with nature: the case of “Case di Luce”

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Abstract. Case di Luce is a Near Zero Energy Building and it is part of a sustainable urban regeneration that avoids land consumption, improving the area, sites in Bisceglie, a city of the south of Italy. A complex system of public spaces increases urban quality, matching residential NZEB with new infrastructures. The design experimentation stems from a holistic approach, linked to the themes of bio-architecture, eco-sustainability, environmental and living comfort. The architectural language is based on Nature and Bioclimatism. The project envisages as principles of sustainability new constructive techniques and natural materials as the backbones of the architectural composition, in a Mediterranean language. These elements are two. The first are greenhouses, the elements of passive capture of solar energy and of mediation between internal and external parts. The second is the "sail" cover - to accommodate the solar thermal and photo-voltaic panels – that allow the improvement of the architectural style and facilitate the achievement of the visual and thermal comfort. Great technical, ethical and environmental attention characterizes the building's walls that are indeed realized with hemp and lime bricks, a mixture that is completely recyclable, bio-compatible, able to capture CO2. The use of breathable, green certified and non-toxic materials facilitates high standards of living. The building is certified by CasaClima Gold 10 kWh/m2a and won the GREEN BUILDING AWARD 2016.

1. Introduction
Case di Luce is an innovative NZEB building that won the GREEN BUILDING AWARD 2016. It comes from an integrated systemic and holistic approach, applied to the entire building process, linked to the themes of bio-architecture, eco-sustainability, environmental and living comfort. It is characterized by a completely natural envelope that applies an innovative system in Hemp and Lime bio-composite building material and Biomattone® of Hemp and Lime. This mixture is completely recyclable, biocompatible, able to capture and sequester CO2 (each cubic meter of material saves 60 kg CO2 from the atmosphere), balancing thus the emissions in the building construction phases. Case di Luce is one of the largest buildings in Europe built with hemp and lime and also it is one of the first examples in Italy to achieve the European Directive 2020 objectives due to its high CO2 absorption (~150,000 kg of C02) and its very low energy consumption. Architecture, sustainability, due to a careful balancing between bioclimatic planning (passive solar energy, passive cooling, natural light) and the use of renewable energy sources (like solar thermal and photovoltaic systems), and eco-wellbeing (green certified and non-toxic materials; high thermal, acoustic and hygrometric performance, exc) are so the key points of this building with near-zero environmental impact. (Main project informations in table 1).

Table 1. Main informations

| Project type            | New construction                          |
|-------------------------|-------------------------------------------|
| Building Type           | Collective housing (21 dwelling) and commercial |
| Climate zone            | Csb Coastal Mediterranean – Mild with cool, dry summer. |
| Net floor Area          | 3200 mq                                   |
| Certifications          | A4; 4.1 Itaca Protocol Puglia; CasaClima Gold |
| Construction year and Site | 2016 – Bisceglie (BT) - 76011- Italy     |
2. Description

2.1. The site
The project, which is in an area located semi-device Bisceglie, coastal town of Apulia, is an integral part of a new urban model that will be the driving force for redevelopment for a district which, although highly urbanized, is in a state of decay and neglect, exacerbated by the presence of abandoned industrial sites. After an incisive environmental cleanup operation, given the presence of asbestos, and demolition of the old settlements, the construction of this NZEB residential building, which took place without using up new territory, can give concrete answers through innovative design solutions "sustainable energy" times to enhance the urban quality and environmental sustainability.

2.2. Architectural features
The proposed design of the residential building, total of 21 accommodation units spread across five floors and an attic floor, comes from an integrated approach to systemic and holistic based on respect for bio-climatic characteristics of the place, from the exploitation of its potential to achieve the goal of sustainability with the maximum reduction of energy needs to self-limit. The complex of constructed spatial articulation has been dictated by introducing elements that allow to maximize free solar gains in the winter cycle: solar greenhouses, solar collection elements and mediation between inside and outside, but difficult to interpret in our latitudes where the attention should be given to both the winter to the summer heat gain that protection. So then, the optimal solution has been implemented, through the study of seasonal variations with solar diagrams, orienting the building towards the South-East and working to the shape of the entire facade, leaning on each floor with a different geometry, allows in winter, the light to penetrate in environments avoiding casting shadow on the underlying greenhouses and, in summer (with the sun overhead), the flow rates of the shadows to shade greenhouses glazed bodies of those below. In addition, to avoid the dreaded phenomenon of overheating in summer, the windows of the greenhouses closures are fully opened and thus turning a parcel, in summer, the nature of the space of each indoor greenhouse for outdoor and usable on a par with balconies. Another characteristic theme of the building is the presence of the “sail” cover, whose lower surface is covered with brown cork in stone, like the blind walls of the greenhouses, specifically inclined towards South/Southeast, to accommodate the solar panels thermal and photovoltaic, always in an integrated manner to the formal language and architectural building.

2.3. Building technology
Considering the nature of the place and the urban context in which the building is included, it was important the choice of sustainability in the design concept of the building with the use of innovative and sustainable technologies. The new building is characterized by very low energy consumption thanks to the use of all the measures for energy savings: elimination of thermal bridges, thermal insulating windows, heated by heat pump and high-performance casing from the thermal point of view, acoustic and humidity in as all-natural hemp and lime, production raw materials with low consumption and environmental impact close to zero.

2.4. Construction type
The bearing system of the building is characterized by concrete frame, with internal partitions tuff, local materials Km zero cost, and external partitions formed by an internal facing 10 cm tuff, a first sprayed layer of 25 cm of hemp and lime (ratio 1: 1), and a second layer of 5 cm (ratio 1: 4). Other walls are in Biomattone made by hemp and lime. The compound in hemp and lime is a completely natural cement, LEED® certified product, is made from vegetable hemp chipboard with a lime-based binder in a variable ratio depending on the thermal and mechanical performance requests. It is different from other insulating material because it combines high insulation properties and thermal mass with high environmental compatibility, recyclability and hygroscopic control; also it has a negative balance of CO2 emission material capable of capturing 60 kg of CO2 from the atmosphere per m3 of material. This innovative
constructive technology allows, with a single homogeneous natural material, act as the casing of insulating function and, solving of interstitial moisture problems and ensuring constant humidity levels in indoor environments without molds and pathogens. The use of masonry in Hemp and Lime (like sprayed layer or used in Biomattone) along with other natural building components, eco-friendly, certified and low or no emission of polluting volatile organic compounds (VOC) ensures high air quality to protect the health and welfare housing.

2.5. Plant characteristics of the building
The balance between energy strategies, plant engineering and construction techniques design guarantees the indoor comfort but with a lower level of consumption of 30 kWh/m²/year, comparing to the winter heating. The production of heat takes place both in a passive way, with the solar greenhouses, that by means of a system with centralized heat pumps having the final adjustment of temperature guaranteed by a radiant system fed by hot water (in winter) or cold (in summer). It’s also present in each apartment, a mechanical ventilation system with heat recovery, to ensure the air changes required by law energy loss due to the opening of windows. For the production of domestic hot water, the system is integrated by a solar heating system located on the roof, together with photovoltaic panels, to make a whole system up close to self-sufficiency.

![Figure 1. Case di Luce.](image)

3. Stakeholders
Construction company: Pedone Working s.r.l. (info@pedoneworking.it – www.pedoneworking.it).
Designers: PS Architetture (ing. Piero Pedone; Arch. Leo Pedone; Arch. Massimo Pedone)
Contracting method: Public Private Partnership

3.1. Owner approach of sustainability
Pedone Working srl, an established company in the construction industry who, with his group, has over 50 years of experience in the field of integrated design and construction management, from engineering to manufacturing, and a specific decade of experience in the construction of buildings eco-sustainable and efficient, both in line with the sustainable development strategy, launched for some time, by the Puglia Region with those that national and European. Using a multi-disciplinary highly qualified and dynamic professional team, Pedone Working possesses extensive know-how devoted to the study and application of new natural construction techniques aimed at environmental sustainability and the achievement of the highest energy efficiency standards according perfect combination of experience, culture and innovation. Pedone Working srl, by exploiting this long and complex journey of excellence corroborated by numerous awards and accolades including the prestigious Golden Cube received during the ceremony CASACLIMA AWARDS 2013, now enters the market as a pioneer and avant-garde company on the road the neo-building and post-drawn sustainability through the creation of new sustainable intervention Case di Luce.

4. Energy

4.1. Energy consumption
Table 2. Energy consumption.

| Description                          | Value               |
|--------------------------------------|---------------------|
| Primary energy need                  | 12.06 kWhpe/mq year |
| Primary energy need for standard building | 48.73 kWhpe/mq year |
| Calculation method                   | UNI TS 11300        |
| CEEB                                 | 0 kWhpe/€           |
| Final Energy                         | 8.49 kWhfe/mq year  |

4.2. Envelope performance

For the wrapping were taken innovative solutions aimed at improving the quality of life through the use of natural materials and eco-friendly as the tuff, local KM zero material, lime and hemp. This building envelope, completely natural is made with with Biomattone in Hemp and Lime and the constructive system of sprayed masonry in hemp and lime (cement completely natural), with LEED® certification. This consists of plant hemp chipboard with a binder based on lime in a variable ratio depending on the thermal and mechanical characteristics required. This compound combines high insulation properties and thermal mass, has a thermal conductivity of 0.053 W/mK, while respecting the principles of sustainability to 100%, is fully recyclable and highly hygroscopic adjustment that besides a negative balance of CO2 emissions. The stratigraphy of the infill walls is thus constituted by an inner facing of tuff, of equal to 10 cm thick, on which the mixture in hemp and lime is sprayed, lime-hemp 1: 1 ratio, 25 cm thick. To complete the drying phase of such facing is performed a further jet spray of termointonaco, hemp-lime ratio of 4: 1, having equal to 6 cm thick, with subsequent leveling. That allow to realize an external monolithic masonry that, with a single material, at the same time will fulfill the casing and insulating function. thermal transmittance of external infill walls: 12.18 W/m2K Wrap thermal transmittance including fixtures: 0:32 W/m2K.

Table 3. Envelope performance.

| Description                          | Value               |
|--------------------------------------|---------------------|
| Envelope U-Value                     | 0.18 W/mqK          |
| Building Compactness Coefficient     | 0.48                |
| Indicator                            | n50 (l4)mc/H.mq n50 (Vol/H) Q4 |
| Air Tightness Value                  | 0.59                |

5. Renewables and systems

Renewable energy production: 90%.

Table 4. Systems.

| Description                | System                  |
|---------------------------|-------------------------|
| Heating system            | Condensing gas boiler   |
|                           | Heat pump               |
|                           | Low temperature floor heating | 0.59 |
| Hot water system          | Heat pump               |
|                           | Solar Thermal           |
| Cooling system            | Reversible heat pump    |
|                           | Floor cooling           |
| Ventilation system        | Natural ventilation     |
6. Environment (water, health and comfort)

- Consumption from water network: 4169.93 mc
- Consumption of grey water: 2403.89 mc
- Consumption of harvested rainwater: 20.00 mc
- Water Self Sufficiency Index: 0.37%
- Water Consumption/mq: 1.30 mc/mq
- Water Consumption/Dwelling: 198.57 mc/Dwelling
- Daylight factor: 2.76

7. Main Product

Biomattone in Hemp and Lime and the constructive system of sprayed masonry in hemp and lime are the principal products used in the construction of Case di Luce. It is a solid insulating material that combines insulation properties and thermal mass. With high insulation, low embodied energy in manufacturing, and the capture (in the hemp shiv) of CO2 from the atmosphere, the main features of buildings made with Hemp and Lime are thermal, acoustic and hygrometric (air moisture content) comfort. Biomattone is permeable to water vapour and resistant to fire, frost, insects and rodents. It is guaranteed to be free from toxic fumes in the event of fire.

The choice to use building envelopes with natural materials such as hemp and lime is because these materials have a positive impact on the environment and maximize health, energy efficiency and comfort for the inhabitants. Energy savings and a healthy indoor environment have become key to quality of life. The hemp plant has many interesting properties. It grows at any latitude from seed to about 5 meters high in just 4 months and does not require pesticides, herbicides and fertilizers. Hemp plant regenerates the soil on which it grows by returning nutrients instead of subtracting them and capturing large amounts of CO2 from the atmosphere, which is stored in its woody stem.

The lime is obtained by calcining limestone at much lower temperatures than those used for cement. The lime Biomattone is to mineralize the plant aggregate, protecting it from the risk of decomposing, catching fire or attack by insects or rodents.

Biomattone and the constructive system of sprayed masonry in hemp and lime are LEED® certified, consisting of chipboard plant hemp with a lime-based binder in a variable ratio depending on the thermal and mechanical performance required. This compound, result of a low energy consumption production process with an environmental impact close to zero, is difference from other insulating materials as it combines high insulation properties and thermal mass, has a thermal conductivity of 0.053 W/mK, with high environmental compatibility, recyclability and hygroscopic setting besides being a material negative balance of CO2 emissions in fact capable of capturing and sequestering CO2 from the atmosphere 60 kg per 1 m3 of material. Also it complies 100% with the principles of sustainability also because, being characterized by high biodegradability, the end of its useful life it naturally decomposes in the environment being completely free of toxic substances. This innovative constructive technology, unlike traditional construction that tends to realize wrappings made by the coupling of most mineral materials, synthetic and natural, allows with a single homogeneous material to simultaneously fulfill the envelope and insulating function. It also has an advantage economic, in this manner are also solved all of interstitial moisture problems due to the different value of permeability of the materials used. The systems in hemp and lime instead prevent the passage of heat from the internal environment to that outside and vice versa, by limiting the changes in temperature that occur during the day or with the changing seasons. The temperature inside the building, as well as the humidity level, are maintained almost constant, making the environment more comfortable, and minimizing the energy consumption for heating and cooling. This construction system, thanks to the wonderful plastic quality of material...
and the ability to be molded, has a wide range of potential applications and can be easily adapted to create tailored projects is cast in situ, for realization of infill walls also of multi-storey buildings, which made dry and adaptable to any type of structure with costs and time remarkably reduced construction.

Figure 2. Biomattone in Hemp and Lime

8. Urban Environment

The design project involves the sustainable redevelopment of an area, situated just outside the railway link of the city, which, though highly urbanized character buildings with predominantly residential and commercial, with a very good access to all amenities of the area, pouring in a state of considerable decay and neglect for the presence of a built rundown and decommissioned. The regeneration plan proposed on private initiative, as foreseen in L.R. 21/2008 standards for urban regeneration, expected to be the replacement construction of these abandoned industrial sites with new sustainable buildings in passive standard with mixed type, residential and commercial, falling from construction bioclimatic and environmentally sustainable (in compliance with LR 13/2008 rules for sustainable living), that the redevelopment of a neighboring area devoted to public gardens to be implemented through the creation of eco-park facilities, genuine "ecological infrastructure", which, with its distances, services and green areas creates a hybrid-integrated system of public and private space.

Here are the key points of this urban restyling:

- **URBAN PLANNING**: Soil-saving thanks to the reclamation of brownfield sites;
- **SMART ENVIRONMENT**: urban green as mitigation of greenhouse gases and heat island emissions; solar design (greenhouses) and bioclimatic strategies (natural cooling); efficient water management with recovery of rainwater, and the entire waste cycle with community composting;
- **SMART ENERGY**: energy autarky generated from renewable sources;
- **SMART MOBILITY**: charging station for cars / electric bikes;
- **SMART LIVING**: high comfort indoor housing.

Ultimate goal is the construction of a piece of the city that constitutes a new urban model capable of regenerating the entire neighborhood with which the project is confronted giving, at the same time, concrete answers through innovative design solution “Sustainable Energy” aimed at increasing the quality urban and environmental sustainability.

Land plot area: 6422.3 mq.