Renewable and Sustainable Energy Reviews 53 (2016) 515–535

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Literature review on the use of phase change materials in glazing and shading solutions

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ARTICLE INFO

Article history:
Received 12 March 2015
Received in revised form
25 May 2015
Accepted 27 July 2015

Keywords:
Building energy performance
Glazing and shading solutions
Indoor thermal comfort
Phase change materials (PCMs)
Thermal energy storage (TES)

ABSTRACT

The large energy consumption of the building sector is mainly resourcing to active systems for cooling and heating of indoor spaces. According this, the external envelopes of offices and commercial buildings are systematically composed by large glazed areas that lead to high energy losses in the winter and large solar gains in summer.

The incorporation of phase change materials into building elements is a growing trend for improving the thermal energy storage capacity in the latent form and the thermal inertia. Thermal Energy Storage systems (TES), using phase change materials (PCM) in buildings, are widely investigated technologies and a fast developing research area. Therefore, there is a lack of publish research reviews on PCM solutions applied into glazed areas.

This review focuses on PCM technologies developed for the translucent and transparent building envelope, such as windows, shutters and other shading devices. This review gives special attention to describe and to discuss the thermal properties, the energy storage and the saving potentials of innovative PCM solutions and presents the main results of research carried out on this domain. The most used strategy to apply the PCM into these building elements is the direct incorporation using macro capsules containers (composed by different materials).

The main conclusions taken from the research studies on prototype solutions show the PCM potential to enhance the thermal performance of buildings through the glazing and shading devices. This studies show that the PCM technology applied to the glazed areas of the building envelope can significantly improve the energy efficiency, and with the reduction of the product costs this technology will appear soon into the typical building construction systems.

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http://dx.doi.org/10.1016/j.rser.2015.07.201
1364-0321/

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1. Introduction

According the International Energy Agency [1] the global primary energy consumption will rise an average annual rate of 1.2% through 2035 and the building sector is the largest energy consumer. By 2035 it is expected that the energy consumption in the building sector increases 29%, which represents an average annual rate of 1%. So, the energy performance and energy consumption of the building sector is targeted in advanced studies and policy making by the European Union and other developed countries [1,2]. According to these needs the EU to improve the energy efficiency of the building sector has introduced some policies and goals, such as: [3–5]

1. The Energy Service Directive and Renewables Directive propose respectively a 9% of energy savings by 2016 and 20% of all energies should be prevenient from renewable energy sources by 2020;
2. All new buildings by 2020 must be nearly-zero energy buildings (NZEBs) and after 2018 new public buildings should be NZEBs;
3. The Energy strategy of the European Union added targets to 2020, known as “20-20-20” that have the objective of 20% reduction of the greenhouse gas emissions, comparatively to the 1990 levels, increase of 20% of energy production from renewable energy sources;
4. Besides of the Energy Strategy, the EU added individual rules and directives for each state members for the use of renewable sources and to improve the energy efficiency until 2020.

Presently, the external envelope glazing, mainly in offices and commercial spaces, are systematically composed by large glazed areas that lead to the increase of energy consumption of the building [6–8]. These areas are crucial because these are the areas where high energy transfer occurs between the indoor and outdoor spaces, that can lead to thermal and visual discomfort conditions [6,8–12]. In terms of energy efficiency and indoor thermal regulation, these areas are presently an object of high-end research and application for enhancing building envelope [6,9,10].

Many studies, prototypes and developments have been done in last years to increase the thermal and energy efficiency of windows. The improvements of the thermal behaviour of windows and glazed areas have been resourcing to new materials, new geometries and shapes and to the use of new techniques and technology in the glazing production.

The phase change technologies market is one of me most promising to improve the thermal behaviour of indoors spaces. According the marketsandmarkets report, in 2013 the phase change material market was 407M€ and it is expected that will grow to 1015M€ by 2018 and 1300M€ by 2019, which represents a compound annual growth rate (CAGR) of 20.1%. According this

Table 1
Comparison of different types of PCMs: advantages and disadvantages.

	Sub-group	Advantages	Disadvantages
Organic compounds	Paraffins Non-paraffins (fatty acids, esters, alcohols, glycols)	• Can be directly incorporated • Can be impregnated into porous buildings materials • Chemically stable and inert • Do not suffer from supercooling • Non-corrosive • Non-toxic • High thermal energy storage (latent heat of fusion) • Wide range of melting temperatures • Low vapour pressure in phase change process • Do not suffer phase segregation • Good thermal performance after large thermal cycles • Excellent melting and freezing properties (non-paraffins)	• Low thermal conductivity (typically 0.2 $W\ m^{-1}\ K^{-1}$ for paraffins) • Large volume change during the phase change process (paraffins) • Non-paraffins are three times more expensive than paraffins • Some are flammable
Inorganic compounds	Salt hydrates Metallics	• Usually high thermal energy storage (latent heat of fusion) • Good thermal conductivity • Less expensive • Non-flammable	• Corrosive to most metals • Supercooling and phase segregation • Loss of thermal performance after large thermal cycles • Requires support and container • Cannot be directly incorporated
Inorganic eutectics or eutectic mixtures	Organic-organic Inorganic-inorganic Inorganic-organic	• Sharp melting points • Usually high volumetric storage density	• Some suffer from super-cooling effect • Low total latent heat capacity