Energy and Buildings 83 (2014) 217–224

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

# An innovative lighting system for residential application that optimizes visual comfort and conserves energy for different user needs

Marco Frascarolo*, Stefano Martorelli, Valeria Vitale

*Department of Architecture, Roma Tre University, Largo Giovanni Marzi 10, 00153 Rome, Italy*

ARTICLE INFO

*Article history:*
Available online 21 April 2014

*Keywords:*
Energy saving
LED technology
Visual comfort
Lighting analysis
Home automation
Flexible layout

ABSTRACT

The primary goal of the project is to design a lighting system that provides the highest visual comfort and conserves energy for different uses and furniture layouts, which considers that the design of the house will be used by many different users. Indoor system designs vary in layout, goals and optics with two levels of intervention: when initially furnished and during daily use. Lighting is managed by a building automation system, which is equipped with motion and daylight sensors and human interfaces with user scenarios. An outdoor design that requires only a standalone system and is powered by photovoltaic and eolic devices has been developed. All systems incorporate LED technology and have been custom-developed for Med in Italy, which resulted in new patents. Lighting system projects have been involved in several competitions, e.g., Med in Italy placed in the Solar Decathlon in Architecture, Electrical Energy Balance, House Functioning, and Sustainability and took third place in the final ranking. Further research developments are in progress and will be seen in next Solar Decathlon Europe in Paris in 2014. This paper describes the project, installation and analyses of the energy savings that the Medinitaly system can achieve compared with traditional solutions. Simulation data are compared with measured data from the period of the Solar Decathlon competition.



## 1. Introduction

The goal of the Med in Italy house, through the valuable contribution by modern technology, is to create more energy-efficient houses by taking advantage of architectural features. The primary objective of traditional Mediterranean houses, in particular, is to provide protection from the heat during the summer using massive walls and reducing the number of openings. Med in Italy provides heat protection using an innovative, prefabricated wall system (wooden structure and internal mass); in addition, it is possible to improve the visual comfort using a large window with high-efficiency glass, which is naturally shaded given the house layout. On the south side, large windows face the patio to allow direct sunlight during the winter and indirect sunlight during summer, which avoids excessive radiation. On the north wall, the skylight creates a zenithal illumination, which is controlled through the partial shading provided by low-efficiency glass. The photovoltaic overhanging roof allows direct sunlight to be screened during the summer (Fig. 1).

To improve the passive system of the house, the area under the skylight wall panels are painted[1] with local sands and glue combined with a natural photoluminescent pigment[2] that provide light in the night, which can charge itself using natural and artificial light. Additionally, these bright materials are used in the bathroom covering; their soft light does not disturb the sleep, and furthermore, users can use the light as a guide during the night.

The artificial lighting system was designed with goals of sustainability, visual comfort, and flexibility that depends on user requirements: essentially, the goal is to logically provide *light when and where it is needed* (Fig. 2) [1–5].

## 2. Lighting design

The design of the artificial lighting of Med in Italy was developed based on innovative technologies that are combined with low-tech

* Corresponding author. Tel.: +39 3355847229; fax: +39 0692597418.
*E-mail address:* marco.frascarolo@uniroma3.it (M. Frascarolo).

[1] Painted by Massimo Catalani, Italian artist.
[2] BRIGHT MATERIALS s.r.l.

http://dx.doi.org/10.1016/j.enbuild.2014.03.072
0378-7788/

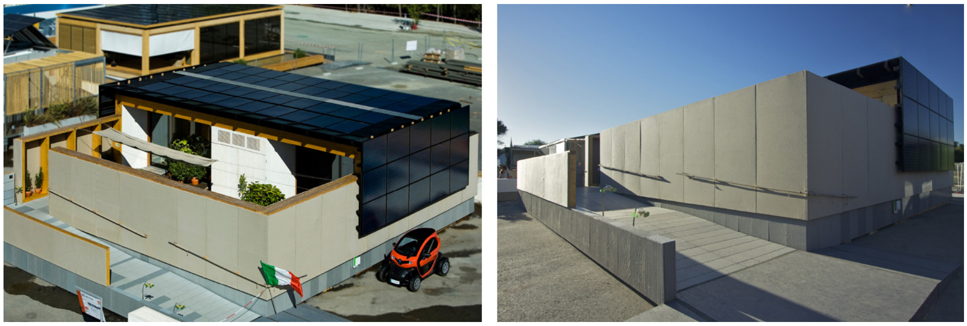

**Fig. 1.** Exterior view of house.

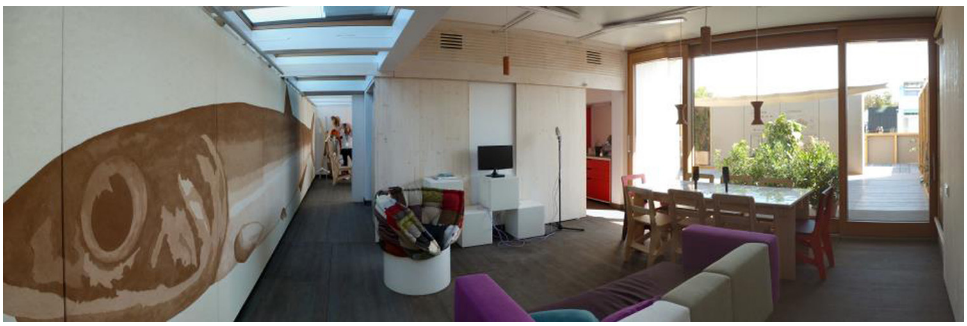

**Fig. 2.** Interior view of house.

materials to attain the maximum visual comfort and energy savings within the warm atmosphere of the Mediterranean housing style. Advanced LED technology[3] was used to optimize the energy efficiency and reduce heat loss, which was combined with ceramic elements and designed by a team[4] to customize all the task lights in the dining room and bedrooms. For the exterior, a system was also developed with stand-alone fixtures, which uses energy from photovoltaics and micro-wind power systems.[5]

The following are the fundamentals of the design project:

- Visual comfort for all activities that could occur in a residential space through the proper luminance balance of the vision field.
- Energy savings achieved by using LED technology, optimizing the optics and electronics, using daylight, creating lighting scenarios dedicated to individual activities, using a variable lighting fixtures layout and using outdoor devices powered by micro photovoltaics and wind power.
- Enhanced perception of the architectural space and materials, with particular attention to painted surfaces and their texture.
- Flexibility of the lighting systems in relation to the furniture layout, where it is essential to consider the multiplicity of uses for a prefabricated house that is intended for mass production.
- Warmth and Mediterranean style achieved through lighting warm temperatures and using traditional materials, such as ceramics.
- Wiring system designed for easy installation of prefabricated components.
- Minimizing the number of light bulb changes and maintenance by using the latest generation LED technology and high-quality drivers (50,000 h, approximately 5 years based on average use of each light for 3 h per day) (Fig. 3).

[3] System engineered by DGA.

[4] DATA – Design and Architectural, Territorial, Environmental Technologies, Sapienza University of Rome.

[5] Engineered by ILM lighting system.

## 3. Lighting systems

The concept of the house is to condense all the active systems into a prefabricated 3-D core, where all the ducts, pipes, and wires in the roof branch off. The wiring system is optimized by locating the electrical sockets and switches on the walls of the 3-D core; however, on the perimeter of the walls, to facilitate users' flexibility, the wiring systems contains wireless switches. The electrical tracks on the ceiling, which provide a flexible layout, are improved by several additional systems.

### *3.1. "Elica": Adjustable suspension spotlight system (living room)*

The system is powered by electrified tracks inserted in the joints between the radiant ceiling panels. The number and type of suspension units can be modified, where their position can be changed along the longitudinal axis of the space. There are three independent switches due to the track driver system. It is also possible to modify the position of the suspension lamp on the transversal axis by means of a rotating support for the fixture, which is called *Elica* (in English, propeller). This support is an aluminum bar that is 110 cm long and is connected to the track with a central joint, which, by its ability to rotate on the horizontal plane, allows the suspension cable to be virtually connected to all the points on the ceiling. The symmetry of the metal bar avoids any torsion on the joint when the fixture will be moved by the users. The bar contains a mechanical system to move the suspension cable to change the horizontal and vertical coordinates of the lighting fixtures. The bar contains the drivers, which facilitates a more rapid installation of the individual modules. *Elica* uses two types of ceramic fixtures. The first type was designed for the dining table and has a double truncated cone section for direct and indirect light emissions:

- One recessed 4-W LED with a 60° beam angle for downlight.
- Four recessed 1-W LEDs with a 120° beam angle for uplight.