

Energy, Environment, and Sustainability

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Energy Sustainability in Built and Urban Environments

 Springer

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Preface

Energy demand has been rising remarkably due to increasing population and urbanization. Global economy and society are significantly dependent on the energy availability because it touches every facet of human life and its activities. Transportation and power generation are two major examples. Without the transportation by millions of personalized and mass transport vehicles and availability of 24×7 power, human civilization would not have reached contemporary living standards.

The International Society for Energy, Environment and Sustainability (ISEES) was founded at Indian Institute of Technology Kanpur (IIT Kanpur), India, in January 2014 with the aim of spreading knowledge/awareness and catalysing research activities in the fields of energy, environment, sustainability and combustion. The society's goal is to contribute to the development of clean, affordable and secure energy resources and a sustainable environment for the society and to spread knowledge in the above-mentioned areas and create awareness about the environmental challenges, which the world is facing today. The unique way adopted by the society was to break the conventional silos of specializations (engineering, science, environment, agriculture, biotechnology, materials, fuels, etc.) to tackle the problems related to energy, environment and sustainability in a holistic manner. This is quite evident by the participation of experts from all fields to resolve these issues. ISEES is involved in various activities such as conducting workshops, seminars and conferences in the domains of its interest. The society also recognizes the outstanding works done by the young scientists and engineers for their contributions in these fields by conferring them awards under various categories.

The second international conference on “Sustainable Energy and Environmental Challenges” (SEEC-2018) was organized under the auspices of ISEES from 31 December 2017 to 3 January 2018 at J N Tata Auditorium, Indian Institute of Science Bangalore. This conference provided a platform for discussions between eminent scientists and engineers from various countries including India, USA, South Korea, Norway, Finland, Malaysia, Austria, Saudi Arabia and Australia. In this conference, eminent speakers from all over the world presented their views

related to different aspects of energy, combustion, emissions and alternative energy resources for sustainable development and a cleaner environment. The conference presented five high-voltage plenary talks from globally renowned experts on topical themes, namely “Is It Really the End of Combustion Engines and Petroleum?” by Prof. Gautam Kalghatgi, Saudi Aramco; “Energy Sustainability in India: Challenges and Opportunities” by Prof. Baldev Raj, NIAS Bangalore; “Methanol Economy: An Option for Sustainable Energy and Environmental Challenges” by Dr. Vijay Kumar Saraswat, Hon. Member (S&T), NITI Aayog, Government of India; “Supercritical Carbon Dioxide Brayton Cycle for Power Generation” by Prof. Pradip Dutta, IISc Bangalore; and “Role of Nuclear Fusion for Environmental Sustainability of Energy in Future” by Prof. J. S. Rao, Altair Engineering.

The conference included 27 technical sessions on topics related to energy and environmental sustainability including 5 plenary talks, 40 keynote talks and 18 invited talks from prominent scientists, in addition to 142 contributed talks, and 74 poster presentations by students and researchers. The technical sessions in the conference included Advances in IC Engines: SI Engines, Solar Energy: Storage, Fundamentals of Combustion, Environmental Protection and Sustainability, Environmental Biotechnology, Coal and Biomass Combustion/Gasification, Air Pollution and Control, Biomass to Fuels/Chemicals: Clean Fuels, Advances in IC Engines: CI Engines, Solar Energy: Performance, Biomass to Fuels/Chemicals: Production, Advances in IC Engines: Fuels, Energy Sustainability, Environmental Biotechnology, Atomization and Sprays, Combustion/Gas Turbines/Fluid Flow/Sprays, Biomass to Fuels/Chemicals, Advances in IC Engines: New Concepts, Energy Sustainability, Waste to Wealth, Conventional and Alternate Fuels, Solar Energy, Wastewater Remediation and Air Pollution. One of the highlights of the conference was the rapid-fire poster sessions in (i) Energy Engineering, (ii) Environment and Sustainability and (iii) Biotechnology, where more than 75 students participated with great enthusiasm and won many prizes in a fiercely competitive environment. More than 200 participants and speakers attended this four-day conference, which also hosted Dr. Vijay Kumar Saraswat, Hon. Member (S&T), NITI Aayog, Government of India, as the chief guest for the book release ceremony, where 16 ISEES books published by Springer, under a special dedicated series *Energy, Environment, and Sustainability* were released. This is the first time that such significant and high-quality outcome has been achieved by any society in India. The conference concluded with a panel discussion on “Challenges, Opportunities and Directions for Future Transportation Systems”, where the panellists were Prof. Gautam Kalghatgi, Saudi Aramco; Dr. Ravi Prashanth, Caterpillar Inc.; Dr. Shankar Venugopal, Mahindra and Mahindra; Dr. Bharat Bhargava, DG, ONGC Energy Centre; and Dr. Umamaheshwar, GE Transportation, Bangalore. The panel discussion was moderated by Prof. Ashok Pandey, Chairman, ISEES. This conference laid out the road map for technology development, opportunities and challenges in energy, environment and sustainability domains. All these topics are very relevant for the country and the world in the present context. We acknowledge the support received from various funding agencies and organizations for the successful conduct of the second ISEES conference SEEC-2018, where

these books germinated. We would therefore like to acknowledge SERB, Government of India (special thanks to Dr. Rajeev Sharma, Secretary); ONGC Energy Centre (special thanks to Dr. Bharat Bhargava); TAFE (special thanks to Sh. Anadrao Patil); Caterpillar (special thanks to Dr. Ravi Prashanth); Progress Rail, TSI, India (special thanks to Dr. Deepak Sharma); Tesscorn, India (special thanks to Sh. Satyanarayana); GAIL, Volvo; and our publishing partner Springer (special thanks to Swati Meherishi).

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This book covers different aspects of energy sustainability: implementation at macro-scale (nation, city, neighbourhood) and building scale, strategies in relation to buildings, neighbourhoods, systems and energy markets and sustainable energy production, use and storage technologies. Topics include sustainable construction practices, urban planning, energy efficiency of residential, school and office buildings, how to manage the impact of future climate conditions, control strategies of microgrids and financial instruments. Wind energy, thermoelectric materials, concentrated photovoltaic, hydrogen fuel clean energy cycle and renewable energy storage are also presented here through a series of chapters.

Ghent, Belgium
Kanpur, India
Ghent, Belgium

Emilia Motoasca
Avinash Kumar Agarwal
Hilde Breesch

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Introduction to Energy Sustainability

Abstract The European Union commits itself to develop a sustainable, competitive, secure and decarbonized energy system by 2050. This is not only a European but also a worldwide challenge included in the 17 Sustainable Development Goals of UN, like *Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all*, *Goal 9 Build resilient infrastructure, promote sustainable industrialization and foster innovation*, *Goal 11 Make cities inclusive, safe, resilient and sustainable*, *Goal 12 Ensure sustainable consumption and production patterns* and even *Goal 13 Take urgent action to combat climate change and its impacts*. Energy sustainability is more than restricting the energy use in industry, buildings and systems or the simple use of renewable energy sources. This calls for a multidisciplinary approach in various economic domains and at various scales. This book provides a holistic approach in terms of energy sustainability implementation, technologies and strategies.

Keywords Energy efficiency • Sustainable energy production and storage
Neighbourhood and buildings

Meeting the energy efficiency (and sometimes the extra energy self-sufficiency) criteria is still a worldwide challenge in all applications (industry, buildings, consumer goods and services, etc.). Energy sustainability does not mean only reducing the energy use and using more energy produced from renewable energy sources or increasing the energy efficiency of processes and devices, but it implies insight and knowledge in various domains. The publication of this book has been motivated by an increased interaction among various disciplines (electrical, mechanical, construction and material engineering, economics, politics, etc.) in various economic domains (industry, constructions, etc.) and at various scales (worldwide, nationwide, neighbourhoods, buildings, devices) where newest developments in solar, wind and waste heat energy harvesting, hydrogen production and energy storage technologies are applied. Besides the scale level, each country deals with own geographic, economic, politic and legal particularities that influence the way some of the energy sustainability challenges are approached and coped with. Therefore,

this book has a broad view and tackles a wide range of topics including energy sustainability implementation, technologies and strategies. Meanwhile, this book shows just a small selection of the multidisciplinary field of energy sustainability.

In the first four chapters, bundled as Part I—*Energy Sustainability Implementations*, some aspects of the implementation at macro-scale (nation, city, neighbourhood, etc.) and at building scale related to energy sustainability are presented. Chapter 1 investigates the sustainable construction practices in West African countries in the context of recent challenges, drivers and implementation and application measures. The increasing interest in sustainable buildings has been driven by a strong increase among relevant stakeholders including clients, sponsors, construction professionals, government agencies and other concerned regulatory bodies. Chapter 2 studies the influence of urban planning in Belgium on the financial and environmental impact of neighbourhoods using a combined life-cycle costing (LCC) and environmental life-cycle assessment (E-LCA). The results reveal substantial impact differences between different neighbourhoods, showing the importance of urban planning to decrease the financial and environmental impact of the built environment. Chapter 3 makes a detailed SWOT analysis together with an extended discussion on the application of high-tech and low-tech designs for reaching the energy efficiency in residential buildings in Vietnam. Up-to-date carefully chosen data and examples are provided. Chapter 4 further discusses the specific situation of Vietnam, providing an overview of the actual design practice for office buildings in Vietnam together with design recommendations for office buildings to achieve high standards of the energy efficiency and indoor climate.

In the next five chapters, grouped as Part II—*Energy Sustainability Strategies*, various energy sustainability strategies are described in relation to buildings, neighbourhoods, systems and energy markets. Chapter 5 focuses on the energy efficiency and sustainability on the urban scale and elaborates how to develop a computational platform combining future climate conditions, assessment of energy demand of a building stock and design and assessment of urban energy systems. Chapter 6 also considers the importance of accounting for climate changes, more specifically in dynamic building energy simulations. This issue is clearly needed when looking for sustainable buildings as buildings have a relatively long lifespan. The chapter discusses widely used methods to predict future weather data and provides an overview of available weather data sets for building simulations. Another essential aspect to achieve energy sustainability in buildings is the application of a reliable and accurate method for the energy use assessment of building designs. Chapter 7 assesses the accuracy of a simplified calculation method in office and school buildings in Belgium by using integrated dynamic building and HVAC system simulations. The simplified approach as currently applied in the EPR calculation tool in Flanders is shown to be suited for the calculation of the final energy use, despite the uncertainties and restrictions of the investigated simulation model. Chapter 8 discusses a fuzzy-based approach to design control strategies for microgrids, where the residential grid-connected microgrids (MGs) that comprise renewable generation and storing capability are constrained to grid operator requirements which include a smooth and bounded grid power profile. Chapter 9

ends Part II with an analysis of the effectiveness of financial instruments to invest in renewable energy on the Spanish market. The financial performance of various alternative energy mutual funds is compared to conventional market benchmarks.

In the last five chapters, grouped as Part III—*Energy Sustainability Technologies*, various technologies related to sustainable energy production, use and storage are considered. Chapter 10 provides a detailed overview of basic concepts related to wind energy: energy calculations, design methodology, construction and electrical power generation using wind turbines. Chapter 11 presents the newest developments and challenges related to the use of thermoelectric materials for waste heat recovery in various applications. Thermoelectric generators based on thermoelectric materials have the capability of converting heat energy into electric energy and therefore have an immense potential to increase the energy efficiency of various processes and devices. Chapter 12 discusses a sustainable approach for cooling needs using concentrated photovoltaic (CPV) in combination with mechanical vapour compression (MVC) and adsorption chillers. The thermal energy recovered from the cooling of CPV system is used in the absorption chillers, and this leads to a strong increase of the system efficiency. Chapter 13 describes an economical, novel method for implementing a complete hydrogen fuel clean energy cycle based on the chemical reaction between salinated (sea) or desalinated (fresh) water and sodium metal with the use of a novel, molten salt electrolytic cell designed to perform electrolysis at a temperature range between 950 °C and 1050 °C. Chapter 14 concludes Part III with a discussion of the use of renewable energy storage at KAUST desalination plant pilot to increase the solar-driven desalination capacity.

The topics are organized into three different sections: (i) energy sustainability implementation, (ii) energy sustainability strategies and (iii) energy sustainability technologies.

Specific topics covered in this book include:

- Sustainable construction practices in West African countries,
- Influence of urban planning on the financial and environmental impact of neighbourhoods,
- Energy efficiency in urban residential buildings in Vietnam,
- Recommendations for the design of office buildings in Vietnam,
- Computational platform linking neighbourhoods to sustainable energy systems,
- Future weather data for dynamic building energy simulations,
- Simplified method to assess heating energy use in non-residential buildings,
- Microgrid energy management strategies,
- Financial instruments to invest in renewable energy in Spanish market,
- Overview of basic concepts related to wind energy,
- Newest developments and challenges related to thermoelectric materials for waste heat recovery,
- Concentrated photovoltaic thermal (CPVT) system for cooling,
- Novel method for implementing a complete hydrogen fuel clean energy cycle,
- Application of renewable energy storage for desalination.

To summarize, this book contains information about energy sustainability implementation at macro-scale (nation, city, neighbourhood) and building scale, energy sustainability strategies in relation to buildings, neighbourhoods, systems and energy markets and sustainable energy production, use and storage technologies. We sincerely hope that you will enjoy its content!

Emilia Motoasca
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