Chapter 57
Solar Building Systems for the Mediterranean Region: Research Outputs Between Italy and France

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Abstract This paper comes from previous investigations carried out by the authors, in France and Italy, and from a cross border cooperation projects based on the joint collaboration between the University of Corsica Pascal Paoli and the University of Genoa. The authors focus on the enhancement of passive solar systems and thermal solar systems, with particular attention to their operation/efficiency and their architectural integration. The exchange between Italian and French experiences, especially between regions with similar climate, can enhance solar building strategies, in accordance with the new European energy standards as well as the Mediterranean climate, the traditional construction technologies and users' needs.

1 Introduction

In the near future, the 'nearly zero-energy' standard imposed by European directives (i.e. 2010/31/EU), will lead the building sector towards a greater use of technology, aimed at maximising both saving energy and producing it from renewable sources.

The use of passive and active solar systems could make a substantial contribution to saving energy, above all in the Mediterranean climatic zone, thanks to the high number of sunlight hours and the mild climate in both winter and summer.

Today, however, energy-efficiency policies for buildings, scientific debate on the subject and technological market solutions seem primarily directed towards the Northern European 'low-energy' building type, considering the Passivhaus standard as the building solution to meet European energy targets. This standard was

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designed on the basis of the Central European climate in which it originated; it essentially consists of energy conservation measures, with minimum energy exchanges between the outside and inside of a building, being particularly suitable for long and harsh winters. However, the application of the Passivhaus standard to the Mediterranean region is not effective because of the higher cooling demand in summer (if possible, by natural ventilation). Moreover, this standard could meet with resistance from users accustomed to a different management of interior spaces and from professionals because of different traditional construction systems. In addition, Passivhaus technologies could be difficult to manage in terms of architectural integration and landscape impact.

This theme is not sufficiently dealt with in the literature, which instead tries to show how this standard could be applied to the Mediterranean region. This might be happening because, as pointed out by Krainer, 'in recent years, Passivhaus has become a religious movement' [1: 393], thus influencing a rather short-sighted attempt to steer policies, European directives and rules of the member states. Krainer highlights the differences between the Passivhaus standard and the bioclimatic approach, where the first tends to alienate people from the natural environment outside their houses, while the second one enhances a strong relationship between inside and outside, in order to obtain advantages in terms of energy, environment, quality of life and health (e.g. a greater amount of natural light, better perception of the passing of time during the day, lower risks of indoor air pollution). Therefore, the bioclimatic approach seems to be more effective than the Passivhaus one, especially in temperate climates (as the Mediterranean climate is), where it may be easily applied. The bioclimatic approach may reduce the 'artificialisation' of the microclimatic and environmental conditions of the interiors, according to a broader concept of sustainable design, not limited to the issue of saving energy.

However, this is not only a matter of interpretation of the concept of sustainability as applied to building design, but also a matter of performance. Some studies [2] show that strategies typical of the Passivhaus model, such as mechanical ventilation with heat recovery, are less effective (in terms of energy and comfort) than natural ventilation in temperate maritime climates (this article also refers to the southern coast of England). Moreover, the trend of the diffusion of dry construction systems (again, of northern European origin), which is appropriate to the Passivhaus approach, although of great interest, is not always suitable for the methods typical of traditional Mediterranean constructions (for example in relation to the consistency and the thickness of external walls or the possibility of taking advantage of the thermal mass). There are also significant problems, especially with the retrofitting of existing buildings, in these geographic areas.

Therefore, a reflection on the southern European 'low-energy building type' seems necessary, considering technologies suitable to the climate, the natural resources and the traditional construction systems of the Mediterranean region.

Two different research centres are active in this field: the University Institute of Technology (IUT) of Corsica and the Department of Sciences for Architecture (DSA) of the University of Genoa. The two research groups have already collaborated in the cross-border cooperation project 'Case Mediterranee' (2010–2012), funded under the Italy–France Maritime Programme. The relationship between the two groups has strengthened as a result of another project, still in progress, within the same programme, called the Me.R or ‘Mediterraneo in Rete–Mediterranee en Reseau’ (www.mediterraneoinrete.eu). This is a ‘simple project’ of scouting, stimulation and coaching actions for the business development of the cross-border area (2014–2015). The lead partner is the DSA, and the partners are Team s.r.l. (Genoa), Lucense (Lucca), the North Sardinia Industrialists Association (Sassari) and the Chambre de Métiers et de l’Artisanat de la Corse du Sud (Ajaccio). The latter is supported, in France, by the Chambre de Métiers et de l’Artisanat des Alpes Maritimes (Nice) and, for scientific issues, by the IUT.

The project aims to identify and bring together public and private actors (mainly small and medium enterprises) in three sectors (renewable energy, sustainable tourism and biotechnology) through the consultation of stakeholders and the organisation of workshops, focus groups, training and coaching actions for the companies situated in the regions involved (Liguria, Tuscany, Sardinia, Corsica and Provence Alpes Côte d’Azur – the PACA Region). Thus, the new business networks may share know-how, optimise their management, manufacturing and commercial systems and, above all, compete for new funding under the Maritime Programme to develop innovative projects in relation to the identified sectors.

With regard to renewable energy, the collaboration between the research groups of the DSA and the IUT has been decisive and the workshops and the training activities, carried out together, have raised interesting new opportunities for exchanging experiences. Sharing their research outputs, the two groups have identified common interests and the need to develop new building products and design tools, well suited to the local climate, the available resources, the construction methods and user habits in the Mediterranean region. Starting with the Me.R project, the DSA and the IUT are currently working together in this direction, involving organisations and enterprises in innovative projects which take into account recent studies on the implementation of new applications and businesses. The new projects concern the enhancement of passive solar and solar thermal systems, with particular attention paid to their operation and performance and their architectural integration.

2 Studies of Active and Passive Solar Systems in the Mediterranean Region

The use of passive solar systems should be of great interest in both new constructions and retrofitting interventions, especially in relation to the enormous number of post-war period buildings in city suburbs, usually characterised by severe functional and aesthetic disrepair and by high energy demand. In this regard, the DSA has carried out a long campaign of monitoring passive solar systems (in particular, solar greenhouses and Trombe–Michel walls), applied to retrofitted buildings, built around the 1960s in Savona (Liguria) and owned by ARTE, the Regional Territorial

Agency for Building. These buildings, made of reinforced concrete structures cast in situ and double-layer brick walls with no insulation, were retrofitted with the following main interventions on the building envelope: thermal cladding on the *façades*, insufflations of thermal-acoustic cellulose flake insulation in the wall cavities, insulation and waterproofing of the roof and installation of passive solar systems on the southern façades.

A winter monitoring campaign (4 December 2013 to 27 January 2014) has, in particular, evaluated the thermal benefits obtained with the solar greenhouse and Trombe–Michel wall systems for the relevant dwellings, while the aim of the summer monitoring campaign was to understand the conditions which could generate overheating in the rooms connected to the passive solar systems and which could provide comfort. The studies also consider several different uses and recognise possible interference deriving from the behaviour of the users in the normal working operations of this technology.

The analysis method used to achieve the aforementioned goals is based on the criteria explained in what follows:

- The reliability and significance of the temperature parameter for a first evaluation of the indoor comfort of the buildings and to illustrate the thermal exchange phenomenon between passive solar systems and the relative space heated by them.
- The necessity of carrying out non-invasive studies which might have caused inconvenience for users and too much expense for the client (ARTE); in this sense, the possibility of installing heat meters near the existing independent heating systems of the concerned building units has been excluded. The fortunate circumstance of having empty lodgings available in one of the tested buildings has allowed the estimation of the real thermal contribution of the solar systems by turning off the heating for the whole survey period (in winter) and obtaining reliable results.
- The integration of various types of instruments: an infrared thermo-graphic camera, eight mini data loggers and a thermo-anemometer.

Two lodgings are directly involved in the tests, denominated A1 and A2 of building A and an interior room, called B1, of building B (Fig. 57.1). All have one south-facing exposed wall where passive solar systems were installed: one greenhouse for lodgings A1 and A2 and two Trombe–Michel walls for B1. Lodging A1 is on the first floor and A2 is on the second; they were chosen because they were empty during the monitoring period. Lodging B2 was occupied; however, the tenant, having understood the purpose of the study, diligently supplied precise time periods in which the heating system was in use.

First, thermo-graphic surveys were conducted inside and outside and primarily highlighted the effectiveness of the insulation solutions of the thermal coat used for the requalification of the buildings under analysis and the decrease in the 'thermal bridges' phenomenon in correspondence with the structures in reinforced concrete. These data are obviously important for the evaluation of the performance of passive solar systems; in fact, the application of this type of system in poorly insulated

Fig. 57.1 Building B, one of the monitored buildings, after retrofitting: *left*: Trombe–Michel walls; *right*: solar glasshouses

buildings can be considered of little use because the heat gathered by the collectors is then dispersed in a short time.

During the monitoring campaign, the mini data loggers were placed in the following positions:

- Outside, in the shade, in order to verify the outside temperature at the site (other climatic data were available from the Savona station of the Regional Weather Observatory)
- Inside the passive solar systems (not exposed to direct solar radiations)
- Inside the rooms which were directly connected to the first through adjustable air vents and, in the case of the greenhouse, also by a French window
- In a cellar exposed to the south in building A; the space was not heated or equipped with thermal insulation or, obviously, with passive solar systems

Practically, the situation that emerged, in relation to the course of interior temperatures during the monitored months, is very similar to that which would have been recorded in the premises facing south of the apartments of the same building if the requalification operations had not been completed. This mini data logger was, therefore, used to provide comparison data to appreciate the effect of passive solar systems on heated buildings.

During the winter monitoring campaign, the solar glasshouse and the Trombe–Michel wall systems were set so as to maximise their thermal contribution during the day. In particular, the glasshouses were never shielded by the exterior sun screen curtains during the whole winter period and their air vents were left open, with some adjustments during the survey; the Trombe–Michel wall had fixed solar shading and its air vents were left open during the survey. The readings of the obtained data have led to several interesting results:

- The passive solar systems demonstrate their efficiency in energy retrofits of existing buildings (if these buildings are adequately thermally insulated). In particular, the use of passive solar systems can take on the heating of the buildings in the Mediterranean climate without harsh winters. In the case study, during the test period which corresponds to the coldest season of the year, even if the recorded temperatures were not particularly rigid and the minimum was 2 °C, the passive solar systems applied to the studied buildings demonstrated that they could guarantee comfort range temperatures inside the buildings on sunny days and temperatures which are significantly higher than the external temperature, even on cold and cloudy days. A general trend of rather balanced internal temperatures was recorded, without particular peaks during daylight or drops during the night. For the whole period considered, without the aid of any heating system, lodging A1 (taken as the reference here because the heating system was never turned on) maintained temperatures between 13.3 and 22.40 °C (see an example of temperature trend on a significant winter day in Fig. 57.2). This implies that these applied solutions are effectively in a position to guarantee a great decrease in energy consumption for the artificial heating of lodgings.

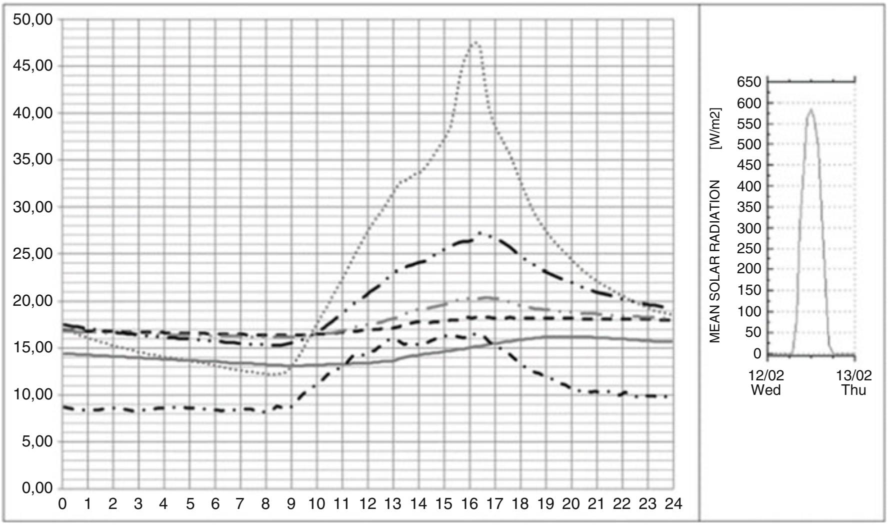

Fig. 57.2 Example diagram showing temperatures recorded by mini data loggers in building A with solar greenhouse on 12 February 2014 (*continuous grey line*: room without passive solar systems; *dash-dot black line*: outside temperature; *dotted grey line*: temperature inside glasshouse; *broken black line*: temperature inside room heated by solar glasshouse; *dash-dot grey line*: temperature inside room heated by solar greenhouse in a semi-direct way; *dash-dot black line*: temperature inside room heated by solar greenhouse in a direct way)

- For an insulated, standard-height room in the Mediterranean climate, to obtain an appreciable convective exchange between the solar greenhouse and the interior of the concerned premises, with a relationship between greenhouse and heated premises volumes of approximately one to two (and a not particularly wide greenhouse able, therefore, to take advantage of the convective motions), a relationship at least higher than 0.4–0.5 % is necessary between the total net area of the wall valves and the air of the separation wall between greenhouse and interior premises. Furthermore, to compensate for the relatively small dimension of the valves, it is useful to leave any windows open during the midday hours (from 10 a.m. to 7 p.m.) on sunny days.

During the summer campaign, we carried out the measurements in lodgings A1 and B1 again. Lodging B1 was occupied by a tenant: this was a limitation, because the indoor thermal conditions were influenced by the tenant's habits. In addition, we could not test extreme situations, which might cause overheating.

The studies of lodging A1, without any tenants, were more interesting. We carried out various measurements with six mini data loggers. We set curtains, wall valves, doors and windows according to different 'layouts' in order to test different situations: overheating, solar shading and reduction, or increase, in air exchanges outside-inside. The results show the different operations of the 'building-solar collector' system.

To reduce the overheating, it was useful to shade and open the windows of the solar collector; moreover, it was also very useful to isolate the greenhouse from the rest of the apartment through the closure devices of the wall valves, even if they reduced airflow. On sunny days, tenants should close the French window and the wall valves that connect the rooms with the greenhouse.

When the windows of the greenhouse are closed and the sunshades are retracted, the maximum temperatures recorded inside the greenhouse were unexpectedly lower than in winter (over 10 °C). In winter, the major sunbeam angle is lower than in summer, so the sunbeams enter more easily below the greenhouse slab and warm the collector for longer. Finally, the summer tests showed that careful management by users could avoid overheating problems.

Starting from the studies conducted in Savona, an interesting degree thesis was carried out (authors: Nicoletta Paladino, Chiara Truffelli, Gio Batta Venturino; tutors: Andrea Giachetta and Chiara Piccardo). As part of this work, additional monitoring campaigns were conducted in Italy on different house types, in weather conditions different from those in Liguria. The studies conducted in the winter season in La Thuile (Aosta) on a single-family detached home, with a two-storey solar greenhouse, have shown the effectiveness of the passive solar system at much lower external temperatures than those recorded in Savona.

Based on the data recorded in Savona and in the other monitoring campaigns, additional studies were carried out to verify whether the most common thermodynamic/energy simulation software for the building design provided similar results. Therefore, the monitored buildings and their solar greenhouses were modelled with the software, setting up their real climatic conditions. We did not expect, of course, that the simulation outputs would coincide perfectly with the recorded data, but the simulations provided very different results, significantly underestimating the performance of passive solar systems. This also happens because the software is unable to simulate the exchange of heat by convection (normally the most significant exchange in passive solar systems). Some software packages (e.g. Energy Plus) may provide more rigorous simulations, obtaining more realistic data, but their use requires time and specific expertise, which is incompatible with the average design process, especially in the case of buildings of modest size.

Although passive solar systems, when tested, show great potential, the lack of effective simulation software for designers (due to a lack of data, studies and the difficulty in controlling and modelling microclimatic changes) has probably contributed to their limited take-up. For this reason, two possible areas could be investigated in the future: the creation of a new database able to lead to more reliable simulation systems or the design of a new versatile window, adaptive to changing microclimate conditions.

3 Studies of the Architectural Integration of Active and Passive Solar Systems

In this regard, the investigations carried out by the University of Corsica provided some interesting outcomes, such as prototypes of shutters with integrated passive and active solar systems for interior (room-side) convective heat transfer.

The concept of a solar air shutter [3], which is patented and called volet'air, produces a low-temperature heat directly from the sun without any other energy supply. The objective is to meet some of the hot air needs for maintaining a healthy ambience in a house. It can be used in the following settings:

- In a principal residence occupied year round;
- In a secondary residence, which is often unoccupied for long periods throughout the year and for which the thermal balance and ventilation are provided by natural energy exchanges from outdoors to indoors;
- Isolated houses which are not connected to the electrical grid.

The same fluid is used for both ventilation and heat supply. The solar air shutter has the same features as a conventional shutter (Fig. 57.3). The internal area is used as a heat converter, and the frame can be built using various materials (wood, aluminium and PVC). The heat converter is composed of two glazing panels in multi-wall polycarbonate (10 mm depth sheets in twin wall form), specially conceived for outdoor utilisation. The outdoor face is transparent and used as a cover and the indoor face is covered by a black thermal painting and is used as an absorber. a-Si PV modules are integrated in the lower part of the black face and are used to supply the air fan. The shutter runs opened, closed and in intermediate positions thanks to its symmetrical conception. The air enters between two plates

Fig. 57.3 Solar air shutter volet'air

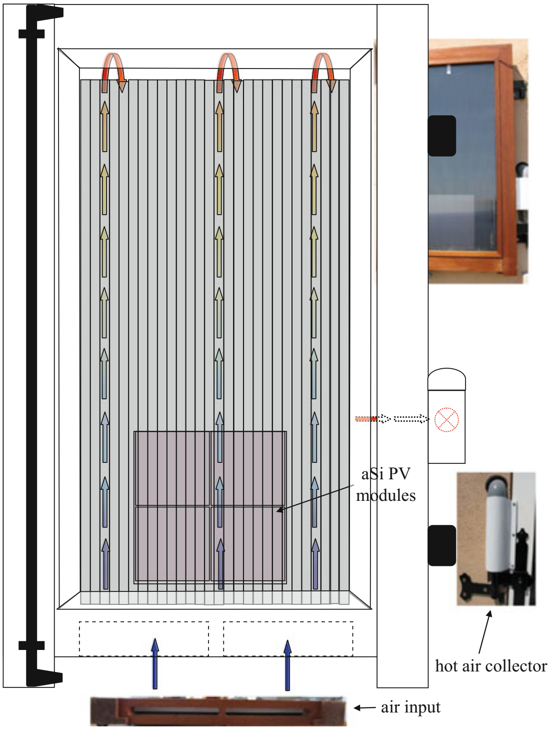

Fig. 57.4 Solar air shutter volet'air

through two openings under the shutter frame and, having been divided into two parts, runs into the channels to the top, then continues between the two black plates (one of each of the multi-wall polycarbonate glazing panels) when it mixes with the air coming from the other side. Finally, this heated air exits by a collector located on the internal part of the frame where the hinges of the shutter are situated (Fig. 57.4). The air fan is located in the wall of the housing (Fig. 57.5).

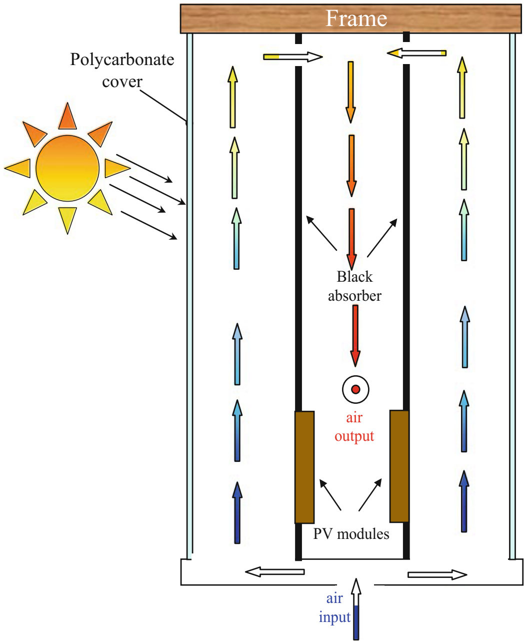

Fig. 57.5 Solar air shutter volet'air

Unlike conventional solar collectors, this collector does not use thermal insulation, and this makes it thermally original, inducing a special thermal modelling and energy performance. The more the fluid is heated, the more of it which enters the shutter, which limits the conductive and convective losses with the outdoors, thereby creating a kind of thermal dynamic insulation.

This new concept of solar air collector has the following advantages:

- A new active function is added to the shutter.
- It can produce heat in all positions: open, closed or intermediate.
- The vertical inclination allows it to produce more energy during winter and less during summer.
- It can be sized and produced for all window sizes because each part is made to measure and can be replaced independently when its lifetime limit is reached.
- It can be very easily installed in existing and new houses: the air is introduced into the house by a rotating air collector without costly and bulky air distribution systems.
- The conventional functions of the shutter – sound and thermal insulation and mechanical resistance – are retained.
- It is an autonomous heater because the fan is supplied by the photovoltaic modules and it can be used in remote areas.
- It must be easily removed because the shutter should be cleaned so as to preserve clean air.

The patented solar water collector, H2OSS [4, 5], presents a high degree of building integration with no visual impact from the ground because it is inserted

Fig. 57.6 Patented solar collector H2OSS

into a drainpipe (Fig. 57.6), which maintains the rainwater evacuation role of the drainpipe. It can be used on east-, west- and south-facing walls (the collector being oriented south into the drainpipe). A north-facing wall is excluded owing to important shading effects. The canalisations connecting the house to the heating collector are hidden in the vertical drainpipe. An installation consists of several connected modules. One module is approximately 1 m long and 0.1 m wide (individual houses), and larger modules can be developed for larger buildings. The number of modules depends on the drainpipe length [6]. The structure of the H2OSS solar collector is composed of a glass layer, an air layer, a highly selective absorber and an insulation layer. The cold fluid flows from the tank through the insulated tube and then into the upper tube in thermal contact with the absorber. These systems have also been tested on historical buildings in the research mentioned earlier, the 'Case Mediterranee' Maritime European project in connection with refurbishment.

Figure 57.7 shows a historical building composed of four small apartments situated in a Corsican village near the centre of the island. Two integrated solar domestic hot water systems are installed in these apartments. One is integrated into a metal porch roof and one into the gutters. The area of the gutter solar collector and part of the area of the solar metal porch roof are connected to one tank for two apartments (rural tourism houses with a collection area of 1.80 m^2). The other part of the solar metal porch roof is connected to another tank for the other apartments (a church rectory with a collection area of 2.02 m^2, tilted 43°). These apartments are used for different purposes: two of them are for tourists, booked for half the year, while the others are used year round.

An effective application of solar building systems to buildings with historical and architectural value is very important in geographical areas with a rich architectural heritage. Some relevant studies have been conducted within the European project SCORE, which stands for Sustainable Construction in Rural and Fragile Areas for Energy Efficiency (www.scoremed.eu), within the framework of the

Fig. 57.7 Historical building with integrated solar systems

MED Programme (2007–2013). The province of Savona was the lead partner and coordinated 10 partners from 7 different countries: Cyprus, France, Greece, Italy, Portugal, Slovenia and Spain. The DSA has supported the province of Savona as a subcontractor.

The SCORE project aims to promote a sustainable approach to planning and to enhance urban and building requalification, showing how this approach harmonises with the high-quality landscapes of the MED areas. It may also represent an opportunity to reinforce a specific identity of the Mediterranean region, in both coastal and rural areas. These areas are of great interest for their history, culture, landscape and nature, but they are also extremely fragile if we consider the possible impact of human activities and the creation of infrastructures and residential, touristic and production sites, as well as the impact of ports and agricultural activities. Thanks to the SCORE project, the partners have exchanged information about their national policies, regulatory framework and best practices in relation to the common sustainable strategies which aim to produce energy from renewable sources, reduce polluting emissions and protect the environment and health of the population, while dealing with the issue of the architectural integration of technologies and systems. Finally, SCORE records, selects, organises and spreads knowledge about good practices.

The project is intended not only to call attention to well-known sustainable strategies for building design and construction but also to assess the best methods for effective implementation of the aforementioned strategies, with reference to the local regulatory and industry framework (taking into account the need for continuous training of operators and enterprises) and to the building tradition. The exchange between Italian and French experiences, especially between regions with similar climates, such as Liguria and Corsica, can enhance solar building strategies, in accordance with the new European energy standards as well as with the Mediterranean climate, traditional construction technologies and user needs.

A new regionalism seems to be a promising approach to sustainable architecture. This is important in order to provide effective solutions taking into account the local climate, the building tradition and user habits. This is not a naive regionalism which responds to local issues by adopting the vernacular style of the area; this approach avoids the uncritical acceptance of systems, technologies, products and standards developed in regions with too different climates and resources. Applied research conducted under the aegis of cross-border partnerships, such as those supported by the project Me.R, may be an interesting way to increase local awareness of resources and their sustainable use.

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