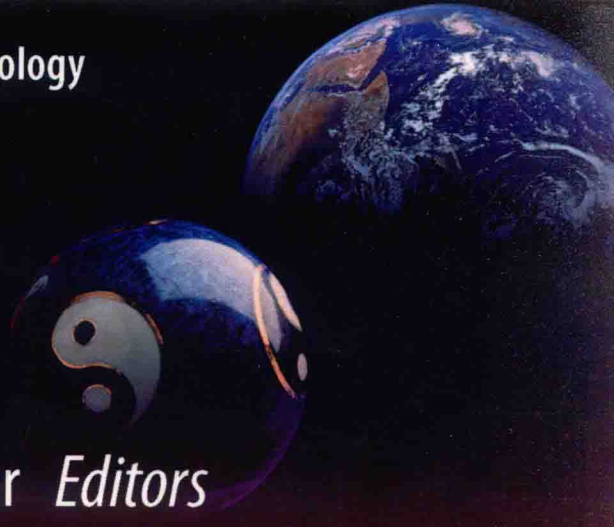
Green Energy and Technology



Atul Sharma
Sanjay Kumar Kar *Editors*

Energy Sustainability Through Green Energy

Springer

Atul Sharma · Sanjay Kumar Kar
Editors

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Editors
Atul Sharma
Mechanical Engineering
Rajiv Gandhi Institute
of Petroleum Technology
Rae Bareli
India

Sanjay Kumar Kar
Department of Management Studies
Rajiv Gandhi Institute
of Petroleum Technology
Noida
India

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Foreword

The debate about climate changes due to industrial activity post mid-nineteenth century is no more a subject of academic discussions and modelling various scenarios. The after-effects of greenhouse gas emissions due to human activity is there for all of us to see manifesting in the form of extreme climatic conditions. In November 2014, it was widely reported in newspapers that all the 50 states of the United States recorded sub-zero temperatures, a never heard before phenomenon. Coupled with such facts another challenge that the world is likely to face by 2030, according to some UN estimates, is the *stress nexus* of rising demands for water, food and energy.

The growing population of the planet, which according to estimates is likely to be around 9 billion by 2050 as against 2 billion during the mid-nineteenth century and aspirations of people leading a reasonably decent lifestyle is putting more and more pressure on the existing *congealed* resources of our planet. And at the same time, it is also being realized that the days of *easy oil* are over. Oil (and its equivalents like gas) as a major source of primary energy is gradually to be explored in inhospitable, difficult and deeper terrains. Thus, the Energy Returned On Energy Invested (EROEI) has also gradually been reducing from the levels of 100:1 in the 1860s to somewhere around 17–18:1 in 2010 and is projected to fall further. This ratio, below the levels of 5–9:1, according to some estimates, will make oil production unviable with the available technology.

Thus, energy being the quintessential requirement for human progress, two fundamental questions need to be considered in right earnest. The *first* being the ability to produce enough primary energy to meet demand and the *second*, not damaging the climate further with human activity leading to greenhouse gas (GHGs) emissions beyond the IPCC (Intergovernmental Panel on Climate Change) recommended limits of 450 ppm.

IPCC, in its latest deliberations, has brought out the following facts:

1. Average surface temperature has already increased by 0.85 °C over the period from 1880 to 2012.
2. Existing levels of three key GHGs—carbon dioxide, methane and nitrous oxide—are the highest in at least 800,000 years.

3. Global mean sea level rose by 19 cm from 1901 to 2010.
4. Period from 1983 to 2012 was the warmest 30-year period in the last 1,400 years.

IPCC has further said that the world will have to totally phase out fossil fuels in power generation by the end of the century.

These developments have, obviously, led to the search for commercially exploitable *other sources* of energy that while meeting human needs do not cause further damage to the environment for the sustenance of our planet. It is expected that *energy mix* of the planet will change substantially in the years to come.

Green Energy or Renewable Energy is an area that will form a substantial portion of the energy mix in the country and will occupy centre stage in providing the much needed fillip to the void likely to be experienced by us in the near foreseeable future. There is enough promise for various green energy initiatives like solar, solar thermal, wind, bio-mass, hydro, hydrogen and nuclear power.

It is, indeed, a very timely effort by Dr. Atul Sharma and Dr. Sanjay Kumar Kar, known to me for over five years now, from Rajiv Gandhi Institute of Petroleum Technology (RGIPT), an institute of national importance, to have come out with a book that discusses myriad ways in which the natural resources of our well-endowed country can be made use of for meeting the energy needs of our millions of citizens without causing further damage to the environment.

In course of my interactions with both the professors of RGIPT, which is co-promoted by various organizations from the petroleum industry, we have often discussed about the likely energy scenarios in the days ahead. During such discussions, the need to publish a book on energy sustainability was felt. I congratulate both the editors for having come out with the book which will be of immense help to students, practising managers and policy makers alike.

Biswajit Roy
Executive Director (HRD)
Indian Oil Corporation Limited
New Delhi

Preface

A few decades ago, energy sustainability was just thought in terms of accessibility relative to the rate of use. Today, in the context of the decent agenda of sustainable growth, including concerns about global warming, greenhouse gas emissions, climate change and so on are very important issues. These include environmental effects and the question of the energy generation process as well as emissions, which are the primary reasons for damage to the earth environment during energy production, distribution and consumption. Sustainable energy development criteria have been promoted in several years into the front line of energy policy, which also showed how we address our energy needs on a sustainable basis.

Energy demand is likely to increase in the entire world, the ratio supplied by electricity is likely to rise rapidly, however, more energy demand is for continuous, and this qualitative consideration will continue to dominate in the energy sector. Meeting the needs of the present energy demand without compromising the needs of the future, the whole world has to pay attention to the energy sustainability, so that environmental protection remains equally important at the same time. Energy sustainability could drive environment friendly technological innovations with viable techno-commercial applications for social upliftment.

Renewable resources such as solar energy, wind energy, biomass, bio-gas and bio-fuels, hydro energy provide a source of sustainable energy. Worldwide, renewable energy resources are available to supply the expanding energy needs without environmental damage. However, the current renewable energy share is less in the worldwide energy production. It is an acknowledged fact that it should have been much higher as much as in favour of the environment, which is the most essential issue globally. Almost everywhere in the globe, clean energy production is given much attention due to the current environmental issues, which can only be solved by the renewables. Many countries are making significant efforts to move up the renewable energy ratio and overall approximated 19 % of global energy consumption produced by renewable energy in 2012 which continued to grow in 2013.

The aim of this book is to share the latest developments and advances in materials and processes involved in green energy generation, transmission-distribution, storage, etc., with chapters written by professors and researchers in the energy

and materials field, using original research materials. This book may be used as a reference book in college/university/training institute/professionals all over the world. This book can also be referred in all the green energy-related laboratories, industries and academic libraries and as a refereed book for "Alternative Energy Sources, Renewable Energy Resources, Climate Change, Energy Sustainability, Energy Policies etc." for undergraduate and graduate students. The book presents a perfect blend of research and practice explained in a very simplistic manner. It also covers the sustainable provision of energy that meets the needs of the present without compromising on the ability of future generations to meet their needs.

Rae Bareli, India — Atul Sharma
Noida, India — Sanjay Kumar Kar

Overview of the Book

The increasing level of greenhouse gas emissions and the rise in fuel prices are the main reason for efforts to more effectively use various sources of renewable energy. Scientists all over the world are in search of sustainable energy options, which demands sustainable planning of sustainable energy developments. This confirms that the urgency of meeting the present needs without compromising the ability of future generations to satisfy their needs.

Increasing the share of green energy sources can trim down greenhouse gas emissions, which is a major factor in global warming as well as climate change worldwide. The operating cost of technologies to capture green energy, which is speedily declining and becoming economically competitive with fossil fuels, while also reducing the risk of climate change is what is actually needed worldwide. Investing in green energy creates a bunch of jobs, quick economic growth, and improves energy security, which is highly required worldwide because of shortage of fossil fuel resources.

The book explores the latest developments and advances in materials and processes involved in energy generation, transmission-distribution and storage, etc., and chapters written by several scientists, researchers and academicians in the field of energy. The results and recommendations are essential reading for policymakers, professionals, researchers and anyone concerned with energy sustainability through green energy. The book with 19 chapters is divided into six parts, which include relevant topics presented in detail below:

- Solar energy
- Wind energy
- Green buildings
- Thermal energy Storage
- Bio-mass, Bio-fuels, Bio-gas
- Other Green Energy

Part I: Solar Energy

Solar Photovoltaic Technology and Its Sustainability

In this chapter, Anil Kumar, Geetam Richhariya and Atul Sharma have discussed the application of solar photovoltaic technology for sustainable growth. The renewable energy sources are the clean green technology, which motivates the healthy environment but also encourages using them in rural areas where grid supply is not applicable. The fundamentals of solar photovoltaic technologies and their sustainability on the earth are discussed. The various internal phenomena that occur inside the sun and the solar spectrum is also discussed. The various applications of photovoltaic and modelling of the solar cell are presented in this chapter.

Solar Drying—A Sustainable Way of Food Processing

Co-authors of this chapter, M.A. Aravindh and A. Sreekumar explore deployment of Solar Drying as a sustainable way of food processing. In a developing country like India, having the second largest population and with agriculture as a source of income to nearly 60 % of the total population, post harvest and storage loss is a major quandary which needs to be addressed in due diligence. There are many food preservation techniques such as cold storage, drying, etc., that have evolved over the years to tackle the above losses. The major constraint is that almost all the technologies utilize fossil fuel resources, which are depleting very fast and wise use of these precious resources are preferred for long-term energy sustainability. Therefore, sustainable methods for food preservation are the need of the hour. Solar drying is one of the best choices in this context. There are many models of solar dryers developed and a good quantum of research is progressing in many parts of the world to propagate the solar drying technology for value addition of agriculture products. The solar drying technology is a classic example to showcase how the sun's free energy could be effectively utilized for the benefit of mankind. This chapter explains the different types of dryers, aspects of solar drying, parameters involved in the drying process and the economic analysis to analyse the feasibility of the solar drying system. Case studies of some of the successful installations are also included to propagate the solar drying technology in the country.

Jawaharlal Nehru National Solar Mission in India

In this chapter, co-authors Atul Sharma, K. Srivastava and Sanjay K. Kar discuss the importance, objectives and achievements of the Jawaharlal Nehru National Solar Mission in India. The global environmental scene has changed fiercely over the last century. The changing scenario demands greater concern and an action-oriented enabling policy framework for use of sustainable and renewable energy. The Government of India has taken necessary cognizance of the global developments and initiated several green environment policy measures under the National Action Plan on Climate Change. One of the initiatives is the Jawaharlal Nehru National Solar Mission (JNNSM). This chapter discusses the objectives of JNNSM and the developments made so far to improve the share of solar energy and reduce energy poverty in India.

Part II: Wind Energy

Insights into Wind Energy Market Developments in India

In this chapter, co-authors Sanjay K. Kar and Atul Sharma discuss wind market developments in India. According to the authors wind power is gaining a stronger position in the Indian electricity market, mainly caused by preferential feed-in tariff and other incentives given by the central and state governments. Through the chapter, the authors assess the growth of the Indian wind market compared to other leading markets across the globe. Then, state level progress is discussed in detail. The authors review wind-specific policy measures and incentive schemes devised by the central government, state government and regulatory bodies to achieve the desired objectives. The authors discuss the challenges of increasing wind penetration in India. They conclude that to achieve greater wind penetration the Central government, the State government and the regulatory bodies need to work cohesively and collaboratively to iron out implementation failures and take appropriate measures for successful implementation of various rules, regulations and policies.

Wind Energy Technology and Environment Sustainability

The author of this chapter Vilas Warudkar emphasizes that wind power plays an important role in the development of a country's economy as it reduces the country's dependency on fossil fuels. Wind energy is generally categorized as a clean, environment friendly and renewable source of energy. India is blessed with an immense amount of renewable energy resources and wind energy is one of the promising sources for energy supply option. The demand for electricity has grown significantly in the recent years and India depends widely on coal and oil to meet its energy demands. In the recent past, there has been intense research activity carried out in the development, production and distribution of energy in India, which results in the development of the need for new sustainable energy due to limited fossil fuel resources and problems associated with the environment (smog, acid rain and greenhouse gass emissions).

Development and promotion of non-conventional sources of energy such as solar, wind, geothermal and bio-energy are also getting increasing attention. Wind energy is a non-polluting source of energy and its mature technology and comparatively low cost makes it a promising and primary non-conventional energy source in India. The gross wind power capacity in the country is estimated at about 49,000 MW; a capacity of 21,264 MW upto May 2014 has been added so far through wind.

Continued research and development to increase the value of forecasting power performance, reducing the uncertainties related to engineering integrity, enabling large-scale use and minimizing environmental impact are some of the areas needing concerted efforts in wind energy. These efforts are also expected to make wind power more reliable and cost competitive with conventional technologies in the future for environmental sustainability.

Part III: Green Buildings

Achieving Energy Sustainability Through Green Building Approach

In this chapter, co-authors Ashish Shukla, Renu Singh and Poonam Shukla throw light on green building approaches for sustainability. There are three urgencies in the UK climate and energy policies (i) reducing greenhouse gas emissions, specifically CO_2 by 80 %, by 2050 (ii) decreasing fossil fuel consumption especially built environment sector; and (iii) reducing dependence on imported energy. Buildings account for 40 % of the total non-transport energy consumption both in the UK and EU, therefore reduction of energy consumption in the built environment will make a significant contribution in meeting these targets. On average, UK residents spend between 2.7 and 8.4 % on gas and electricity bills. Water bills also account for 0.5–3 % of their income. These scenarios make it important to consider green building design and reduce the social, environmental and economic impacts building are creating on us. Sustainability through green building design should encompass "cradle-to-grave analysis". Building Research Establishment Environmental Assessment Methodology (BREAM) is the world's foremost environmental assessment method and rating system for buildings. BREAM was launched in 1990 and sets the standard best practice in sustainable building design, construction and operation. The assessment uses measures of performance against established benchmarks. This chapter highlights interesting features for achieving sustainable development through green building design.

Aerogel-Based Materials for Improving the Building Envelope's Thermal Behavior: A Brief Review with a Focus on a New Aerogel-Based Rendering

In this chapter, co-authors M. Ibrahim, Pascal Henry Biwole, Patrick Achard and Etienne Wurtz recommend aerogel-based materials for improving the building envelope's thermal behaviour. Most developed countries have set the objective to reduce their energy consumption and greenhouse gas emissions. In most countries, the building sector is the largest energy consumer. This sector offers a significant potential for improved energy efficiency through the use of high-performance insulation and energy-efficient systems. For existing buildings, renovation has high priority in many countries, because these buildings represent a high proportion of energy consumption and they will be present for decades to come. Several studies have shown that the best way to reduce the energy consumption in buildings remain the reduction of heat losses through the envelope. Nowadays, there is a growing interest in the highly insulating materials such as Aerogels. Due to their highly insulating characteristics, aerogels are becoming one of the most promising materials for building insulation. Although the cost of aerogel-based materials remain high for cost sensitive industries such as buildings, this cost is expected to decrease in the following years as a result of the advancement in the aerogel production technologies as well as the large-scale material production leading to lower unit costs. In this study, a brief review of aerogel applications in buildings is presented. Some examples of opaque aerogel-based materials and translucent aerogel-based systems are illustrated. Then, a new insulating rendering based on silica aerogels is presented. Its impact on energy performance for different houses is examined.

An Overview of Phase Change Materials for Building Applications

In this chapter Helia Taheri and Atul Sharma offer an overview of phase change material for building applications. The increasing level of greenhouse gas emissions and the rise in fuel prices are the main reasons for efforts to more effectively use various sources of renewable energy. One of the effective ways to reduce the economic consumption of fuel is by using thermal energy storages. The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has advantages of high-energy storage density and isothermal nature of the storage process. Nowadays, by using lightweight materials in buildings, architects need lightweight thermal storages, therefore the use of PCMs has started. In this chapter, the authors discuss the benefits of using PCMs as thermal mass instead of the common thermal mass. Next, the characteristics of PCMs, their categories and building applications that can use PCMs as thermal mass are discussed. Finally, PCMs can be of benefit for lightweight buildings as thermal mass for reducing building loads and fuel consumption.

Part IV: Thermal Energy Storage

Phase Change Materials—A Sustainable Way of Solar Thermal Energy Storage

G. Raam Dheep and A. Sreekumar emphasize the use of phase change material for sustainable solar thermal storage. Renewable energy sources are time-dependent in nature and the effective utilization of devices based on renewable energy requires appropriate energy storage medium to commensurate the mismatch between energy supply and demand. Solar energy is the primary source of energy among renewable energy sources which can be used for a wide variety of electrical and thermal applications. The intermittent and unpredictable nature of solar energy generally necessitates a storage medium in-between that stores energy whenever it is available in excess and discharges energy whenever it is inadequate. Therefore, the storage of thermal energy becomes necessary to meet the larger energy demand and to achieve high efficiency. Thermal energy storage using latent heat-based Phase Change Materials (PCM) tends to be the most effective form of thermal energy storage that can be operated for a wide range of low, medium and high temperature applications. This chapter explains the need, desired characteristics, principle and classification of thermal energy storage. It also summarizes the selection criteria, potential research areas, testing procedures, possible application and case studies of PCM-based thermal energy storage system.

Latent Heat Thermal Storage (LHTS) for Energy Sustainability

Latent Heat Thermal Storage (LHTS) has been an interesting topic for researchers, readers and producing companies across the globe. In this chapter, co-authors M.A. Rahman, M.A. Kibria, M.M. Hossain, S. Rahman and H. Metselaar describe application of LHTS in solar power production and green buildings. In order to restrain the trend in present fossil fuel consumption, Latent Heat Thermal Storage (LHTS)

using Phase Change Material (PCM) has received a common interest among scientists as it has high energy storage capacity. In this chapter, LHTS System and their applications for solar thermal power generation and building application have been discussed. The prospect of LHTS in reducing present fossil fuel consumption has also been demonstrated. Moreover, the recent development of PCM has been reported for practical LHTS application.

Part V: Bio-mass, Bio-fuels, Bio-gas

Energy Sustainability by Biomass

Energy generation from biomass has been a subject of discussion for quite some time, especially in the emerging and developing countries. Co-authors of this chapter, Manjari Shukla, Sanjay Singh, Sarfaraj Ahmad Siddiqui and A. Shukla look into sustainable energy production from biomass. With rapidly growing energy demand and concerns over energy security and environment, researchers worldwide are exploring deeply to deploy renewable energy sources. Development of economical biofuel at sufficiently large scale may provide a major breakthrough in this direction, with strong impact on sustainability. More importantly, environmental benefits may also be achieved by the utilization of renewable biomass resources, which could help the biosphere for a longer time. In this chapter, the authors review the availability and bioenergy potential of the current biomass feedstock. These include (i) food crops such as sugarcane, corn and vegetable oils, classified as first generation feedstocks, and environmental and socio-economic barriers limiting its use. (ii) Second generation feedstocks involving lignocellulosic biomass derived from agricultural and forestry residues and municipal waste followed by constraints for their full commercial deployment. Key technical challenges and opportunities of the lignocellulosic biomass-to-bioenergy production are discussed in comparison with first generation technologies. (iii) The potential of the emerging third generation biofuel from algal biomass is also reviewed.

Biofuels as Alternate Fuel from Biomass—The Indian Scenario

The co-authors of this chapter, Renu Singh, Sapna Tiwari and Monika Srivastava discuss the role of bio-mass as an alternative to fossil fuel. Biofuels are produced from living organisms or from metabolic byproducts (organic or food waste products). Fuel must contain over 80 % of renewable materials in order to be considered as biofuel. Biomass is carbon dioxide neutral and its sustainable use minimizes the seasonal variation and pollutants' emission into the air, rivers and oceans. This energy plays an important role in the replacement of renewable energy resources for fossil fuels over the next several decades. Enormous range of biomass is processed to produce bioenergy biologically, thermochemically and biochemically. In developing countries such as India, biomass is the primary source of bioenergy. Global climate change policies would overcome many barriers to secure the future of biomass and, indirectly, biofuels. Due to social and economic benefits, biomass is considered as a deserving alternative for sustainable development.

Technology Development and Innovation for Production of Next-Generation Biofuel from Lignocellulosic Wastes

The author of this chapter, Vinod Kumar Sharma, highlights the evolution of biofuels while giving priority attention to next generation biofuel from lignocellulosic waste. Both biochemical (chemicals, enzymes and fermentative microorganisms) and thermochemical (heat and chemical) processes are addressed. For biochemical processes, topics related to the pre-treatment, hydrolysis and fermentation steps as well as process integration, are also discussed. For thermochemical processes, research topics such as process development and process analysis are dealt with. Important R&D technical aspects, economic assessment of available technologies, limitations of certain technological approaches, etc., are also discussed.

Advancement in Biogas Digester

In this chapter, co-authors Anil Kumar, B. Mandal and Atul Sharma discuss the advancements in biogas digester for green energy production and consumption. Biogas is a renewable energy source with different production pathways and various excellent opportunities to use. Biogas usually refers to a gas produced by anaerobic digestion or fermentation of organic matter including manure, sewage sludge, municipal solid waste, biodegradable waste, energy crops or any other biodegradable feedstock. Biogas primarily comprises of methane and carbon dioxide. In this review, is discussed the worldwide status of biogas production, history of the biogas digester in the world, classification of biogas digester and its advantages and disadvantages. Government policies concerning the use of kitchen waste-based digesters and the social and environmental effects of the digesters have also been covered. More subsidies need to be given and more initiative needs to be taken by the government. The government has many policies for biogas digester plants, however, there is a lack of awareness among people inhibiting the adaptation of technology.

Part VI: Other Green Energy

Natural Gas to Drive Green and Sustainable Developments in India

The author of this chapter, Sanjay K. Kar, offers detailed insights into natural gas market developments in India. The author points out that the per capita primary energy consumption in India has been increasing and there is great scope for growth to reach somewhere closer to leading economies like the United States, Russia and China. India's primary energy consumption is still dominated by coal with 54.5 % followed by oil (29.5 %), natural gas (7.8 %), hydro (5 %), renewables (2 %) and nuclear (1.2 %). India being one of the leading emerging economies requires plenty of energy to maintain the pace of its economic growth. India's economic development should be driven by green energy, with desirable levels of environment protection and ecological preservation. Along with the

renewable sources of energy, natural gas is considered to be the fuel for green and sustainable developments in India. The author discusses the outcomes of green economy as green production, green marketing, green transport, green housing, green electricity and green consumption. The current scenario suggests that natural gas could be the one of the most preferred green fuels by 2030 in India. Some of the enabling factors likely to drive gas-based sustainable economy in India are: higher domestic production, import of equity gas, import of relatively cheaper shale gas (in the form of LNG) from the US, and import of dry gas through pipeline from central Asia, development of regasification infrastructure in India, and development of a fully functional national gas grid.

Scope for Small Hydro Projects in India

The author of this chapter, A.K. Chaturvedi has discussed the Scope for Small Hydro Projects in India. Energy is essential for the sustenance of life. Also energy and the economic growth of a nation are interlinked. Energy security of a country entails optimum utilization of indigenous and those sources of energy to which a nation can have access. Hydropower is an important and an economically competitive source of electricity. In India, hydro projects up to 25 MW capacities have been categorized as small hydro power projects (SHPs) and the Ministry of New and Renewable Energy (MNRE) is responsible for their construction. The technology for the SHP is fully indigenized. SHPs though economical and less environmentally degrading, suffer from cascading due to a number of plants in tandem, may result into poorer quality of water and may have hydrology impacted at the sub-basin level. India has a potential of about 20,000 MW through SHP, and as such, it has been declared as one of the thrust areas. The Ministry is encouraging the development of small hydro projects both in the public and in private sector. There are about 25 equipment manufacturers of SHP turbine in the country with an estimated capacity of about 400 MW per year.

Hydrogen and Fuel Cells

In this chapter, Bahman Shabani and John Andrews focus on the new generation future fuel, hydrogen. Considering social (e.g. energy security), economic and environmental issues associated with the reliance on finite fossil fuel resources for energy generation, hydrogen (based on renewable energy and energy efficiency) is seen by many scientists and economists as a sustainable solution that can help the end users of energy meet their future supply requirements as well as greenhouse gas and other emission reduction targets. While diversity of renewable energy resources is the key advantage of these alternatives, their intermittency and unpredictability have to be addressed by complementing them with proper energy storage options such that these resources can be reliably employed to power stationary and mobile applications uninterruptedly as required. Hydrogen energy systems as reviewed in this chapter can play a strong energy storage role in conjunction with renewable energy resources, particularly in applications with long-term (e.g. in standalone stationary applications with highly variable seasonal input of renewables, central grids, or microgrids) and/or long-range (i.e. in automotive applications) energy storage

requirements. The main components of a hydrogen energy system include hydrogen generation arrangement; hydrogen storage; distribution and delivery systems (long or short distance); and the means of converting the chemical energy of hydrogen into a desirable form of energy (e.g. electricity) for end consumers. The latest research and development related to these elements are discussed in this chapter.

Combined Cooling, Heating, and Power (CCHP) or Trigeneration Technology: An Approach Toward Higher Energy Efficiency, Emission Reduction Potential and Policy

The author of this chapter, Anant Shukla, points out that the energy demand in India is growing at a very fast rate; the present energy generation cannot keep pace with this increasing demand with energy shortage of 6.2 % and peak shortage of 2.3 %. To address the increasing gap between demand and supply there is an urgent need to bridge the gap through energy efficiency and integration of renewable energy in the energy mix of the country. This chapter presents a new concept in the Indian building sector which addresses energy efficiency through the Trigeneration technology. A gas engine with natural gas is used to produce power and waste heat from the engine for cooling and heating through Vapour Absorption Machine (VAM) and hot water recovery from Low Temperature (LT) jacket water. This increases the efficiency upto 85 % or more compared to the conventional methods of power production. The author discusses one such case study on a pilot project implemented under the Indo-German Energy Programme. The Indo-German Trigen project is the first project successfully implemented under the International Climate Initiative in India. The pilot project is funded by the German Federal Ministry of Environment, Nature Conservation Building and Nuclear Safety (BMUB) and is the first project completed successfully under International Climate Initiative (IKI) of BMUB in India. This chapter presents information on the techno-economics of the pilot project at New Delhi.

Energy Sustainability Through Nuclear Energy

In this chapter, A. Shukla reiterates that energy sustainability is one of the most vital factors for the growth of any nation as well as for global mankind. With exponentially increasing energy demand and concerns for carbon emission/climate change, it is inevitable to pave a pathway for energy production, which takes care of the ever-increasing energy requirements as well as provides clean energy resources. Though there are concerns related to the safety of nuclear reactors and safe treatment of nuclear waste, nuclear energy is still one of the most clean energy sources in terms of carbon emissions with large availability of fuels to run nuclear power plants. Thus, nuclear energy has strong potential to fill the present gap between need and supply and to provide energy sustainability. This chapter explores the possibility of achieving energy sustainability through nuclear energy along with the possible challenges in this direction.

Acknowledgments

Before the start of this project in late 2013, we were not fully aware of the investment in time and effort that would go into editing a book. We thought of bringing out an edited book to share knowledge, development and scientific advancement in the field of green energy for a large group of interested readers. So we felt we could simply get connected with researchers around the world and request them to share their work in the form of book chapters for an edited volume. To us this sounded quite simple at the beginning. But to our surprise, we were proven wrong on many occasions. Now we understand better...! Since the authors who have contributed to this book are from the scientific and academic community with prior commitments, our deadlines for submitting book chapter proposals, first drafts of the chapters, peer reviews of all manuscripts, and submission of final revisions of the contributions received frequent challenges. Throughout, however, we received remarkable encouragement and enthusiasm from our contributors and reviewers. We are really honoured to have contributions from all the contributors who have been very supportive, dedicated and responsive throughout our interaction. We are extremely thankful to all our passionate contributors and reviewers!

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Finally, this project consumed quite some of our leisure time that should have been dedicated to our families. There is no doubt that we are very excited, enthusiastic and proud about the final output of our work, we also feel sorry about unwittingly neglecting them on many occasions, especially weekends. For all their patience and moral support, we dedicate this book to Iti, Druv, Yash, Tapaswini and Kashyapi.

Atul Sharma
Sanjay Kumar Kar