Adaptation of the new technologies developed in the EU project MESSIB to Cultural Heritage applications

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ABSTRACT

The EU MESSIB project addresses the development, evaluation and demonstration of an affordable multi-source energy storage system (MESS) integrated in buildings, based on new materials, technologies and control systems, for significant reduction of its energy consumption and active management of the building energy demand. This new concept will reduce and manage smartly the electrical energy required from the grid favouring the wider use of renewable energy sources (RES).It will reduce raw material use for thermal performance and improve the indoor environment, the quality and security of energy supply at building, including Cultural Heritage. Furthermore, a significant reduction of the energy unit cost for end-users will be achieved.

KEYWORDS

Cultural Heritage conservation, energy saving, microclimate, HVAC, PCM, geothermal energy, Flywheel, Redox batteries

INTRODUCTION

In the European Union promoting energy efficiency (EE) and integration of renewable energy sources (RES) in buildings in one of the main topics. A lot of Directives have been issued or are in discussion since the early 1990s. This topic is a priority within the EU energy policy because of its potential contribution towards meeting energy security objectives, the Kyoto Protocol targets, a reduction of the pollution, in particular the CO2.

Many governments have committed to reduce CO_2 emissions into the atmosphere. For this reason they have decided to strengthen their national efforts to increase the utilization of RES, so far not enough to satisfy the increasing energy demand. The competitiveness of the proposed different RES with the fossil fuels is still not sufficient, but research and developments are quickly evolving trying to overcome regulatory and market barriers.

Moreover, to install additional conventional energy generation and distribution network assets with the capacity to accommodate to the maximum (short-term) demand is economically inefficient. Furthermore, productivity decreases when power plants cannot operate at full capacity in periods of reduced demand, so a significant reduction of the energy unit cost for end-users can be achieved.

The EU project Multi-source Energy Storage System Integrated in Buildings – MESSIB tries to help in improving the actual state of art. In fact it is a Large-scale integrating project of the 7FP-NMP focused on the development, evaluation and demonstration of an affordable multi-source energy storage system (MESS) integrated in buildings, based on new materials, technologies and control systems. The project, actually in progress, started the 1st March 2009 and involves 23 partners coming from Spain, Germany, Slovenia, Italy, France, Netherlands, Poland, Greece, China, Finland and it is founded by the Commission for 5.999.045 € and coordinated by ACCIONA. The multi-source energy storage system (MESS) integrated in buildings, is aimed to significantly reduce the energy consumption.

It is based on an active management of the building energy demand, a new concept that permits a smart management of the electrical energy required and favors a wider use of renewable energy sources (RES).
In the project the use of raw material will be reduced and at the same time the thermal performance of the indoor environment, the quality and security of energy supply at building, including Cultural Heritage will be improved.

The basic idea behind energy storage in buildings is to provide a buffer to balance fluctuations in supply and demand. To reach this MESS is composed by two thermal and two electrical storage systems, integrated with the building installations and a control system to manage the building energy demand.

The MESSIB basic principles are based on:

- a rational use of thermal energy for primary energy savings and for increasing the building indoor comfort
- an improvement of electrical energy storage, equally integrated with RES in order to shift the demand with the production and to optimise the use of low cost “off peak” power from the grid
- an integration of the new technologies with conventional installations (heating ventilation and air conditioning systems (HVAC) and electrical grid) optimizing their functionality in the building.
- an active control/actuation system will smartly manage the profile of use of each storage system and their interactions contributing to an intelligent management of building energy demand and to ensure its security, quality and reliability.

The new technologies integrated with the conventional ones in MESSIB are:

- new phase change materials (PCM) implemented in building envelope, indoor walls, floors and ceilings to improve active components
- an advanced ground storage (GS) technology combined with radiant systems and ground thermal contact improvement by the development of a conductive fluid material (CFM).
- Composite materials (with nanomaterials) for flywheels (FW) to increase the storage capacity. Adaptation of the whole system for new use in buildings.
- More durable vanadium-redox flow batteries (VRB) improving vanadium stability and more compact system adapted for its use in buildings.

The storage is a combination of short and long term effects by means of:

- short storage (during a day): by means of the phase change materials and flywheels.
- medium term and seasonal storage: by means of ground storage and vanadium-redox flow batteries.

Moreover, simulation tools are being developed to properly integrate the technologies developed, in the design phase of the building and simulate the effects or the advantages.

An advanced intelligent control system to manage the energy demand of buildings by adapting the storage times and rates to the different energy customers demand profiles is also being developed.

MESS are being installed, monitored and evaluated in two buildings: one new residential house in Greece (Mediterranean climatic conditions), and the second one, an existing office building at the Fraunhofer ISE, the Solar House in Freiburg (Germany), specially equipped with RES (central European climate).

CULTURAL HERITAGE AND NEW TECHNOLOGIES

The Cultural Heritage buildings are a particular reality needing a different approach. They need to control their environment differently from modern buildings [1,2,3,4]. They are highly energy consuming for different reasons but many potential energy saving systems cause to historic buildings an unacceptable impact on their cultural value. Moreover they have to guarantee the comfort of both men and particularly moveable and immoveable works of art. For this reason any new technology applied to this sector must be evaluated not only in terms of traditional energy savings and cost reduction but also in terms of physical barriers and the impact on its cultural value and the internal environment. For this reason the less invasive, possibly reversible and cost-effective technologies and systems aimed to significantly improve the energy efficiency in the historic buildings should be developed or adapted. The application of energy efficiency solutions is not easy. These buildings due to their high technical and non-technical restrictions needs specific solutions.

Moreover the national standards regarding the Cultural Heritage until today are mainly made up by general principles or methodologies of conservation (e.g. Italian normative UNI 10969, 2001 [5], regarding the general principles for the microclimatic control for the conservation of works of art). This is due to the big difficulty in establishing strict rules that must be applied to Cultural Heritage. For this reason, it is necessary to also establish the best, more intelligent strategies for the control and management of the indoor microclimate.

Inside the MESSIB project we are analysing the specific codes for CH buildings in different European countries to evaluate the state of art and the needs to improve this topic at European level. Moreover operational conditions are being identified for "possible" application of the proposed technologies to a historical building considering some critical points, such as confined spaces for installation, difficult working conditions, no physical and aesthetics impact.

The identification of the strong and weak points, the technical and non-technical barriers and possible solutions to apply MESSIB technologies in CH buildings is in progress through an European analysis of the energy behavior (energy consumption-comfort) of chosen European historical buildings. For this reason an evaluation of the requirements of these different types of historical buildings in relation with its features (architectural typologies, design, materials, …) its functionality, its location, etc., is in progress and these buildings will be finally classified in relation to the different critical parameters. For this aim a table with the main common parameters is defined amongst the different European partners and typology of Historical buildings.

S. CROCE: A CASE STUDY

In this context of research and classification of some Cultural Heritage Buildings the complex of S.Croce Museum and Church in Florence has been considered as a case study in Italy.

The Santa Croce Complex consists of the well known Santa Croce Church, the Convent and the Santa Croce Museum. It is one of the most popular Churches in Florence and a unique monument. The Complex is visited every year by about one Million persons.
Currently, due to the huge cost, the church is no longer heated and its heating system has been disconnected.

The heating system of the Museum and the Convent disposes of two boilers. In winter, during the opening hours of the Museum, the largest boiler is operating to service both the Museum and the Convent. Upon closure of the Museum, the smaller boiler is started up instead of the larger one to service the Convent whilst the heating of the museum is switched off.

In the Museum, the first five rooms are heated via radiators (Figure 1) and the Refectory is heated with fan coils (Figure 2). For aesthetic reasons the radiators are behind panels reducing their effectiveness. The temperature control is done by manually setting the heating water temperature at the entrance of the heating circuit.

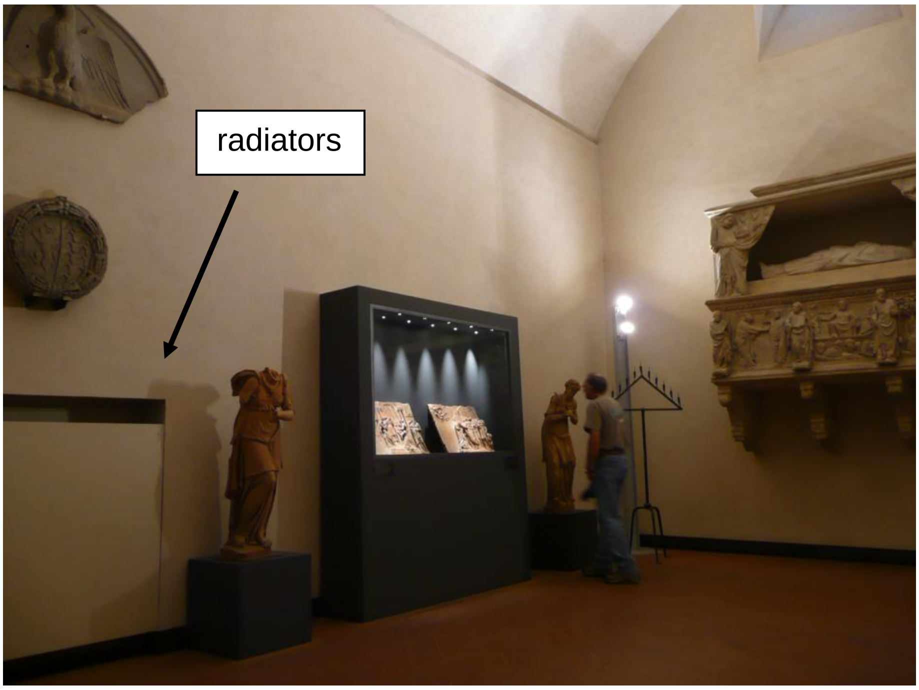

Figure 1. One of the first five rooms in the S.Croce Museum heated via radiators

Figure 2. The Refectory in the S.Croce Museum heated with fan coils

There is no ventilation and air cooling system available to use in the summer period. Cooling is provided by natural ventilation from doors being opened by the museum staff.

A microclimatic monitoring system, now in operation for about two years throughout the Museum, has shown substantial fluctuations of temperature and humidity (Figure 3, Table 1) affecting the stability of the works of art and the comfort of the people inside the Museum.

Table 1. Smallest and largest variations of temperature (T) and relative humidity (RH) recorded during a year of monitoring in the S.Croce Museum

	Refectory		**Room n.3**	
	Δ T	**Δ RH**	**Δ T**	**Δ RH**
smallest variation	5,3°C *January '10*	20,7**%** *November '09*	2,6°C *January '10*	31,1% *January '10*
Largest variation	12,6°C *May '09*	47,5**%** *July '09*	8,3°C *October '10*	56,6% *October '10*

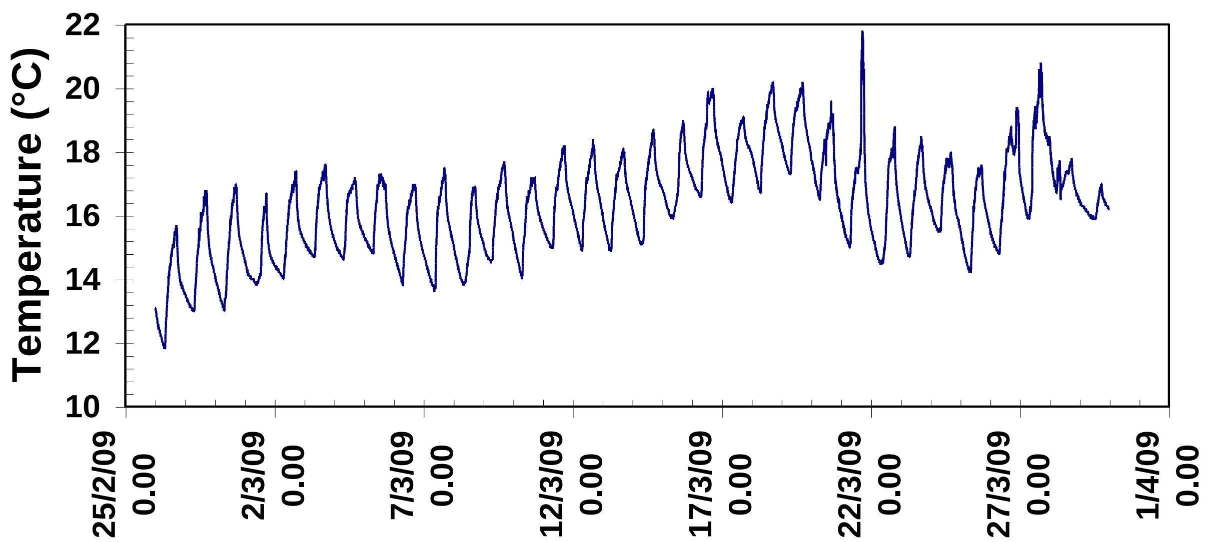

Figure 3. Temperature fluctuation in the refectory room in winter

The owner of the Complex, the Opera di Santa Croce, is considering to renew the actual heating system of the Museum for a better efficiency and comfort in combination with a disconnection from the Convent and energy conservation interventions to the building. Such a renovation should take into account the principles of conservation, in other words stable thermohygrometric conditions over the whole year which also means a high energy demand with conventional systems. This is where there may be an opportunity to incorporate solutions being developed in the MESSIB project. A plan of possible actions based on preliminary studies is in progress and offers the opportunity to propose to the owner to study and to use the MESSIB results as part of his renovation plans.

This study would follow the methodology outlined in the work package on Cultural Heritage of the MESSIB project. An identification of the configuration of this building in relation with its architectural typology, design, materials, functionality, location, etc. as defined with the partners in the MESSIB project is in progress. A thermal energy study for heating and cooling must identify the opportunities to use MESSIB technologies in combination with conventional building and HVAC system renovations.

Possibly a fluid dynamic model of the refectory will indicate possibilities to use one of the MESSIB solutions, PCM's, to stabilize the thermal patterns around the cubical where two of the most important paintings are exposed. Inside the museum an experiment of the application of the Phase Change Material has already been started (Fig.4). Some simulated paintings have been installed on panels containing PCM's. Temperature and humidity of the surfaces and the environment are being monitored as well as the eventual emission of VOC's.

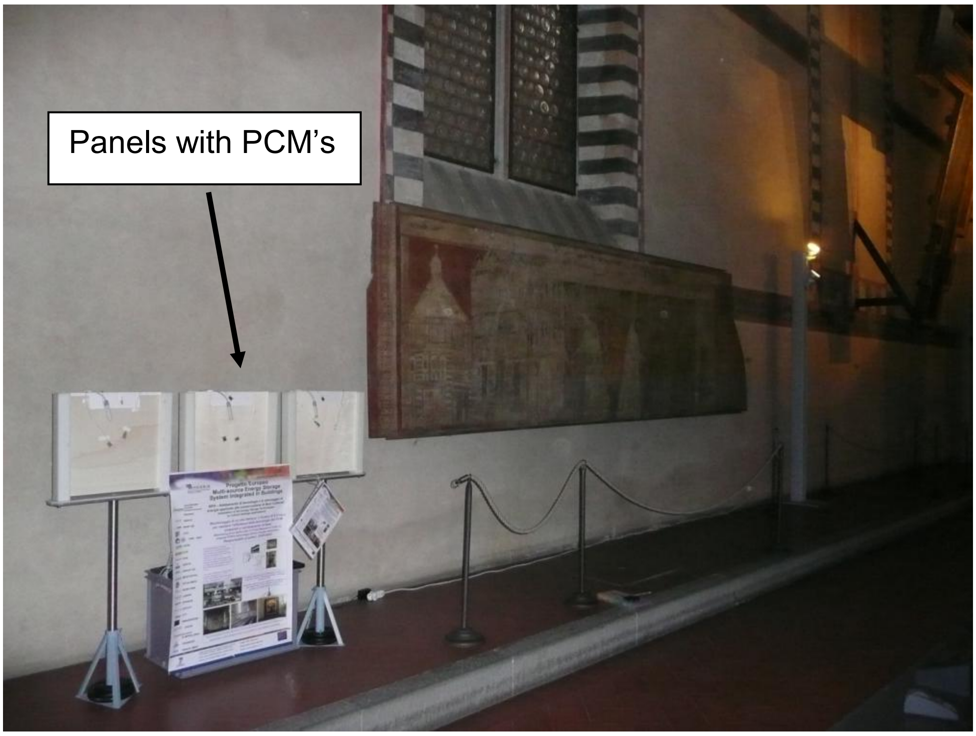

Figure 4. Monitoring of temperature and humidity of environment and simulated paintings installed on panels containing different PCM's in the Refectory

Application of geothermal probes in combination with the solutions being developed in MESSIB to improve conductivity and storage capacity would be ideal due to the presence of the cloister between the museum and the church. However, the presence of archeological elements in the underground could give problems to apply this technology. A georadar study is however already commissioned by the owner. As the boilers are housed in a separate room close to the cloister, there should not be major problems to house heat pumps and to connect them in a discrete way to the probes.

The use of flywheels and redox-vanadium storage, designed to store electrical energy, are more problematic in this application. First of all local electrical power generation should be part of the renovation plans. Secondly, appropriate space should be available to house the equipment.

CONCLUSIONS

The four energy storage systems of MESSIB have been developed for conventional buildings and are close to the demonstration phase of the project. Hence, the time is right to evaluate their applicability in historic buildings. Their application in these historic buildings is very important because they may enable energy savings allowing changes in the operating mode of the HVAC systems resulting in more stable thermo hygrometric conditions for the benefit of the works of art exposed in these historic buildings.

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