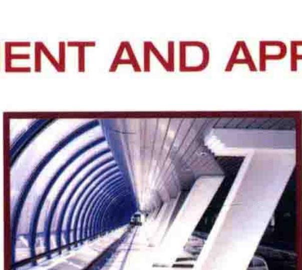
THERMAL ENERGY STORAGE TECHNOLOGIES FOR SUSTAINABILITY

SYSTEMS DESIGN, ASSESSMENT AND APPLICATIONS





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Thermal Energy Storage Technologies for Sustainability

Systems Design, Assessment and Applications

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Thermal Energy Storage Technologies for Sustainability

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Preface

Energy is considered the lifeline of all human activities and, as such, it has to be conserved at every stage, starting at societal and going to national development. Energy management among the spectrum of sectors of a country can facilitate proper usage of energy based on actual demand. Proper guidance in handling and utilizing energy systems can further maximize energy conservation by the energy producer and the end user.

From this perspective, this book addresses the key energy challenges to be met through gaining knowledge on thermal energy storage (TES) technologies that can lead to a sustainable energy future. This book contains rich information on bridging energy gaps through the incorporation of TES technologies.

The publication of this book at this point in time suggests that the described ideologies and assessments can provide immediate solutions to the current energy market and strategic planning for combining such technologies with real-world engineering systems.

Our primary objective is to deliver a quality work demonstrating the concepts of TES that would be of significant interest to students, researchers, and academics, as well as industrialists, to whom this book can serve as a comprehensive tool for immediate reference while providing information pertaining to the multitude of aspects on TES technologies for sustainable development.

From this perspective, Chapter 1 explains the energy concepts, project energy demand/consumption, and possible energy management techniques that would be helpful for the development of a sustainable future.

In Chapter 2, the significance and functional aspects of a variety of energy storage technologies intended for meeting demand side energy requirements are demonstrated.

TES technologies, on the other hand, offer a wide range of opportunities and benefits to end-use energy and demand side management facilities, primarily in terms of cost effectiveness and energy savings, which are covered in Chapter 3.

Chapter 4 discusses the potential application of sensible TES technologies in residential buildings, in which the implementation of passive and active thermal storages can result in the enhancement of energy efficiency and thermal efficiency.

The nucleus of Chapter 5 is divided into two topics: (1) apposite latent thermal storage materials having excellent thermophysical properties and (2) the potential opportunity for such materials to be effectively integrated into real-time passive and active cooling applications in buildings.

The reversible chemical reactions occurring between working reactants or reactive components help to store and release the required heat energy. In this context, the concepts and inherent operational characteristics of various thermochemical energy storage systems are explained in Chapter 6.

In Chapter 7, the description and the operational characteristics of a variety of sessonal TES technologies are elaborately discussed.

Chapter 8 is exclusively dedicated to nanotechnology-based TES systems. This is an ever-growing and emerging field of interest to a variety of research communities, as well as to industrial professionals worldwide. It is suggested that heat storage materials embedded with nanomaterials exhibit improved TES properties, which enable them to be considered as suitable candidates for future TES applications.

Chapter 9 explains the energy efficiency and cost-energy savings potential of TES systems integrated with conventional and renewable energy systems that can collectively contribute to a reduction in green house gas (GHG) emissions and pave way for the development of a sustainable future.

To enable thermal storage systems to be fully functional, some crucial factors need to be considered during the design phase. From this perspective, Chapter 10 demonstrates the basic design of some sensible and latent thermal energy storage systems with example calculations.

Prior to the implementation of phase change materials into real-time building applications, their operational performance can be effectively analyzed by modeling and simulation methods. In this context, the major attributes of a variety of modeling and simulation approaches are reviewed and presented in Chapter 11.

Chapter 12 presents the exergetic assessment of thermal energy storage systems that reveal positive attributes on reducing the greenhouse gas emissions for the development of a sustainable future with adequate results on energy efficiency of the system.

The significance of providing proper control and optimization schemes in buildings integrated with TES systems to accomplish reduction in the operating cost without compromising energy efficiency are elaborately discussed in Chapter 13.

In Chapter 14, the economic and societal prospects of thermal energy storage technologies are presented. The application potential of thermal energy storage technologies and the scope for futuristic developments are included in Chapter 15.

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Contents

CHAPTER

Energy and Energy Management

1

1.1 INTRODUCTION

Energy and energy management are two facets of a mature technology that would move the economic status of a country from normal to the height of societal development. A nation with a strong mission of ensuring energy efficiency at each step of its societal development can sustain higher economic growth on a long-term basis. The increasing concerns about climate change and environmental emissions have led to conserving energy through the development of several energy-efficient systems. The underlying concept behind this is the reduction of extensive utilization of fossil fuel or primary energy sources and their associated carbon emissions. From this perspective, the following sections are designed to explain energy concepts, project energy demand/consumption, and describe possible energy management techniques that would be helpful for the development of a sustainable future.

1.2 ENERGY RESOURCES, ENERGY SOURCES, AND ENERGY PRODUCTION

In the spectrum of energy and energy management, energy resources, energy sources, and energy production are extremely vital starting from their discovery, conversion, and production to end-use consumption. Although the terminologies related to energy resources and energy sources seem to be associated, a basic difference exists that helps the scientific community to move the task of energy production forward to meet energy demand.

Energy resource refers to a reserve of energy, which can be helpful to mankind and society in many ways. On the other hand, energy source also means the system that is devised for extracting energy from the energy resource. For example, the availability of fossil fuels under the earth in the form of coal can be categorized as an energy resource. The system or the technology that is incorporated to extract the energy available from the fossil fuel (coal) can be classified as the energy source.

Earth has large energy resources or basins including solar, hydro, wind, biomass, ocean, and geothermal. Through the application of the human ideologies and emerging technologies, tapping the energy from these reserves in an efficient manner has always been a paramount task. Earth's finite and renewable energy reserves along with recoverable energy from these resources are depicted in Fig. 1.1.

It is not only important that the energy be extracted from these reserves or reservoirs; the real success of the task depends on efficient transformation to the actual societal requirements. In simpler words, the extracted energy has to be generated or produced in a more usable form and has to be transported so that it caters to end-user energy demand. To sustain the living standards in developed nations as well as improve societal and economical status in developing countries, it is of great importance to balance the huge gap between energy generation and consumption.

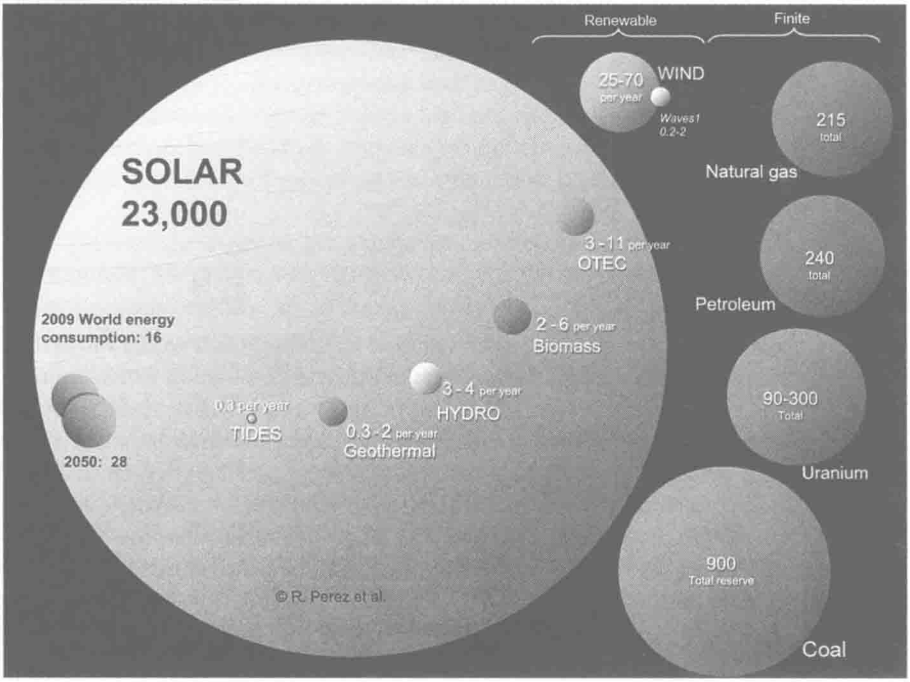


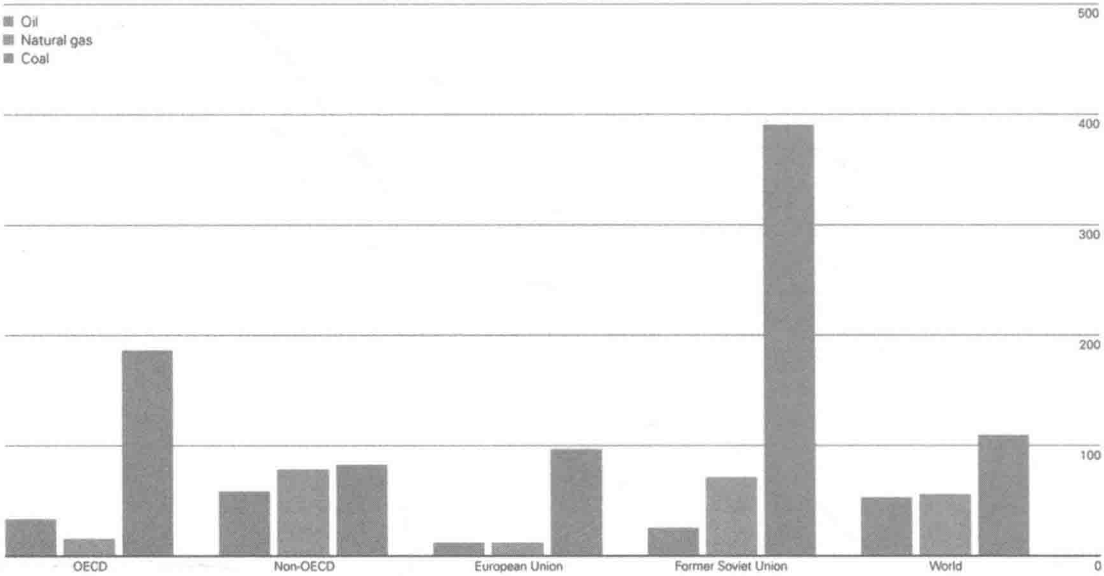
FIGURE 1.1

Finite and renewable planetary energy reserves (Terawatt-years, TWy). Total recoverable reserves are shown for the finite resources. Yearly potential is shown for the renewable [1].

The availability of reserves and the possible recovery of energy projected in Fig. 1.1 are more attractive and helpful. This is a basic step in the process of energy planning and energy management. It can be seen clearly from Fig. 1.1 that the total energy reserves available for the fossil fuel category account for nearly 2000 TW per year (TW—Terawatt). The reserves available for nuclear energy are comparatively less compared to fossil fuel reserves. The ratio of fossil fuel reserves to production globally at the end of 2012 is shown in Fig. 1.2.

The projected ratio of fossil fuel reserves to their production in Fig. 1.2 infers that the reserves for coal, oil, and natural gas in some parts of the world have increased over time. This could be attributed to emerging technological advancement in the search for new fossil fuel reserves or beds. It can also be seen clearly from Fig. 1.1 that energy recovery from nuclear energy can now help fulfill immediate energy needs. However, from the long-term energy perspective, dependence on nuclear fuels imposes certain environmental risk factors and unsafe conditions in terms of nuclear emissions and radioactive decay.

It is interesting to note that after the Industrial Revolution, human inventions (interventions) for using fossil fuels to satisfy the energy demand increasingly grew from region to region worldwide.



Coal remains the most abundant fossil fuel by global R/P ratio, although global oil and natural gas reserves have increased significantly over time. Non-OECD countries possess the majority of proved reserves for all fossil fuels and have a higher R/P ratio than the OECD countries for oil and natural gas.

FIGURE 1.2

Global projections on the ratio of the fossil fuel reserves to production at the end of 2012 [2].

The values projected in Fig. 1.3 infer continuous growth in fossil fuel-based primary energy sources in recent years as well as in the near future.

Tough competition exists between the world's nations in the search for new reserves of oil, natural gas, and coal. This process is even more encouraged in developed countries. This is in some ways advantageous, but the uncontrollable exploitation of such energy reserves leads to carbon emissions and other environmental risk factors.

The projections on the additions of world power generation capacity and retirements from 2013-2035 shown in Fig. 1.4 infer that the participation of developing nations including India and China is considerable. This means that developing countries are more interested in resolving issues related to energy usage per person, as compared to developed nations. Nearly 40% of the world's new power-generation capacities is being made by India and the China. At the same time, almost 60% of the power capacity additions have contributed for the replacements of retired plants in the Organization for Economic Co-operation and Development (OECD) countries.

On the other hand, developed nations are also equally interested in developing renewable energy sources-based systems for accomplishing demand-side energy management. However, in this type of task, aside from the cost implications involved, adding renewable energy as the source for power generation (electricity production) as depicted in Fig. 1.5 would facilitate maximum energy advantage with reduced or net zero emissions to the environment.

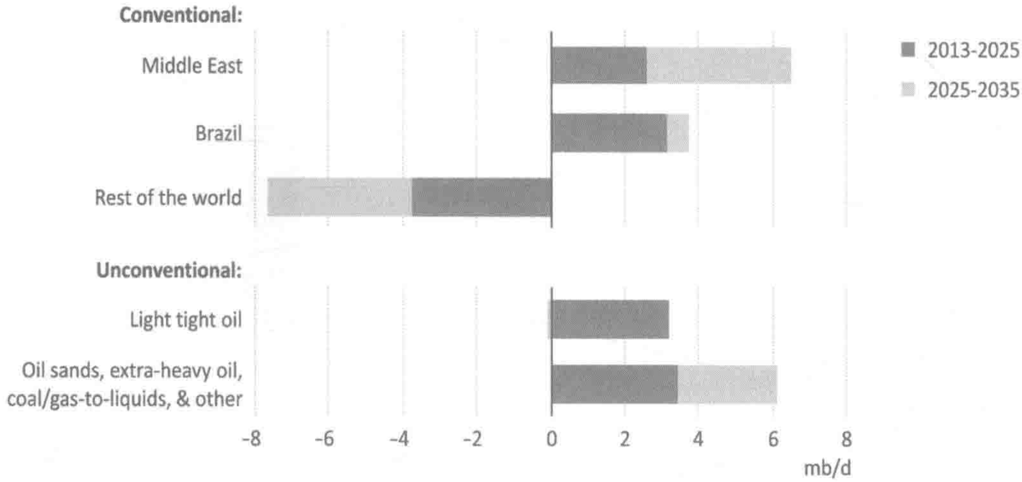


FIGURE 1.3

Projections on global oil production growth contributors [3].

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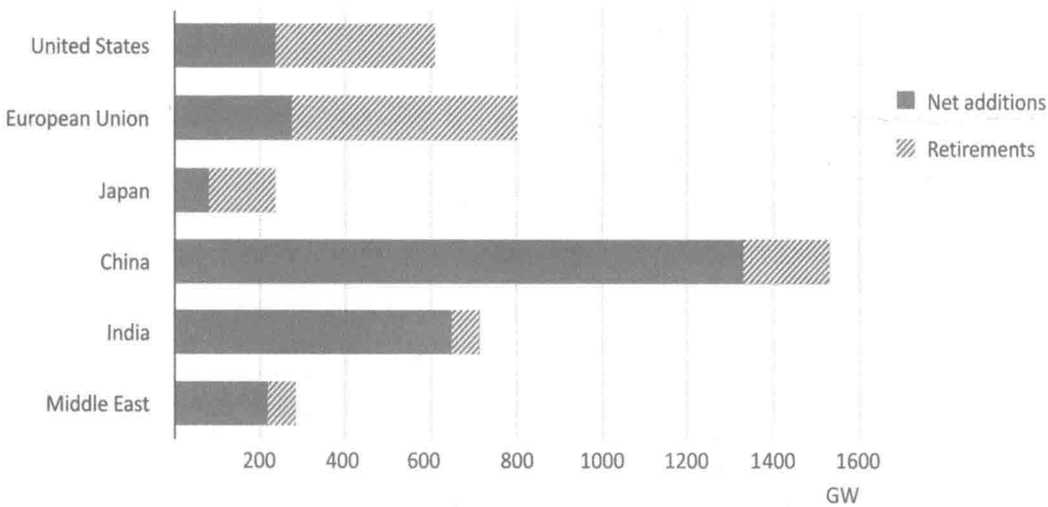

FIGURE 1.4

Projections on additions of power generation capacity and retirements from 2013–2035 [3].

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