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Renewable Energy and Sustainable Technologies for Building and Environmental Applications

Options for a Greener Future

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Preface

This book highlights state of the art, advancements, challenges, and options in the areas of renewable energy and sustainable technologies for building environmental applications. It aims to provide insight into existing knowledge about renewable energy and sustainable technologies while demonstrating their significance to greener environmental approaches. This book contributes to significant expansions in the energy technologies' research horizons; while highlighting a paradigm shift in the research and discusses substantial improvements to renewable energy and sustainable technologies for building environmental applications.

It consists of various relevant articles from world-leading experts which are chosen exclusively to illustrate the main areas of renewable energy and sustainable technologies, arranged in 14 different chapters. Chapter 1 presents a review on the inverse problem for phase change materials and application in building envelopes. The review would serve as a useful reference for the readers who are particularly interested in studying building envelopes thermal performance design. Chapter 2 provides an overview of different types of natural polymer composite membranes and their potentials in water remediation. In Chapter 3, discusses types of polymers that can be used in the development of heat exchangers for energy recovery applications in buildings. These polymeric heat exchangers are predicted to be built upon four bases; new polymers, new reinforcement or additives, new design, and new fabrication techniques. Chapter 4 highlights the potential and limitations of the solar-induced ventilation strategy in the tropical region, particularly in its subtypes of tropical rainforest climate and tropical monsoon climate. The chapter is based on the scientific results from the previous studies, recent innovations and latest technologies associated with such ventilation strategies and several significant examples of its applications in the contemporary tropical buildings. Lighting technologies and the impact of lighting design are covered in Chapter 5. This chapter also discusses user behavior to the energy consumption of lighting and life cycle assessment of luminaires. With the aim to have an in-depth understanding of energy recovery technology for building applications, Chapter 6 presents the mechanism and the application of this technology in various climatic conditions such as winter and summer conditions; cold and extremely cold climate conditions; and hot-humid condition based on previous data in the open literature. This chapter also examines the limitations, research gaps, and future recommendations pertaining to this technological development. Chapter 7 includes a discussion on critical design concepts of toplighting systems based on natural light for building interiors in different geographical locations. This chapter also covers issues on daylight in passive and sustainable architecture.

Understanding nature and biodiversity as part of sustainable agents will be advantageous to the environment and ecosystem. With this aim, Chapter 8 addresses polychaetes as biological agents of sustainable technology for environmental applications. This chapter focuses on the distribution of polychaetes in the world, and explains its role in tackling environmental issues. Examples include, detoxifying inorganic contaminants into less toxic compounds, processing organically enriched sediments via their digestive system and overcoming hypoxia and anoxia cases plus sulphidic condition are highlighted. Chapter 9 explores the role of incorporating plants in green building designs as one of the approaches to reduce energy consumption in buildings and to mitigate global warming. The nature of plants, their characteristics, and localized setting to benefit the microclimate are discussed. A discussion on low-carbon technology concept and characteristics of turbine ventilator as eco-friendly technology is presented in Chapter 10. The mechanism and concept are discussed by taking into account conventional and hybrid designs of turbine ventilators. Due to environmental concern, research and engineering interest have been changed from using synthetic adhesive to a new biobased adhesive or self-bonding board that is free from synthetic adhesive called binderless board. With this regard, Chapter 11 presents a review on binderless board manufacturing, treatment, and other processes using oil palm biomass as raw materials. The scope of this chapter is only based on the environmental aspects without coinciding with any economic factors or costing. Chapter 12 gives an overview of the lifecycle approach in materials selection and the assessment of materials used in construction based on ISO 14040:2006 and ISO 14044:2006. Analysis of life cycle assessment on building materials adopted in mosque construction in Iraq is also presented. Chapter 13 provides a review on the prospects of algae for biofuel production. Macroalgae integration into a biorefinery is also discussed. This chapter concludes that further research must be intensified to identify novel and the most appropriate algae species with high oil contents and fast-growth rates in a specific environment in the future. Chapter 14 presents a detailed review on energy production by microorganisms such as bacterium and algae. Sustainability of energy recovery by biological process is also highlighted at the end of this chapter. This information should be useful background for the understanding of energy production comparing competing options for biological and environmental applications.

Last but not least, we would like to take this opportunity to convey our appreciation to all contributors of the articles in this book. Special thanks entrusted to all reviewers that have provided comments and recommendations to the articles contained in this book. Our special thanks to Ms. Tiffany Gasbarrini, Mr. Brian

Halm, and Ms. Zoe Kennedy from Springer US for their kind support and great efforts in bringing the book to fruition. For the Editorial Team of Springer, we express our thanks for their contribution in making this book publishable. It has been a pleasure working with the team in the publication process of this book. We hope that this book can be a valuable reference for senior undergraduate and graduate students, engineers, architects, practitioners, scientists, researchers, planners, and employees in the area of renewable energy and sustainable technologies.

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Nomenclature

ATRP	Atomic transfer radical polymerization
BMI	Bismaleimides
BPA	Bisphenol A
DMAc	N,N-Dimethylacetamide
DMF	N,N-Dimethylformamide
DSC	Differential scanning calorimetry
ESC	Environmental stress cracking
HIPS	High impact polystyrene
LCP	Liquid crystal polymers
NMP	Nitroxide-mediated polymerization/N-methyl-2-pyrrolidone
PB	Polybutylene
PBI	Polybenzimidazoles
PC	Polycarbonate
PDI	Polydispersity index
PE	Polyethylene
PEEK	Polyether ether ketone
PEI	Polyether imide
PES	Polyether sulfone
PET	Polyethylene terephthalate
PF	Phenol formaldehyde
PFA	Perfluoroalkoxyl
PMMA	Polymethyl methacrylate
PP	Polypropylene
PPO	Polyphenylene oxide
PPS	Polyphenylene sulfide
PS	Polystyrene
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride

PVOH	Polyvinyl alcohol
RAFT	Reversible addition–fragmentation chain transfer
UP	Unsaturated polyesters
UV	Ultraviolet
VA	Vinyl acetate

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Contents

Chapter 1
Inverse Problem for Phase Change Materials and Preparation in Building Envelope

Xin Wang, Rui Yang and Saffa Riffat

Abstract Conventional methods to analyze building energy are of limitation and difficult to determine the best building envelope structure, best material thermal properties, and the best way for heating or cooling. In this paper, the research on the inverse problem for phase change materials and the application in building envelope by our group was reviewed, which can be used to guide the building envelope thermal performance design, material preparation and selection for effective use of renewable energy, reducing building operational energy consumption, increasing building thermal comfort, and reducing environment pollution and greenhouse gas emission. This paper also presents some current problems needed further research.

Keywords Sustainable energy · Energy storage · Nonlinear · SSPCM · Phase change temperature · Latent heat

1.1 Introduction

Over the past two decades, the world's primary energy usage has grown by 49 %, with an average annual increase of 2 %. Buildings account for 20–40 % of the total energy consumption [1, 2]. In order to get energy conservation and greenhouse gases reduction, renewable energy is encouraged to replace conventional fuels.

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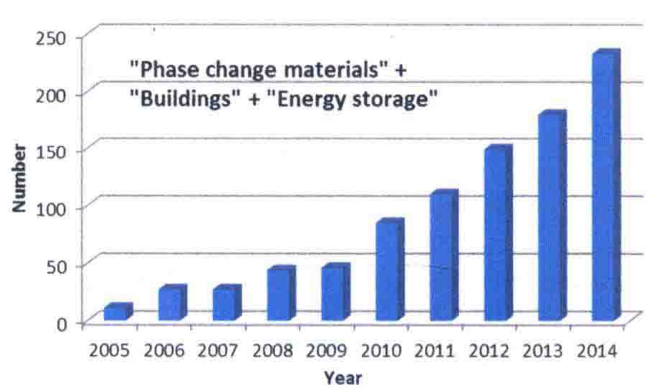
However, renewable energy is of low energy density and intermittent, which can be solved by thermal energy storage. Effective thermal energy storage materials are required for the wider application of solar energy, which is the most abundant renewable energy source, and for novel materials development and application either.

A phase change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature (or range), is capable of storing and releasing large amounts of energy [3]. Due to high latent heat within a narrow temperature range, PCM has more suitable features in peak shaving, tariff reduction, energy saving, equipment capacity reduction, and thermal comfort increase. The development of new material, theory, and technology brings new chances and challenges for PCM energy storage.

Figure 1.1 shows the publications numbers on the Web of Science in the recent 10 years with topic words "PCMs," "Buildings," and "Energy storage." It is shown that there is a rapid increase in the related research and the number in 2014 is about 20 times of that in 2005. The use of thermal energy storage with PCM has become a great concerned topic of interest not only within the research community but also within the architects and engineers.

As the indoor and outdoor environment interface, building envelope can not only offer security, privacy, access, and view, but also adjust various forms of energy flow (light, heat, sound, humidity, etc.). The main functions of building envelope are in the following aspects: vision, lighting, shading, thermal insulation, heat preservation, ventilation, and sound insulation. Improving the form and thermal performance of building envelope is an important way for building energy conservation [4]. Cabeza et al. [5] reviewed PCMs available and problems and possible solutions on the application in buildings. Zhu et al. [6] reviewed the previous research work on dynamic characteristics and energy performance of buildings due to the integration of PCMs, especially in using PCMs for free cooling and peak load shifting. Al-abidi et al. [7] reviewed the numerical modeling of PCMs through commercial computational fluid dynamic (CFD) software and self-developed programming to study the heat transfer phenomena in PCMs. Conventional approaches are commonly used for analyzing the building envelope thermal performance in

Fig. 1.1 Publications in Web of Science (2005–2014)



most of references. For a given building envelope, where the thermal properties of building material is known, thermal performances of a building are analyzed and the heating and cooling loads are supplied. This method is of limitation and difficult to determine the best building envelope structure, best material thermal properties, and the best way for heating or cooling. Thus, an inverse problem for PCMs and application in building envelop was proposed by our group, which aimed for effective use of renewable energy, reducing building operational energy consumption, increasing building thermal comfort, and reducing environment pollution and greenhouse gas emission [8–10].

Another value of the inverse problem research is to guide the building material preparation. According to the inverse problem research, the thermal performance of PCM is similar to the ideal building material, which provides the theoretical foundation. PCMs can be categorized as organic, inorganic, etc. Table 1.1 lists the main characteristics of inorganic and organic PCMs [4]. SSPCM is composed of an organic PCM, e.g., paraffin, and a polymer matrix which can encapsulate PCMs and maintain the shape no matter the PCM is in solid state or in liquid state. The SSPCM can be made into different shapes, such as grain, stick, and board.

In this paper, the inverse problem research for PCMs and application in building envelop by our group is reviewed, including the heat transfer research and SSPCM preparation research. It is very different from the conventional approaches and can be used to guide the building envelope thermal performance design and material preparation and selection. At last, this paper also presents some current problems needed further research.

Table 1.1 Classification and properties of PCMs [4]

Classification	Inorganic	Organic
Category	Crystalline hydrate, molten salt, metal, or alloy	High aliphatic hydrocarbon, acid/esters or salts, alcohols, aromatic hydrocarbons, aromatic ketone, lactam, freon, multi-carbonated category, polymers
Advantages	Higher energy storage density, higher thermal conductivity, nonflammable, inexpensive	Physical and chemical stability, good thermal behavior, adjustable transition zone
Disadvantages	Supercooling, phase segregation, corrosive	Low thermal conductivity, low density, low melting point, highly volatile, flammable, volume change
Methods for improvement	Mixed with nucleating and thickening agents, thin layer arranged horizontally, mechanical stir	High thermal conductivity additives, fire-retardant additives